DEVIANT SPEECH-VOICE DIMENSION IN DYSKINETIC DYSARTHRIAS AND THEIR NEUROMUSCULAR BASIS

Thesis submitted for the award of the degree of
Doctor of Philosophy (Ph.D)
to the National Institute of Mental Health and
Neuro Sciences (Deemed University), Bangalore, India

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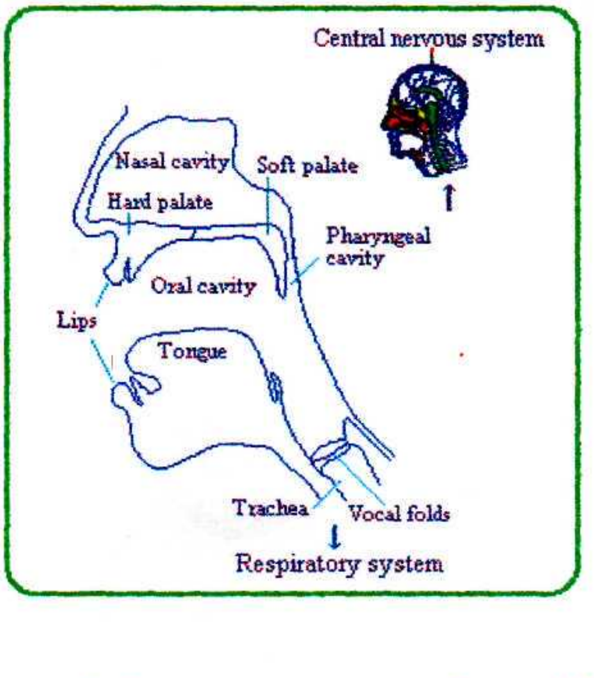
December 1998

Dedicated to

Bali, Kavya & Gahan



' Speech is movement made audible '

- Raymond H. Stetson (1928)

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DECLARATION

This thesis entitled 'Deviant speech-voice dimensions in dyskinetic dysarthrias and their neuromuscular basis' is the result of my own study carried out under the guidance of Dr. M. Jayaram, Additional Professor and Head, Department of Speech Pathology and Audiology, NIMHANS, with Dr. D. Nagaraja, Additional Professor, Department of Neurology, NIMHANS, Bangalore as a joint guide. I further declare that this thesis or part thereof has not been submitted earlier to any University for the award of any degree or diploma.

3rd December 1998

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CERTIFICATE

This is to certify that this thesis entitled 'Deviant speech-voice dimensions in dyskinetic dysarthrias and their neuromuscular basis' is the bonafide work of Mr. S. Basava Raj, submitted for the award of the degree of DOCTOR OF PHILOSOPHY to the National Institute of Mental Health and Neurosciences (Deemed University), Bangalore. The thesis has been prepared under our supervision and guidance. We further certify that this thesis, or part thereof, has not been the basis for the award of any other degree or diploma of this or any other University.

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Date : 3rd December 1998

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C E R T I F I C A T E

This is to certify that this thesis entitled 'Deviant speech-voice dimensions in dyskinetic dysarthrias and their neuromuscular basis' is the bonafide work of Mr. S. Basava Raj under the guidance of Dr. M. Jayaram, Additional Professor and Head, Department of Speech Pathology and Audiology, NIMHANS, with Dr. D. Nagaraja, Additional Professor of Neurology, Department of Neurology, NIMHANS, Bangalore as a joint guide.

The work for the thesis has been carried out at the department of Speech Pathology and Audiology, NIMHANS.

It is further certified that this thesis, or part thereof, has not been the basis for the award of any other degree or diploma of this or any other University.

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S. Basava Raj

CONTENTS

Chapter 1

INTRODUCTION

Speech is a motor act and involves the production of sounds and meaningful sequences of sounds for the transmission of language. Neurologically, speech production is dependent upon

a) the motor speech programmer, an area of the dominant hemisphere corresponding roughly to Broadman's area 44 on the inferior-lateral-posterior frontal lobe (Broca's area) and supplemental motor cortex; and

b) the speech effectors, consisting of the motor strips bilaterally; extrapyramidal and pyramidal tracts; subcortical nuclei, including the basal ganglia; the brainstem and the cerebellum; and the cranial and the spinal nerves that directly subserve motor speech control (Dworkin and Hartman, 1988). Peripherally, speech production requires an intact and well-coordinated respiratory, phonatory and articulatory system, along with a normally functioning auditory system for feedback.

Given the complexity of the systems involved in speech production and the coordination required between them, it can be said that speech production is susceptible to a host of external and internal influences. One such major factor influencing speech production is any damage - structural and/or physiological - to the motor speech programmer or the speech effectors. Damage to these systems, usually results in the condition of dysarthria. Dysarthria represents a group of speech disorders characterized by disturbances in speech muscular control due to paralysis, paresis, weakness, slowness, incoordination and/or altered tone.

Dysarthrias are speech disorders and should not be confused with the oral -expressive manifestations seen in language disorders. In dysarthria, one or more of the motor processes of speech production including respiration, phonation, articulation, resonance and prosody may be affected. Depending upon the site of lesion, six different types of dysarthrias have been identified, each of which has characteristic symptomatology (Darley, Aronson, and Brown, 1975).

Six major types of clinical dysarthrias. each of which may present deviations in one or more motor processes of speech production - respiratory, articulatory, phonatory, resonance and prosody - and their components presents a very complex picture. It is important that the clinician understands this complex pattern, not only for characterizing and 'diagnosing' a disorder, but also for planning appropriate strategies for speech management. It is also true that descriptions of speech - voice deviations in dysarthrias may help in the medical diagnosis of these conditions (Mernitt, 1969; Chusid, 1979).

1.0 Mayo Clinic Research (or DAB Study)

A single most important contribution to (he study of dysarthria was the identification of deviant speech-voice dimensions by Darley, Aronson and Brown (1969a, 1969b). Darley et al analyzed the perceptual judgments of dysarthric speech by a set of listeners and their investigation demonstrated that major forms of dysarthrias could be differentiated by unique clusters of deviant speech-voice dimensions that underlie each dysarthria. Implied is the suggestion that the characteristic patterns of speech-voice deviations can also be used to infer the site of lesion in each dysarthria. This study, well-known as DAB's study or Mayo Clinic research, has been cited as one of the most comprehensive systems of auditory perceptual rating in the field of Speech Pathology. The conclusions reached by these authors (1975) are central to many contemporary descriptions of dysarthria and DAB system of classification is regarded as one of the most comprehensive classification systems of dysarthria. Mayo clinic studies have strongly influenced contemporary thinking on motor speech disorders.

Perceptual analysis has a role in the investigation of dysarthrias, but it alone is inadequate as it is subjective in nature and thus lacks specificity and uniformity. Therefore, objective analysis of dysarthria arc warranted to quantify the speech deficits seen in dysarthrias and to record the pre- and post-therapeutic evaluations. In recent years, following the publication of DAB's study, more emphasis is laid on physiological and acoustic studies of speech deviations in dysarthria not only to bring about objectivity into the characterization of each dysarthria, but also to validate the findings of perceptual studies.

However, objective studies on dysarthrias are restricted to the study of one or two aspects of speech production. Univariate comparison that emphasize a single specific feature as characteristic of the whole group may be misleading. It is well known that it is not unusual for patients to have dysarthria related to more than one impaired system. Speech pathologists have the awesome task of assessing complex patterns of neuroniotor disturbances underlying dysarthric speech production. Therefore, multivariate approaches are more appropriate for a comprehensive assessment of dysarthria. A multivariate approach is more likely to differentiate subcategories of dysarthrias and also in understanding the complex interplay of the various systems in accomplishing speech production. Therefore, multivariate approaches should be of greater utility in identifying the degree of impairment as well as the effects of treatment on dysarthria.

Perhaps, a more meaningful understanding of dysarthria may result from a combination of acoustic measurements and perceptual analysis of dysarthric speech. A combined cluster analysis of these two dimensions performed in a manner similar to that of Mayo Clinic research, may yield invaluable data on understanding dysarthrias. Such multidimensional analysis of the speech in different types of dysarthria, will not only be useful for differential diagnosis, but also in initiating and terminating therapy for these disorders.

2.0 Definition, Description and Domain of Dysarthria

The term "dysarthria" means imperfect articulation of speech, as described in medical dictionaries. According to Peacher (1950), the word dysarthria' can be used to cover all motor disturbances of speech exclusive of symbolic and integrative functions. However, he also suggested the term dysarthrophonia' for neuromuscularly based disorders of speech in which phonation and articulation are impaired. Grewal (1957) proposed the term dysarthria-pneumo-phonia' to designate speech problems in which the respiratory system is also implicated. The term dysarthria has traditionally been defined as disorders of oral speech resulting from lesions within the nervous system (Arnold, 1965). Recently, dysarthria[1] has become an inclusive term to encompass coexisting motor disorders of respiration, phonation, articulation, resonance and prosody' (Darley, et al, 1975), including isolated single process impairments such as an articulation problem due to XII cranial nerve paresis, or an isolated palatopharyngeal incompetence of neurogenic origin, or an isolated dysphonia due to unilateral vocal cord paralysis. Based on the above concept, the term motor speech disorders' has been used synonymously with dysarthria. It is convenient to use the term dysarthria' generically to cover motor speech disorders of neurologic origin (except apraxia of speech), despite this being semanticaily incorrect (Hardy, 1967; Netsell, 1986).

There are various definitions of dysarthria, some based on the site of lesion, some on causative agents, some on speech deviation, some on different speech motor systems that are affected. The essence of all these definitions, can be expressed as follows:

> 'dysarthria represents a group of speech disorders resulting from disturbances in neuromuscular control. This is caused by damage to the central or peripheral nervous system which may result in either paralysis, or paresis, or weakness, or slowness, or incoordination, or altered muscle tone, which changes the characteristics of the speech produced. One or more of the motor process of speech production, including respiration, phonation, articulation, resonance and prosody may be involved' (Darley et al, 1975; Enderby, 1980; Netsell, 1983; Wcismer, 1984; Yorkston et al, 1988; Rosenbek et al, 1991, World Health Organization, 1991).

Dysarthria results from disruption of muscular control as a result of damage to the central or peripheral nervous system, or both (Darley et al 1975). There is some involvement of the basic motor processes used in speech, and this results in movement disorder. Speech movements may show abnormal speed, range, strength, or coordination. Thus dysarthria differs from apraxia of speech, another motor speech disorder.

3.0 Classification of Dysarthria

Dysarthrias are basically neurological signs. Hence, the most useful systems of classification are those that focus on neuroanatomic and neurophysiologic considerations indicating the cause, disease process, part of the nervous system involved, central or peripheral and those that describe the dysarthric speech-voice characteristics. Dysarthrias have been classified based on one or more of the following criteria (adapted from Darley et al., 1975) :

a) Age of onset (congenital or acquired);

b) Etiology (vascular, neoplastic, traumatic, inflammatory, toxic, metabolic, degenerative);

c) Neuroanatomic area of involvement (cerebral, cerebellar, brainstem, spinal; and central or peripheral;

d) Cranial nerve involvement (V, VII, IX-X, XII);

e) Speech processes involved (respiration, phonation, resonance, articulation, prosody);

f) Disease entity (Parkinsonism, Huntington's disease, Multiple Sclerosis, Wilson's disease etc);

g) Speech valves involved (respiratory, laryngeal, pharyngeal, velar, lingual, dental, labial);

h) Speech events involved (neural, muscular, structural, aerodynamic, acoustic, perceptual; or

i) Perceptual characteristics (pitch, loudncss, voice quality, respiration, prosody, articulation).

DAB's study resulted in a classification of dysarthria with six categories and this classification is in vogue even in current clinical practice. It should also be mentioned that the 6 different types of dysarthria based on DAB's study are speech diagnoses, comparable to medical diagnoses. Table 1.1 lists the 6 different types of dysarthria as enunciated in DAB's study. This system of classification was followed in the present study to categorize dysarthrias. Speech-voice deviations in each of these dysarthrias have specific perceptual characteristics; each indicates the probable site of lesion in the nervous system; each is associated with specific causes; and each results from specific abnormal neuromuscular conditions.

4.0 Dyskinetic Dysarthrias : Hypokinetic and Hyperkinetic Dysarthrias

The term extrapyramidal system was first used by Wilson (1912) to refer to those parts of the central nervous system concerned with motor functions but which are not part of the pyramidal system. The major part of the extrapyramidal system include the basal ganglia within thc cerebral hemispheres plus the

Type	Site of Lesion
1. Flaccid dysarthria	Lower motor neuron
2. Spastic dysarthria	Bilateral upper motor neuron
3. Ataxic dysarthria	Cerebellum and/or its pathways
4. Hypokinetic dysarthria in Parkinsonism	Extrapyramidal system
5. Hyperkinetic dysarthria	Extrapyramidal system
Quick	
chorea	
palatal myoclonus	
Slow	
dystonia	
tardive dyskinesia	
- Other	
essential voice tremor	
and others	
6. Mixed dysarthrias	Lesions of multiple systems
Wilson's disease	
multiple sclerosis	
and others	

Table 1.1 : Classification of dysarthrias used in this study (following Darley et.al., l975).

various brainstem nuclei that contribute to motor functioning and include paired substantia nigra, red nuclei and the subthalamic nuclei. Overall, the extrapyramidal system appears to control muscle tone for the maintenance of posture and for supporting movements. It contributes to complex movements by integrating and controlling the component parts of the movements and also in inhibiting unplanned movements.

Movement disorders are the primary features of the extrapyramidal syndromes, and where the muscles of speech mechanism are involved, disorders of speech may occur. Lesions of the extrapyramidal system result in dyskinetic movements, either reduced or increased. These are well-known as movement disorders. The reduced movements are referred to as hypokinetic dysarthrias while the increased movements are referred to as hyperkinetic dysarthrias.

There are many subtypes in these two types of dysarthrias (Darley et al, 1975; Aronson, 1981; Dworkin and Hartman, 1988 Metter and Hanson, 1986). Hypokinetic dysarthrias arc seen in Parkinson's disease and progressive supranuclear palsy. Hyperkinetic dysarthrias are found in chorea, myoclonus, Gilles de la Tourrette's syndrome, athetosis, dystonia, tardive dyskinesia and essential voice tremors. The discussion here is limited to hypokinetic dysarthria (Parkinson's disease) and hyperkinetic dysarthria (chorea, dystonia, dyskinesia - specifically to tardive dyskinesia - and essential voice tremor).

It is said that marked degenerative changes in the substantia nigra, in the nuclei of the extrapyramidal system that are functionally related to the basal ganglia, or in the specific extrapyramidal tract fibres that interconnect these nuclei may result in hypokinelic dysarthria. There are quick, slow and tremor forms of hyperkinetic dysarthria which result from lesions of the extrapyramidal system. The quick form includes the speech of chorea while the slow form is observed in individuals with dystonia and some of orofacial dyskinesia. Tremor is observed in essential voice tremor. Dystonia results from lesions of the striatum and globus pallidus and is characterized by slow undulating, twisting, variably prolonged, and involuntary movements of limbs and orofacial structures. Dyskinesia results from lesions of the basal ganglia, though the specific underlying lesions are not known. Similarly, the site of lesion of essential voice tremor, is not known, but is thought to be extrapyramidal within the brainstem.

4..1 Hypokinetic Dysarthrias

4.1.1 Parkinson's Disease

The four major types of symptoms of Parkinson's disease are tremor, rigidity of the muscles, akinesia and loss of normal postural fixing reflexes. It has been suggested that muscle rigidity and tremor seen in Parkinson's disease are the result of areas of the extrapyramidal system being released from the control normally exerted over them by other areas of the central nervous system.

As said earlier, when the muscles of the speech mechanism are involved, it leads to speech problems. It is generally accepted that speech disturbances occur in half of all cases of Parkinson's disease and become more prevalent as the disease progresses (Uziel et.al, 1975).

It should be said that the speech deviations vary tremendously depending on the stage of the disease and the effectiveness of medication. A perceptual study of the vocal characteristics of 200 Parkinson's patients found 80% of the patients to have deviant speech while only 11% did not have any speech problems (Logemann, et. al., 1978).

4.1.1.1 Speech Characteristics in Parkinson's Disease

Speech characteristics in Parkinson's disease, and in general, in hypokinetic dysarthrias, follow largely from the generalized pattern of hypokinetic behavior which includes marked reduction in the amplitude of voluntary movements, slowness of movement, initiation difficulties, muscular rigidity, loss of automatic aspects of movement (Darley et. al., 1975). Marked limitation of the range of movement of the speech musculature seems to be the outstanding characteristic of hypokinesia as it affects speech. Reduced mobility, restricted range of movement and supernormal rate of the repetitive movements of the muscles involved in speech production lead to various manifestations of hypokinetic dysarthria, while tremor does not seem to affect speech (Darley et. al, 1975).

A number of researchers have documented the perceptual speech characteristics of hypokinetic dysarthria (Enderby, 1986; Darley et. al., 1969 a, b; Zyski and Weisiger, 1987; Chenery, Murdoch and Ingram, 1988; Critchley, 1981; Canter, 1963; Darley et. al., 1975). The most prominent deviant speech characteristics of hypokinetic dysarthria were deviations in prosodic aspects (monopitch, reduced stress and monoloudness), although imprecise articulation, inappropriate silences, short rushes of speech, harsh and breathy voice-quality and variable rates of speech were also reported (Darley et. al., 1969 a,b).

A : Prosodic Disorders

Speech loudness level is reduced in most cases of Parkinson's disease. Some Parkinson's patients speak slowly while some speak slightly more rapidly than normals (Critchlcy, 1981). In DAB study (1969 a, b), Parkinson's patients were found to be unique among dysarthrics having a slightly faster than average speaking rate. There is evidence from acoustic studies (Hammen and Yorkston, 1996) for the observation that Parkinson's patients have speech rates that are faster than normal. A few of the Parkinson's patients demonstrate a progressive acceleration of rate towards the end of the sentence thus attracting the label of "festinant" by some researchers. Other speech deviations observed include poor intelligibility of speech and difficulty in initiating speech.

A common characteristic of the spectrograms of the speech of Parkinson's patients is a reduction of acoustic contrast or detail. The pattern for a normal speaker can be divided into fairly distinct acoustic segments, but such contrast is lacking in the speech of Parkinson's patients. Specifically, the stop gaps are replaced by low intensity frication which results from a failure to achieve complete oral closure for the stops (Kent and Rosenbek, 1982). The perceptual observations that Parkinson's dysarthrics have a faster rate of speaking and hypernasality has been confirmed through spectrographic findings which show continuous voicing into the voiceless segments, reduction of energy in the higher harmonics and a strong concentration of energy below 500 Hz (first nasal formant).

B: Phonatory Disorders

Abnormalities of the phonatory system in Parkinson's patients have been reported by many researchers. Logemann et. al (1978) observed laryngeal dysfunction in 89% of their patients, hoarseness being the major perceived characteristic. Presence of hoarseness, strain-strangled phonation, intermittent breathiness, lack of variation in pitch and loudness (Chenery, **Murdoch** and Ingram, 1988), reduced phonation and intonation, and reduced control over volume (Enderby, 1986) are some of the phonatory deviations observed in the speech of Parkinsonics.

C: **Nasality**

Velopharyngeal functioning in Parkinson's disease is controversial. Some researchers (Darley, Aronson and Brown, 1969a; Mueller, 1971; Tanner, 1976; Logemann et.al., 1978) have minimized the problem, suggesting that even if hypernasality exists, it is mild. Other researchers (Morrison, Rigrodsky, and Mysak, 1970; Netsell, Daniel and Celesia, 1975; Hirose ct.al., 1981; Kent and Rosenbek, 1982; Ludlow and Bassich, 1983) have provided evidence that velopharyngeal problems occur systematically in Parkinsonian speakers. Moreover, hypernasality may represent the most prominent dysarthric symptom in certain individuals. The problem of velopharyngeal control in Parkinson's disease seems to be one of deteriorating neural control. Hoodin and Gilbert (1989) in an acoustic study of nasal airflows in Parkinson's speakers found that with increase in the severity of Parkinson's disease (mild to moderate), nasal airflow increased. In another perceptual and acoustic study, Hoodin and Gilbert (1980) repeated these findings regarding nasal airflows, but the listeners who rated the speech for hypernasality could not differentiate between mild and moderate Parkinson's patients although they perceived the speech of both groups of patients as hypernasal.

D : Articulatory Deviations

Though prosodic deviations tend to dominate the speech of Parkinson's patients, there is evidence to show that other aspects of speech like phonation, articulation and resonance are also affected (Darley et.al., 1969 a,b; Logemann ct.al., 1978; Logemann and Fisher, 1981) Logemann et.al (1978) observed articulation disorders in 45% and hypernasality in 10% of their patients. Hoarseness was the major perceived characteristics in their patients. Logemann and Fisher (1981) reported that manner of articulation errors were dominant in comparison to place of articulation errors in their patients. Plosives, affricates and fricatives were most affected, as were features of continuancy and stridency. Analysis of the articulatory deficit revealed inadequate tongue elevation to achieve complete closure on stop-plosives and affricates. Logemann and Fisher concluded that both the incomplete contact for stops and the partial construction for fricatives represent an inadequate narrowing of the vocal tract at the point of articulation.

All these deviant speech characteristics make for a distinctive type of dysarthria that can be perceptually distinguished from other dysarthria types. No doubt, Parkinson's patients are heterogeneous in their speech characteristics, but Zyski and Weisigcr (1987) found that hypokinctic dysarthria can be perceptually identified with greater accuracy than any other dysarthria type.

4.1.1.2 Objective Validation of Perceptual Studies in Parkinson's Disorder

A number of studies, by means of acoustic and/or physiological techniques, have attempted to confirm the features of hypokinetic dysarthrias identified by perceptual studies. Canter (1965) concluded that many of the deficiencies in the speech of Parkinsons patients derive, at least in part, from reduced physiological support for speech. He documented (1963, 1965 a,b) higher pitch levels than normals, imprecise production of plosives, and incoordination of phonatory and articulatory activity in the speech of Parkinsonic patients. Parkinson's patients had similar vocal intensity and speaking rate levels as normals. Mueller (1971) found his Parkinson's patients to have reduced phonation time and to expend a lower volume of air than normals during the sustained production of vowel /a/; reduced phonation time, a reduction in the total number of syllables produced and a reduced intra-oral pressure during repeated utterance of/sa/; however, the rate of syllable production was the same as for the control group.

The sustained phonation, syllable diadochokinesis and reading rates of Parkinson's subjects were compared with those of normal young adults and normal elderly adults by Kreul (1972). He found no significant difference between the control and Parkinson's patients in the syllable diadochokinesis task, but found the Parkinson's patients to differ significantly on diadochokinetic rates for repetition of vowel *hi* and vowel glide /u-i/.

Patients with Parkinson's disorder, Huntington's disease and control subjects (normals) were compared by Ludlow, Connor and Bassich (1987) on three aspects of speech timing, namely, planning, initiation and production. The most affected aspect of speech timing in both the patient groups was the rate of speech movements and their controlled alterations during speech production, but neither the initiation nor planning was affected in either patient group. Furthermore, these authors did not find any evidence of abnormally fast syllable repetition or sentence production rate in their Parkinson's group to support the clinical impression of accelerated rate in Parkinson's disease. The differences between the two clinical groups was only a matter of degree rather than type of errors. In fact, Enderby (1983) preferred to classify these two groups under 'extrapyramidal dysarthria' rather than dividing this into the hypokinetic and hyperkinetic groups of Darley et.al (1975).

The validity of perceptual impressions of speech deviations in Parkinson's disease has also been investigated through physiological measurements and spectrographic studies. Reduced articulatory movements (Hirose et.al, 1981; Kiritani and Sawashima, 1982 b); gradual increase in the frequency of repetitive production of a monosyllable (Hirose et.al., 1981), among others, have been reported in Parkinson's patients.

Spirantization in the speech of Parkinson's patients (incomplete contact for stops) has been supported by Kent and Roscnbek (1982) and Weismer (1984) through spectrographic and acoustic measures. Kent and Roscnbek (1982) also provided spectrographic evidence of the presence of continuous voicing, hypernasality and poor consonant articulation which they suggested could possibly be misperceived in a perceptual analysis as a faster than normal speaking rate. Weismer (1984) found evidence for continuance voicing (into voiceless stop closure), but he attributed this to the age of the Parkinson's patients, rather than the disease itself.

4.2 Hyperkinetic Dysarthrias

Hyperkinetic dysarlhria is seen in association with a variety of extrapyration or sentence production rate in their Parkinson's group to support the clinical impression of accelerated rate in Parkinson's disease. The differences between the two clinical groups was only a matter of degree rather than type of errors. In fact, Enderby (1983) preferred to classify the.se two groups under 'extrapyramidal dysarthria' rather than dividing this into the hypokinetic and hyperkinetic groups of Darley et.al (1975).

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4.2 Hyperkinetic Dysarthrias

Hyperkinetic dysarthria is seen in association with a variety of extrapyramidal disorders in which abnormal involuntary movement of the limbs, trunk, neck, face etc. disturb the rhythm and rate of motor activities including those involved in speech production. Darley et.al (1975) distinguished between quick and slow hyperkinesias although the dichotomy is somewhat artificial. The quick and the slow abnormal involuntary movements form a continuous spectrum on the one hand and a mixture of these movements may occur in a given patient, on the other hand. Myoclonic jerks, tics, chorea and ballismus come under quick hyperkinesias while athetosis, dyskinesia and dystonia fall under the slow hyperkinesias. Tremors, though they are a form of hyperkinetic dysarthria, are traditionally considered as a separate category by themselves.

4.2.1 Speech Problems in Huntington's Chorea

All aspects of speech production can be disrupted in patients with chorea. During contextual speech, the choreiform movements are superimposed on the normal movements of the speech mechanism. The result is that articulation, phonation, resonance and respiration are all affected in chorea. Phonatory disturbances include momentary voice arrests, strained-strangled voice, grunting and transient breathiness. Abnormal involuntary movements of the soft palate may lead to hypernasality in some patients. Articulation of speech sounds may be normal for some duration, but when choreiform movements of the lips, tongue and mandible suddenly appear, speech becomes distorted. Speech flow is often jerky. In fact, prosodic disturbance constitute a significant part of the perceived speech deficit in patients with chorea.

Darley et.al (1975) attributed the prosodic errors to an attempt by the choriac patients to avoid articulately and phonatory interruptions by variably altering their rate of speech, prolonging phonemes, and prolonging the intervals between words, equalizing the stress on syllables and introducing inappropriate silences.

Darley et.al (1975) reported that the speech problems of patients with chorea are most distinctive in the area of prosodic disturbances, although imprecise consonants was rated the most deviant speech dimension by judges in their study. The ten most deviant speech dimensions observed in patients with chorea by Darley et.al (1969a) were (a) imprecise consonants, (b) prolonged intervals, (c) variable rate, (d) monopitch, (e) harsh voice quality, (f) inappropriate silences, (g) distorted vowels, (h) excess loudness variation, (i) prolonged phonemes, and (j) monoloudness.

The usefulness of acoustic perturbation measures as a screening tool for neuropathological groups has not been clearly documented. Ludlow et.al (1983) found that Parkinson disease patients did not differ significantly from normal controls on frequency perturbation measures. On the other hand, Ramig et.al (1988) found that acoustic analysis of the voice (for fundamental frequency, jitter, shimmer, and harmonic-to-noise ratio) contributed to a differential diagnosis between myotonic dystrophy, chorea and Parkinson's disease and may document disease progression. Zwirner, Murry and Woodson (1991) found that only the standard deviation of fundamental frequency could differentiate between Parkinson's, chorea and cerebellar ataxic groups while other phonatory measures like jitter, shimmer, signal-to-noise ratio and fundamental frequency could not differentiate between these groups.

Moreover, the acoustic parameters studied did not clearly reflect the perceived dysphonia for all subgroups. These results denote the poor diagnostic value of phonatory parameters in differentiating neuropathological groups, on the one hand, and the discrepancy between the perceptual and acoustic findings, on the other hand.

In another study, Zwirner and Barnes (1992) investigated phonation and upper airway stability in Parkinson's patients and patients with chorea (Huntington). The choriac patients had significantly higher scores than controls (normals) on the standard deviation of fundamental frequency and peak frequency of Fl and F2 while Parkinson's' patients differed from normals only with respect to peak Fl frequency. Speech profile analysis showed that the two dysarthric groups exhibited a significant difference in their percentage of articulatory and laryngeal involvement. The Parkinson's patients showed more laryngeal than articulatory involvement, and in contrast, the chorea group more articulatory than laryngeal involvement. The investigators could not observe a relationship between the laryngeal/articulatory involvement based on perceptual ratings and the acoustic measures.

4.2.2 Speech Problems in Dystonia

The slowest of the movement disorders are the dystonias. Dystonic movements are abnormal involuntary movements which are slow and sustained for prolonged periods of time. When dystonia delays the start of voluntary movements required for speech, it interferes with speech production. In addition, the voluntary movements of dystonic patients tend to be slow in attaining their desired excursions and also the repetitive movements are restricted in range. Articulation, phonation and prosody are all significantly affected in dystonia. Darley (1969 a, b) found imprecise consonants, distorted vowels, harsh voice quality, monopitch, monoloudness, irregular articulatory breakdown, strain-strangled voice quality, inappropriate silences, short phrases and prolonged intervals as the prominent speech deviations in dystonia. Hypernasality and unintelligible speech were also observed in some of their patients.

4.2.3 Speech Problems in Dyskinesia

Dyskinesia is defined as 'impairment of the power of voluntary movement' (Miller and Keane, 1978). By this definition, all involuntary movements could be described as dyskinetic, although it is usual to consider only tardive dyskinesia and levadopa induced dyskinesia under this category. Tardive dyskinesia, a side-effect of long term neuroleptic treatment, may be limited to bulbar musculature, in particular the muscles of the tongue, face and oral cavity. Therefore, it is sometimes known as 'lingual-buccal-facial' dyskinesia.

There are not many reports in the literature on the speech disturbances in tardive dyskinesia. Maxwell, Massengil and Nashold (1970) described the symptoms of 2 cases. The connected speech of both these patients was described as muffled and unintelligible, though both patients could produce some individual sounds correctly. Both patients exhibited tongue thrust behavior, but only one patient showed hypernasality.

Portnoy (1979), in a description of a single case of tardive dyskinesia, noted intermittent voice breaks with arrests in expiration in conversational speech, irregular articulatory breakdowns, changes in articulatory posturing, prosodic abnormalities (monopitch and monoloudness) and marked fluctuations in the study of 12 patients with tardive dyskinesia, Gerrett (1984) found that, of the six patients who had speech abnormalities, temporal organization and voice production dimensions were the most severely deviant. These were related to the overall intelligibility and bizarre quality of speech in these patients. Articulatory deviations were less prominent.

In general, the speech alterations in tardive dyskinesia may be sufficiently subtle as to be overlooked, or misread by all but those observers trained in the acoustic perceptual analysis of respiration, phonation, articulation, resonance and prosody (Aronson, 1981).

4.2.4 Speech Problem in Essential Voice Tremor

A pathologic form of tremor of the extrinsic and intrinsic muscles of the larynx only, or in concert with tremors of other regions of the body, is variably called essential, organic or heredofamilial tremor. It is often said that essential tremor of the laryngeal muscles produces a condition called organic voice tremor. Patients with organic voice tremor were said to have acoustic features similar to that found in patients with spastic dysphonia, including regular voice arrests (Brown and Simonson, 1963; Aronson et. al., 1968). These authors also observed excessively low pitch, monopitch, strain-strangled harshness and pitch breaks in organic voice tremor. But, the distinguishing feature of essential voice tremor is the rhythmic alterations in pitch and loudness giving the perception of tremulous or quavering voice. More severe tremor patients may show complete voice stoppage, resembling that found in spastic dysphonia.

5.0 The Motor Speech Assessment

Assessment of speech-voice characteristics constitutes an important facet of the evaluation of dysarthria, as many a times, changes in speech pattern are the sole manifesting symptoms, particularly in the early stages of the disease. Therefore, for an early diagnosis, it is important to identify and classify the subtle changes in motor speech production. McNeil and Kennedy (1984) listed the following reasons for assessing the dysarthric speaker:

- to detect or confirm a suspected problem
- to establish a differential diagnosis
- to classify under a specified disordered group
- to determine the site of lesion or disease process
- to specify the degree of seventy of the involvement
- to establish a prognosis
- to specify, more precisely, the treatment focus
- to establish criteria for treatment termination
- to measure any change

Speech examination of the motor speech mechanism is of special importance to the speech pathologist. It is done in two stages:

(a) testing the muscular strength and coordination of peripheral speech mechanism during performance of nonspeaking activities, and

b) listening to the patients speech for the purposes of description and analysis, and for correlation of its acoustic abnormalities with the remainder of neurologic findings.

The aims of speech examination are to (a) identify the site of lesion, (b) identify the different deviant voice-speech dimensions and (c) to establish the base rate of speech and its deficits (if any) in order to plan and base therapy procedures.

The various parameters to be considered for a thorough and comprehensive assessment of speech output should include the five aspects of motor speech production, namely, (a) respiration, (b) phonation, (c) resonance, (d) articulation and (e) prosody. These highly interdependent factors, influence the production of speech and are affected either independently and/or collectively following neuromuscular disruptions. Objective examination may bring about further specificity while describing the motor control system impairments in dysarthria, that is, it may be possible to characterize impairments in dysarthria in terms of motor subsystem impairment like respiratory, laryngeal, mandibular, velopharyngeal, lingual and labial (Aronson, 1985).

On the basis of physiologic data, Abbs, Hunker, and Barlow (1983) argued that different speech motor subsystems are controlled differently by the central nervous system; therefore, suprabulbar lesions yield different impairment to these subsystems. In fact, available research evidence suggests that Parkinson's disease patients have laryngeal system impairment as a major component of their speech impairment (Logemann, et al, 1978), while Huntington disease patients show more of upper articulatory subsystem impairment (Darley, et. al., 1975). Speech-voice evaluation methods should be sensitive to identify this kind and level of subsystem impairment in dysarthria.

5.1 Perceptual Analysis

Perceptual analysis of the overt symptoms of speech deviation has been the method of choice in evaluating dysarthrias by speech pathologists. Perceptual analysis has its own merits, but a major disadvantage of this type of analysis is its subjective nature. Professionals discussing dysarthria, more often than not, lack specificity in their usage of the terms. The conventional method of description can have little reliability or sensitivity as the adjectives used to describe speech behavior in dysarthrics do not have the same consistency among speech pathologists. The descriptions of speech produced by patients with multiple sclerosis by different authors (Ivers and Goldstein, 1963, Merritt, 1967; Darley, et. al, 1975) illustrates the problems of the different emphasis on different characteristics of the speech produced.

It is common to hear speech pathologists describing the speech associated with certain neurological disorders simply as 'dysarthric speech' or using relatively inexact terms like "slurred", thick', unclear', clumsy' etc. More descriptive adjectives used are 'slow', 'nasal', 'explosive' and so on. Much of this subjectivity in the usage of terms has to do with the fact that methods of objective quantification of the deviant speech dimensions in dysarthrias have been lacking. Many professionals talk of scanning staccato speech of multiple sclerosis, quivering explosive articulation of cerebellar disorders, tremulous slurring speech of general paresis, the slow speech of striatal rigidities, and the explosive unintelligible speech of suprabulbar palsy. Although these descriptions suggest a tentative diagnosis to a phonetically trained car, a proper clinical diagnosis or the rigors of scientific research require more objective descriptions than the perceptual impressions.

Rating systems developed by Darley. Aronson and Brown (1969a, 1969b); the Frenchay dysarthria assessment (Enderby, 1983) and the Assessment of intelligibility of dysarthria speech (Yorkston and Beaukleman, 1981) are classical examples of perceptual assessment of speech in dysarthric population. The Frenchay Dysarthria Assessment has been found to discriminate between five types of dysarthria - spastic, mixed, extrapyramidal, cerebellar and flaccid types (Enderby, 1986). However, it is essentially a perceptual assessment scale, the results of which need to be validated by other researchers and laboratories. The DAB study showed that nearly all patients with dysarthria suffer from what is perceived as 'imprecise consonants', 'monopitch and 'slow speech'. On an average, patient groups differed only by a few percentage points with respect to degree of impairment on any, or any combination of these parameters in the DAB study.

The Frenchay Dysarthria Assessment System is aimed at identifying components of the speech phonation system that may be affected (respiration, velopharyngeal function, voicing, etc). This has been referred to as the component approach which is most useful when particular cranial nerves or their nuclei are affected as in lower motor neuron disease (Netsell and Daniel, 1979). In the majority of the dysarthrics, however, suprasegmental segments of speech like rhythm and rate of speech production are affected. But, the Frenchay system may not be suitable in evaluating this. The Frenchay Dysarthria Assessment suffers from all the disadvantages that are associated with rating scales, that is, questionable reliability, validity and objectivity.

Intrinsically, dysarthria can be perceptually confusing, as frequently more than one speech system is affected. The Assessment of Intelligibility of Dysarthria Speech (Yorkston and Beuklcman. 1981) provides an objective measure of intelligibility, but provides no other information on other aspects of speech production which are affected. The different dimensions of coordination, timing and rate of speech production and their interplay in dysarthric speech are not assessed by either Frenchay Dysarthria Assessment or the Assessment of Intelligibility of Dysarthria Speech. Perceptually. 38 deviant speech-voice dimensions have been identified by Darley et al, (1969 a, b) but, as said earlier, the dysarthric groups differed from one another by only a few percentage points on these speech characteristics.

A number of authors have documented the perceptual speech characteristic of hypokinetic dysarthria (Enderby, 1986; Darley, et. al., 1969a, b; Zyski and Weisiger, 1987; Chenery, Murdoch and Ingram. 1988). Most of the times, hypokinetic dysarthria refers to Parkinson's disease. The most prominent speech characteristics of hypokinetic dysarthria, as reported by Darley, et. al. included monopitch, reduced stress and monoloudness, all of which represent alterations in the prosodic aspects of speech. Other speech deviations included imprecise articulation, inappropriate silences, short rushes of speech, harsh and breathy voice quality and variable rates of speech.

Although, as reported by Darley, et al (1969). the prosodic changes tend to dominate the speech disorder in Parkinsonism, it is evident from other studies that disturbances also occur in other aspects of speech production, including articulation, phonation. and resonation. Logcmann, et. al (1978) in a study of the vocal tract characteristics of 200 Parkinson's patients identified disorders of phonation, rate and articulation as well as occasional instances of hypernasality. Overall, laryngeal dysfunction was present in 89 % of their 200 subjects, articulation disorders in 45 %, rate disorders in 20 % and hypernasality in only 10 percent. Of the many laryngeal dysfunctions, hoarseness was the most perceived characteristic.

No doubt, there are many advantages to the DAB system of identification of dysarthria which can be summarized as follows.

a) such systems may allow the evaluator to be detailed, quick, accurate, and consistent in the description of the individuals speech characteristics (Simmons and Mayo, 1997),

b) such systems may provide the clinician with guidelines for evaluation and treatment development (Duffy, 1994), and

c) the results of physiological or acoustic analysis need to be perceptually validated and therefore, perceptual studies are essential.

However, the DAB system of classification does have limitations. One major limitation is that the classification relies solely on perceptual judgment of speech (Gerret, et. al., 1991). Zyski and Weisiger (1987) found that identification by means of perceptual analysis alone is not feasible. These authors, in their study, found that the overall accuracy for their listener groups (students and experienced clinicians) was only 56% and moreover, there was no difference in the accuracy levels between experienced clinicians and students.

Another limitation is that the DAB system of classification was developed as a descriptive tool for disorders of speech and that it was not designed to be a diagnostic tool (Kent, 1994). At best, these perceptual scales may provide a basis for communication between professionals and may provide some useful information on the diagnosis and site of lesion. Irrespective of these limitations, it has been found that the DAB system of classification is still one of the most widely used assessment systems for dysarthria (Simmons and Mayo, 1997) and that the professionals face less and less difficulty in using this tool with increased years of work experience. Most of the respondents in the Simmons and Mayo (1997) study also felt that the DAB system is helpful in the design of a treatment protocol.

The major limitation of perceptual assessments of dysarthric speech is that, in most circumstances, they are unable to accurately and reliably identify which part of the motor speech mechanism is responsible for the perceived speech deficit. For example, it is possible that a perceived phonatory disturbance could be the result of a deficit in cither the respiratory or laryngeal system, or both. Similarly, pitch deviations in voice may be due to the spectral composition of the signal other than its frequency.

While perceptual assessment has a role in the investigation of dysarthrias, by itself alone, is inadequate as it is subjective in nature and thus lacks specificity and uniformity. Furthermore, it does not provide measures to quantify the deficits which is required not only for a precise diagnosis but also for pre- and posttherapeutic evaluation. Therefore, there is a need for objective evaluation and quantification of deviant speech-voice characteristics in dysarthria (Ramig, et. al., 1988; Keller et al., 1991). Furthermore, the acoustic and physiological studies of dysarthric speech which followed DAB's study have questioned some of the perceptually recognized characteristics of Parkinsons disease. These include the perception of accelerating speech rate and the assumption that all subsystems of the speech mechanism are similarly affected in Parkinsons disease. These observations warrant physiological and acoustic studies of the speech of dysarthrics.

5.2 Objective Assessment

Many speech-language pathologists who assess and treat dysarthric patients routinely employ perceptual measures of speech-voice deviant dimensions to identify dysarthria type. If perceptual analysis is to be considered an effective and reliable aid in the diagnosis and classification of dysarthrias, it becomes clinically relevant to determine the accuracy of this method when used in isolation. Zyski and Weisigcr (1987) have shown that their judges (experienced clinicians and students) had only minimal success in the accurate identification of specific dysarthric types based on perceptual judgments. As has been stated earlier, some of the acoustic and physiological studies of dysarthric speech have questioned some of the perceptually recognized characteristics of dysarthrias, notably hypokinetic dysarthria. This suggests the need for more objective assessment of the speech-voice deviant dimensions in dysarthrias.

Objective assessment is possible by way of instrumental acoustic analysis and measurement of components of speech. Recent advances have expanded the scope of dysarthria examination to include this acoustic and physiologic measurement in addition to the traditional perceptual speech analysis. Over the past thirty years, it has become increasingly attractive to perform signal processing and analysis of audio signals such as speech by using 'digital computers'. A number of reasons motivate the choice of an instrumental acoustic approach over a perceptual analysis of neurologically impaired speech. The former promises to provide more detailed and more distinctive details than the latter. A systematic analysis of speech-voice deviations in dysarthria may well lead to a more conclusive identification of the speech perturbations in dysarthria than is possible with purely perceptual evaluations.

Objective measures of quantification of speech production parameters may result in valid and comprehensive measures for the assessment and analysis of dysarthrias. Objective correlations of perceptual deviations have been attempted, but such attempts are far and few. Ludlow and Bassich (1984) developed a set of objective acoustic measures which reflected the perceptual attributes, reported to be associated with hypokinetic dysarthria by Darley et al (1969a, b) through their perceptual assessments. Their method was based on acoustic measures of speech production from spectrographic and graphic level recordings. The results demonstrated that both the assessment systems arc valid in differentiating between dysarthria and normal speech. However, in both assessment systems, the differentiation between two groups of dysarthria required multivariate approach using a composite score of several measures. The implication of this is that it is the pattern rather than the degree of impairment that is of importance in characterizing a patient's speech disorder. Finally, the study demonstrated that the acoustic analysis of speech is more helpful in identifying suitable therapeutic targets for modification than the results of perceptual analysis. Ludlow and Bassich determined, through acoustic measures, two dysfunctions which principally contribute to the speech disturbances seen in Parkinson's disease. They are: (a) impaired laryngeal control and (b) impaired rate and stress control.

Weismcr (1984) using acoustic analysis found that Parkinson's patients had segmental and phrase level durations that were slightly shorter than corresponding durations in age-matched controls. This may contribute to the often cited perception that rate is increased in the speech of Parkinson's patients. Ludlow, Connor and Bassich (1987) found no evidence of an abnormally fast syllable repetition or sentence production rate to support the clinical impression of 'accelerated rate (festinant)' in their Parkinson's patients.

A number of studies based on physiological measurements have indicated that Parkinson's patients have reduced articulatory displacements (Hirose et al, 1982; Hunker, Abbs and Barlow, 1982). Hirose et al. suggested that the festinant speech is related to a disturbance of the inhibitory function of the extrapyramidal system and that the reduction in the range of movement of the articulators can be attributed to a deterioration in the reciprocal adjustment of the antagonistic muscles.

Many physiological studies have been conducted into dysarthrias particularly to understand the articulatory dynamics on the premise that analysis of the dynamic aspects of dysarthrias is a promising approach for elucidating the nature of central problems of speech production. Barlow and Abbs (1983) contend that because dysarthria is due to abnormal speech motor physiology, its diagnosis must include quantifiable and independent assessments of the motor control integrity of each motor subsystem. Conventional x-ray cinematographic technique (Kiritani, et al., 1975), computer controlled x-ray microbeam system (Hirose et.al., 1978) and electromyography of articulatory muscles (Hirose et.al., 1978) are some of the physiological instrumentation approach to dysarthrias. Barlow and Abbs (1983) used a device designed to transduce lingual force exerted toward the alveolar ridge, while Dworkin and Hartman (1979) and Dworkin, Aronson and Mulder (1980) used a force transducer designed to measure anterior and lateral tongue strength. Electromagnetic articulography technique has been employed by Ackerman et.al (1993) to study speech freezing in Parkinson's disease. These studies, in general, have contributed important information for understanding the control mechanism of speech articulation.

Perceptual identification of "spirantization" in the speech of Parkinson's cases by Logemann and Fisher (1981) was studied by Kent and Rosenbek (1982) and they too found spectrographic evidence of the presence of continuous voicing, hypernasality and poor consonant articulation which they suggested could possibly be misperceived in a perceptual analysis as a faster than normal speaking rate. Weismer (1984) also found evidence for*spirantization and continuation of vocal fold vibration into voiceless stop closure. He attributed the continuous voicing characteristic to the influence of the age of his subjects rather than to the effects of the disease itself. Since Parkinson's subjects, in general, fall into the gerontological age group, Wcismcr recommended perceptual analysis studies wherein listeners may compare the voice characteristics of Parkinson's cases with the expected speech characteristics of aged persons. Consequently, even though Parkinson's patients may speak at a rate similar to young adults, they may be perceived as having a faster than normal speech rate when compared to the slower speech rate of geriatrics.

Abbs, Hunker and Barlow (1983) reported evidence of differential subsystem impairment in their Parkinson's subjects. The degree of muscle rigidity and impairment in the range of movements were found to be differentially involved in the upper and lower lips. The patient's ability to sustain a steady force was also found to be differentially impaired in the lips, tongue and jaw. Although the implications of these findings for speech production have not been investigated, it can be expected that they influence speech sound articulation (imprecise and weak consonants) and may also have effects on such aspects of prosody like rate and duration of speech.

The research of Zwirner, Murry and Woodson (1991) and Zwirner and Barnes (1992) failed to find a relationship between the acoustic features and perceived dysphonia in their patients. The first study employed Huntington's, Parkinson's and ataxic groups while the latter study investigated Parkinson's and Huntington's groups. The reasons may be several for this discrepancy. One methodological reason is that the perceptual ratings were based on judgment of speech samples (standard passage) while acoustic analyses were based on samples of sustained phonation. These results may also be a commentary on the poor diagnostic value of phonatory parameters. In general, these results seem to suggest the need for a combined perceptual and acoustic analysis, rather than sole emphasis on either of these methods.

In summary, the studies using acoustic analysis have questioned some of the perpetually recognized characteristics of Parkinson's disease. These include the perception of accelerating speech rate and the assumption that all subsystems of the speech mechanism are similarly affected in Parkinsonics.

6.0 Acoustic Analysis of Voice and Speech

The advent and proliferation of personal computers has made the task of acoustic analysis within the reach of a clinician in any setting. The digitization of speech has opened up enormous possibilities for the analysis of any segment of speech, be it in the frequency, intensity or the time domain of acoustic signal.

Once the speech signal has been put into a form suitable for storage and analysis by a computer, several different operations can be performed. The waveforms can be measured and edited (for example, deleting one portion and connecting the two pieces together to make an entirely different sound). Spectra can be computed using methods like Fast Fourier Transformation, cepstrum, and linear predictive coding. Digitization of the acoustic signal (converting the analog signal to a digital representation) is the central tenet of the whole process.

Filtering, sampling and quantization are the basic operations in digitizing a signal. The basic process in digitization is to convert a continuous (analog) signal to a discrete (digital) representation. The digital representation is a series of numbers using 0 and 1 only. The reverse operation of digital to analog conversion is the process by which the series of numbers stored in the computer are converted to analog form. This is required to play back the signal as well as to synthesize speech. When an analog signal (speech) is digitized, two operations are performed simultaneously. The first is a discretization in time, meaning that the analog signal is sampled at certain time points usually periodically spaced. The periodic spacing is reflected in the sampling rate which specifies the regularity of the sampling process. A sampling rate of 16 kHz means that the original analog signal is sampled 16,000 times per second.

The second operation is the discretization of signal amplitude. This operation called 'quantization' represents the continuous amplitude of the original analog Signal as a SerieS Of levels Or Steps. Sampling and quantization are the essence of digitization. The digitized signal may be subjected to time domain or frequency analysis as detailed below:

Frequency domain	:	FFT or LPC spectrum
		Formant tracking and transition
		Fundamental frequency (FO) analysis
		Signal to noise ratio
		Speech synthesis
Time domain	:	Waveform display and editing
		Playback - original or edited signal in part or in full
		FO analysis and amplitude variation
		Jitter and shimmer analysis

7.0 Neuromuscular Basis of Speech Motor Control

Speech production is a highly developed motor skill which takes years to acquire and some would say that it is still developing even up to the early teens. It involves the production of a sequence of movements which are controlled by several regions of the nervous system. Given its extreme complexity, the speech production process is usefully conceptualized in terms of different physical levels. In addition to the CNS involvement, one must consider the structures involved in speech production and aerodynamics of speech. The structures involved include not only the most obvious such as larynx, the tongue, the pharynx, the velopharynx, the jaw and lips, but also rib cage, the diaphragm and the abdominal muscles, all of which, if affected, can produce abnormalities in speech.

Aerodynamic features include oral, nasal and glottal airflow. Intraoral air pressure affects the ability to produce certain phonemes and subglottal air pressure affects phonation (Netsell, 1986).

According to Paillard (1983), motor planning involves selection of an appropriate movement strategy in the light of intended goals and prevailing physical conditions. Intended goals for speech may be thought of as words or phrases and thus, in planning a speech utterance, such units may be represented or coded as either spatial, aerodynamic or acoustic targets. A general strategy for the achievement of such targets would be part of the speech motor plan. In order for this plan to be enacted, there has to be a motor programming stage and this would entail provisional specifications of how precisely the motor plan is to be achieved. For example, which muscles contract and at what time. It is probable that this programming stage also involves sensory aspects so that when the movement is started, the programming and execution can change according to the sensory feedback received.

Through the course of this execution process, the discharge of motor neurons is influenced by numerous brain centres and sensory pathways. Thus, the neural correlates of motor planning, programming and execution are likely to vary with the type of movement and the degree of learning along with any impediments - physical or emotional.

Although the nature of these process is not well understood, advances in clinical ncurophysiology have increased our understanding of the physical aspects of dysarthria in the last decade (Abbs, 1982).

The cerebral cortex is recognized as the major structure of speech processing (Abbs and Cole, 1982). Abbs and Welt (1985) suggest that multiple representations of muscles in cortical areas, may provide a partial basis for the control of diverse speech gestures in a single structure. For example, lip movement for rounding and closure. It has been found that primary motor cortex activity is well correlated with muscle force changes in learned movements (Hoffman and Luschei, 1980). This would suggest that the motor cortex is an important site for sensory motor integration immediately prior to the lower motor neurons.

Further integration takes place in the cerebellum which is specialized for movement control and which plays an important role in the coordination of speech production. The two distinct cortico-cerebellar pathways which seem to be important in the regulation of output of speech are discussed by Nielsen and O'Dwyer (1984) who concluded that the intermediate cerebellum utilizes sensory input to effect rapid modifications of cortical motor output during movement execution.

The distinct nature of dysarthric speech associated with basal ganglia disease suggest that this collection of subcortical nuclei plays a very specialized role in speech motor control. In general, the basal ganglia are seen to be important in the planning and programming of learned movements which may involve setting the kinematic parameters of movements, for example, the direction and amplitude of such a movement.

The existence of different types of motor units which act as an interface between the nervous system and the mechanical system is an important concept in motor physiology (Burke and Edgerton, 1975) and has direct application in the assessment and treatment of dysarthria. The variety of properties of each motor unit is utilized in different muscle systems to achieve unique functions (Clamman, 1981). Netsell (1986) has suggested that the muscles used in speech production tend to have motor units with properties that are intermediate between those for the eyes and for the limbs. For example, there is considerable variability in motor neurons in the lip muscles.

In previous decades, the majority of the work was on motor control but the contribution of sensory feedback to speech motor control has attracted more attention recently. It is not only important to recognize the role of proprioception and touch in speech, but also the role of auditory receptors in detecting air pressure. MeClean (1987) calls for continued research in this area and points out that recent investigations on the neural mechanisms underlying dysarthria have emphasized the potential significance of abnormal processing of sensory information. Nielson and CTDwyer (1984) suggest that the disordered movement processes associated with cerebral palsy speech are due to sensory deficits resulting from congenital deformity of the neural pathways projecting over the ventral thalamic nuclei.

The temporary dysarthria experienced by patients who have received local anesthesia for dental or oral surgery demonstrates some similarities to other pathologies. However, the separation of the oral motor and oral sensory system is clearly not so straightforward as previously suggested.

Efficient movements of the muscles require accuracy of timing, force, direction and range of movement. These parameters are affected in both hypo- and hypcrkinetic type of dysarthrias because of the regulatory influence of the extrapyramidal system on the accuracy of movements of speech musculature originated elsewhere. Therefore, one can predict that the individual movements are characterized by inaccuracy and abnormal movements of the affected muscles. There is sufficient evidence, although determined by perceptual assessment studies, that the Parkinsonic speech (hypokinetic dysarthria) is characterized by prosodic insufficiency. Further, the speech is of variable rate and is characterized by short rushes and imprecise consonants (Darlcy et al., 1969a, b). It is believed that the prosodic insufficiency, in hypokinetic dysarthrias, is due to the reduced range of individual and repetitive movements, and also due the repetitive movements which are fast, but have very limited range. When we talk of neuromuscular basis of deviant speech-voice dimensions, our interest is to find experimental evidence for the above mentioned features. This would include determining the site of lesion, particular systems, structures and muscles that are involved, the nature of involvement, the resultant effect on the nature of movement of the muscles and the speech functions that are affected.

The results of acoustic studies and information on what segments and processes of speech are affected in different dysarthrias may help understand the motor control of speech. We expect that from the results of acoustic studies of speech in dysarthrias two types of analysis can be done:

a) after determining the site of lesion and the muscles involved, predict the speech dimensions that could be affected, or

b) after an analysis of the speech functions, use deductive logic to predict the system and muscles that could be involved and the particular effect of the lesions of these systems/muscles.

This includes information on the site of lesion, particular structures and muscles involved, nature of involvement, the resultant effect on the nature of movement of the muscles and on the speech functions that are affected. A correlational analysis between these, it is hoped, would establish a neuromuscular basis of the deviant speech-voice dimensions. The establishment of neuromuscular basis of deviant speech-voice dimensions is expected to help in finding out one to one relationship between the speech-voice deficits and the underlying abnormality. This will also help in developing therapeutic management for this problem. However, it is beyond the scope of this study.

8.0 Scope of the Present Study

8.1 Statement of the Problem

The literature reviewed with regard to the speech characteristics of both hypokinetic and hypcrkinetic dysarthrias shows that most of the studies have employed perceptual assessment techniques to evaluate dysarthric speech. Many of the demerits of the perceptual assessment of speech, highlighted earlier, makes the clinician to look for more objective evaluation techniques in the assessment of dysarthria. In this context, the acoustic analysis of speech in dysarthria has been shown to be promising technique. Most importantly, thorough and comprehensive acoustic analysis of voice and speech (in the domain of phonation, resonance, articulation, and prosody) of dysarthria has not been done so far. Some of the acoustic studies question the perceptually identified speech characteristics particularly in Parkinson's disease. Furthermore, it is not true that all subsystems of the speech mechanism arc similarly affected in any given dysarthria.

There are only a few studies which have attempted objective assessment through acoustic analysis. Furthermore, such studies have looked into only a few deviant dimensions of speech. Among dysarthrias, Parkinson's disease is one type of dysarthria which has been investigated for phonatory, resonatory, prosodic, articulatory and respiratory deviations while the hyperkinetic dysarthrias have not been studied to that extent. Even in Parkinson's disease, articulatory and prosodic studies dominate in comparison to phonatory and other aspects. Moreover, their is no one study which has undertaken a comprehensive assessment of all the motor systems of speech, in some detail.

Canter (1963, 1965a,b) studied only phonatory and articulatory aspects and concluded that many of the deficiencies in the conversational speech of persons with Parkinson's disease derive, at least in part, from reduced physiological support. Mueller (1971) studied the sustained phonation and diadochokinetic rate in hypokinetic dysarthria and concluded that in Parkinson's disease, the nuuromuscular impairment prevents the individual from generating sufficient amounts of aerodynamic energy for normal speech production. Ackerman, et. al (1986) studied only diadochokinetic rate. Thus, the studies reported so far have restricted themselves to the study of one or two aspects of speech production in dysarthria.

Univariate comparison that emphasizes a single specific feature as characteristic of the whole group may be misleading. Multivariate approaches more accurately differentiate subcategorics of the subjects, and should be of greater utility in identifying the degree of impairment and the effects of treatment for dysarthria. The most meaningful understanding ol'dysarthria may result from a multiple acoustic analysis and measurements performed in a given dysarthric patient, with the factor and cluster analysis performed in a manner similar to that used by Darley, et. al (1969a, b). Therefore, it is the purpose of this study to make a thorough and comprehensive acoustic evaluation of the speech of subjects with hypokinetic and hyperkinetic dysarthrias. This study looks at some aspects of phonation, articulation, resonance and prosody. The process of respiration has not been looked into for lack of instrumentation.

8.2 Need for the Present Study

Darley et al. came out with clusters of deviant voice and speech dimensions that are differently affected in different dysarthrias which is useful in the differential diagnosis of dysarthrias. Such a type of multidimensional diagnostic formulation is not available based on the results of acoustic analysis of speech. This is because there is no one comprehensive study which has considered all the acoustic parameters that could be deviant in dysarthric speech, or which has considered all types dysarthrias. As pointed out earlier, different investigators have focused on a single aspect of speech signal (like frequency, or perturbations or prosodic deviations), or have considered one or two dysarthrias, mostly of Parkinsonism or cerebellar disorder (Jayaram, 1997).

In the evaluation of speech disorders like dysarthria which are a sequel to known neurological disorders, the speech pathologists have the awesome task of evaluating complex patterns of neuromotor disturbances underlying speech expression. Speech production in normals is an automatized skill and patients with dysarthrias exhibit disturbances of these automatized skills of speed, control, fluency and timing in speech production. As the patterns of movement control are disturbed, the integrity of the oral mechanism, its structures, and muscular components are no longer predictive of the patients speech production impairment. Assessment, therefore, must identify and quantify the alterations in speech movement patterns that are due to motor control disturbances.

In the assessment of these disturbances, one technique is to use the perceptual judgments of the degree and type of impairments exhibited by patients in connected speech. For example, the rating scale systems of Darley et.al (1969, a, b). No doubt, the rating scale systems like those of Darley et al are easily understood and also are of help in classifying a speech disorder. Strict criteria are not available, however, for others to use such scales reliably. Also, some perceptual systems have limited analytical power in identifying and determining aspects of affected speech motor patterning. Furthermore, perceptual systems are difficult to standardize over time and across different settings, thereby affecting the inter- and intrarater reliability. Perceptual rating systems are also difficult to replicate, thus, limiting the comparability of the results from different laboratories

Some of these problems can be avoided by measurement of components of speech signal through acoustic analysis. However, it must also be said that, though the acoustic analysis of speech can be objective and reliable, it may not have the same degree of content validity for assessing a patients communicative impairment that listeners perceptual ratings do. In other words, the acoustic measures may not assess those aspects of speech production that are important for the patients to be able to communicate accurately with others. As stated earlier, many researchers, have examined motor speech disorders in dysarthria by means , of EMG, laryngoscopy, ultrasound, x-ray film and x-ray microbcain (1 tosh, ct.al., 1982; Keller 1987; Hunker and Abbs, 1984; and many others). However, it can be argued that at the most fundamental level the acoustic aspects of speech provide the essential communicative interface between the patient and the listener. While underlying articulatory performance is of great diagnostic and theoretical importance, a patient's communication or rehabilitation performance is ultimately concluded with reference to the acoustic and perceptual levels. Therefore, there is a need for developing a complete evaluation procedure to be developed exclusively around instrumental acoustic analysis.

Therefore, there is a need for a comprehensive study which looks into the distribution of a number of acoustic variables of speech and their disorders in dysarthrias. A preliminary study, under this project reported that, of all the acoustic parameters, the perturbation factor (jitter and shimmer) and the diadochokinetic rate may be the more critical variables in the differential diagnosis of dysarthrias (Basavaraj et.al., 1995). This study also provided evidence that perturbation and DDK rate have the potential to differentiate normals and dysarthrics; between spastics and ataxies; between hypokinctic and hypcikinetic dysarthrias; and among mixed dysarthrias .

Objective quantification of the speech-voice dimensions of dysarthrias is needed for the following reasons:

a) Not all the institutions, or not all the speech pathologists may have access to information from the sophisticated investigation of a neurologist. In such instances, it becomes necessary for the speech pathologists to identify the deviant speech pattern and arrive at a tentative diagnosis.

b) Quantification may also help professionals to make differential diagnosis of dysarthrias. However, quantification would definitely help the speech pathologists to establish the base line of speech status prior to speech therapy and to measure the effect of therapy. Quantification would also help the clinician to classify their subjects into categories based on severity which is required in research many a times.

c) It helps the speech pathologists to give diagnostic information to the neurologists to cross-check or substantiate the latter' findings.

8.3 Objectives of the Study

The objectives of this study were to

a) identify and quantify phonatory, articulatory, resonatory and prosodic deviations in the speech of hypokinetic (Parkinson's disease) and hyperkinctic dysarthrias,

b) to identify and quantify the deviant-voice-speech dimensions among the hyperkinetic dysarthrias, namely, chorea, dystonia, dyskinesia and essential voice tremor, and

c) to identify deviant speech-voice dimension(s) that may be relevant to the diagnosis of a given dysarthric condition, and

d) to identify deviant speech-voice dimensions that may be most relevant to differentiation of hypokinetic and hyperkinetic dysarthrias.

Chapter 2

METHOD AND MATERIALS

1.0 Introduction

Literature reviewed in Chapter 1 has shown that most of the studies on the evaluation of speech-voice deviations in dysarthrics have employed perceptual system of assessment. While perceptual assessment systems have their own advantages, many of their demerits, more particularly, their subjective nature and consequently their poor reliability have led the clinicians to look for more objective methods of evaluation. Most of these objective evaluation methods employ some kind of acoustic analysis of speech as one of the methods to identify the speech-voice deviations in dysarthria. A chief advantage of objective quantification methods over the perceptual system of assessment is that the former can reliably identify the part of the motor speech system responsible for the perceived speech defect. For example, perceived phonatory difficulty in dysarthrics may be because of respiratory abnormalities rather than laryngeal defects and the objective systems of identification are better suited to resolve this controversy. However, it is a different matter altogether that the measurements based on acoustic analysis are to be perceptually validated.

Though, in recent times, there have been many studies employing acoustic analysis or other objective methods of identification and quantification of speech deviations in dysarthric patients, Parkinson's disease seems to have been the subject of most of these studies. Not many studies can be found, in any case, on the hyperkinctic type of dysarthrias. Also, there is no one study which has looked into abnormalities of more than one motor system of speech control. There are studies which have dealt with articulation or phonation or resonance, but there is no one study which has investigated a combination of these motor control systems. The purpose of this study, therefore, was to identify the deviant speech-voice dimensions with respect to motor control systems of articulation, phonation, resonance and prosody in the two clinical groups of

a) hypokinetic dysarthria, essentially, Parkinson's disease and

b) hyperkinetic dysarthrias, including chorea, dystonia, tardive dyskinesia and essential voice tremor.

2.0 Method

2.1 Subjects

Patients with some kind of dyskinctic dysarthria (that is, hypo- or hyperkinetic dysarthria) attending the department of Neurology, or the department of Speech Pathology and Audiology, at the National Institute of Mental Health and Neurosciences, Bangalore were taken up for the study. Only those patients, who fulfilled the following criteria were included in the study:

a) subjects in the age range of 20 to 60 years,
b) literate speakers of Kannada, a Dravidian language spoken in this region,
c) subjects with normal hearing,
d) subjects who have had no prior speech therapy or medical treatment for their speech problems or dysarthria at the time of reporting.

Patients who had one of the following characteristics were not considered for the study:

a) patients with apraxia of speech
b) subjects using artificial dentures
c) patients with no teeth
d) patients who had some neurological impairment other than those resulting in speech impairment, and
e) patients who had, at the time of reporting, some kind of upper respiratory infection.

In this manner, two groups of patients were selected. The First group, with 8 subjects, was the hypokinetic group (Parkinsonism). The second group included 16 patients with hyperkinetic dysarthrias, consisting of 4 patients with chorea, 4 patients with dystonia, 4 patients with orofacial tardive dyskinesia and 4 patients with essential voice tremor. All these patients were included in the study only after a clinical diagnosis of dysarthria by a neurologist. Table 2.1 gives details of subjects selected for the present study.

Patients in the hypokinetic group, that is, Parkinsonics were in the age range of 20 to 60 years with a mean age of 40.7 years. Patients in the hyperkinetic group were between 32 to 60 years (chorea), 45 to 60 years (essential voice tremor), 22 to 60 (dystonia), and 27 to 60 years (tardive dyskinesia). There were 6 males and 2 females in the hypokinetic dysarthric group while there were 11 males and 5 females in the hyperkinetic dysarthric group. Within the hyperkinetic dysarthric group, the chorea group had 3 males and 1 female; the cssential voice tremor group had 2 males and 2 females, the dystonia group had 2 males and 2 females while the tardive dyskinetic group 4 males and no females. Table 2.2 gives more details about the subjects of this study.

Subject Group	Male	Female	Total
Normals	8	2	10
Hypokinetic dysarthria:			
Parkinsonism	6	2	8
Hyperkinetic dysarthria:	11	5	16
consisting of			
Chorea	3	1	4
Dystonia	2	2	4
Tardive dyskinesia (oro facial)	2	2	4
Essential voice tremor	4	0	4

Table 2.1 : Number and category of subjects included in the study.

A control group of 10 normal subjects was formed for obtaining normative data. Subjects for the control group were selected from the general population, at random, and the subjects fulfilled the following:

a) normal hearing
b) normal speech and speech mechanism

c) no neurological problem or history of neurological disease

d) no infection of the upper respiratory or laryngeal system

e) literate speakers of Kannada, a Dravidian language of this region.

SI. No.	Diagnostic Category	Min. age	Max. age	Mean age	Mean durn. - Speech	Problem Dysarthria
		......Years......				
1.	Normals	25	45	34.9		
2.	Hypokinetic Dysarthria.					
	Parkinsonism	20	60	40.75	1.13	2.75
3.	Hyperkinetic Dysarthria:	22	60	48.56	3.44	6.44
	a) Chorea	32	60	44.25	1.25	4.75
	b) EVT	45	60	52.6	6.50	6.75
	c) Dystonia	22	60	46.0	3.50	3.50
	d) Dyskinesia	27	60	43.0	2.50	10.50

Table 2.2 : Age of the patients and the duration of their dysarthric and speech problem

Normal subjects were in the age range of 25 years to 45 years with a mean age of 34.9 years. Of the 10 normal subjects, 8 were males and 2 were females.

Formal consent was obtained from the patients after explaining to them the purpose and nature of the study. The subjects had the freedom to drop out from the study at any time without having to give any reason for doing so. Patients were assured that their participation or non-participation in the study will not have any bearing on the treatment they will get at the institute (Appendix 1).

2.2 Material

Detailed case history of the subjects in both the experimental and the control group was collected in terms of neurological and speech findings after clinical examinations by a neurologist and a speech pathologist, respectively.

2.2.1 Proforma for Neurological Examination of Dysarthria

Detailed information about each patient was obtained and recorded through medical records and an interview with the subject or his/her family members (Appendix 2). Information obtained pertained to family history; age of onset of the problem; and course of illness, among others. Neurological examination included evaluation of cranial nerves, motor, sensory, pyramidal and extrapyramidal, and cerebellar systems. Clinical speech evaluation by a neurologist was also a part of the neurological examination of dysarthria. CT scans were taken for all subjects.

2.2.2 Proforma for Dysarthria Evaluation

Detailed information on dysarthric speech was collected by the experimenter, after a through speech evaluation as per the proforma (Appendix 2), with emphasis on linguistic background, on the onset of speech problem, disease progression; structure and function of speech mechanisms, vegetative functions; nature of speech problem and communication behaviour.

2.3 Protocol for Speech Examination

A battery of tests was developed to evaluate the phonatory, resonatory, articulatory and prosodic aspects of the speech of the subjects of this study. Table 2.3 gives the protocol for speech examination developed and used in this study.

Voice and Speech Test Protocol

1. Sustained phonation of vowels in isolation: /a/, *Iil* and *Iul*
2. Pitch glide : phonation of/a/ from low to high pitch
3. Loudness glide : phonation of/a/ from soft to loud voice
4. Sustained production of *Is/* and *Izl* for s/z ratio
5. Picture-word articulation test
6. List of 36 CVCCV words for voice onset time measurement
7. Phonation of/a/ for the measurement of voice initiation time and voice termination time
8. Two sentences for measurement of speech initiation time
9. Rapid repetitions of :

a) stop consonants : /pa/, /ba/, /ta/, /da/, /ka/, /ga/ in isolation, with and without bite block

b) an affricate /ja/ in isolation

c) bisyllabic CVCV combinations: /pata/, /bada/, /paka/, /baga/.

d) trisyllabic CVCVCV combinations : /pataka/ and /badaga/

e) vowels /a/, /i/, and /u/ in isolation

f) vowel combinations : /a-i/, /i-u/ and /u-a/.

g) CVCVCV Combinations - trisyllables : /pipapu/, /titatu/, /kikaku, /bibabu/, /didadu/, /gigagu/

10. a) Phonation of isolated vowels : /a/, /i/, /u/, /e/, /o/; production of humming /m/ and sustained *Izl* sounds for evaluation of nasality

    b) Two sentences - one with nasal sounds and another without any nasal sounds

11. Spontaneous speech - narration on a picture story chart

12. Reading of a 395-syllable all-phoneme passage

13. Reading of a part of 'all-phoneme passage' in whispered mode

14. Two-sentences for rate of speech production

Table 2.3 : Voice - speech test protocol

2.3.1 Phonatory Parameters

Patients with neurological impairment are known to have laryngeal dysfunction in many ways including (a) the adductory presetting of the glottal aperture, (b) vocal attack (onset characteristics) which reflects the coordination between ventilatory and laryngeal function, (c) the generation, and maintenance of a suitable balance between vocal fold length and tension, unilaterally or bilaterally, and (d) the ability to coordinate laryngeal and supralaryngeal systems.

2.3.1.1 Phonation Samples of Isolated Vowels : /a/, /i/ and /u/

Two types of phonation samples of vowels /a/, /i/ and /u/ in isolation were recorded from the subjects. In the first instance, the subjects were asked to sustain phonation of/a/ for as long as possible at **a** comfortable loudness level following a deep breath. This sample was used to measure the maximum phonation duration. This task evaluates the combined contribution of respiratory support and glottal competence for phonation.

In the second instance, the subjects were asked to sustain phonation of vowels /a/, /i/ and /u, at a comfortable loudness level and for a comfortable duration. These samples were used for evaluating :

a) measures of vocal attack or rise time and fall time,

b) measures of steadiness of voice or intensity decay,

c) fundamental frequency,

d) vocal intensity,

e) perturbation measures of jitter and shimmer,

f) harmonic-to-noise ratio

g) long term average spectrum, and

h) fluctuations of frequency and intensity (voice tremor)

2.3.1.2 Frequency Range : Phonation of Vowel /a/

Phonation sample of vowel /a/, where the subjects were asked to start phonating at their lowest frequency and then to continuously change it to attain the highest frequency that he/she is capable of, was collected. This task determines whether the subject has the capacity to alter fundamental frequency on a non-speech task in a range adequate for speech intonation.

2.3.1.3 Intensity Range : Phonation Sample of Vowel /a/

Phonation sample of vowel /a/ where the patient was asked to start at the lowest intensity and continuously change it to attain the highest intensity that he/she is capable of, was collected. This task determines whether a subject has the capacity to achieve low and high intensity levels on a non-speech task in a range adequate for speech intonation.

2.3.1.4 Sustained Production *of /s/* and /z/ Sounds

Samples of sustained productions of hissing voice /s/ and buzzing sound /z/ were collected from the subjects. This task is to infer on the presence or absence of any laryngeal pathology that might be contributing to phonation problem. However, this task does not rule out any incompetency of the respiratory system.

2.3.2 Resonatory Parameters

Dysarthric subjects may exhibit hypernasality and nasal emission of the air stream during speech. The following speech and voice samples were recorded from the subjects to assess the velopharyngeal function:

a) Sustained phonation of vowels /a/, /i/, /u/, /e/ and /o/ in isolation
b) Humming of a nasal sound /m/

c) Production of a buzzing sound /z/

d) Reading or repetition of the following two sentences:

Sentence 1 : ni:nu namma manege banðu no:ḍu

Sentence 2 : a: pusθaka bahaḷa ðoḍḍaðu

Sentence 1 above has both nasal and non-nasal sounds while sentence 2 has no nasal sounds.

TONAR and nasalance were measured on these voice and speech tasks. The term 'TONAR' refers to 'The oral Nasal Acoustic Ratio'. Nasalance is a complementary measure of TONAR and is expressed in terms of percentage.

2.3.3 Articulatory Parameters

In dysarthric subjects, the loss of precision, timing, and/or strength of movements of the muscles of speech mechanism may lead to articulatory deviations. Articulatory disorders were evaluated in the following tasks:

2.3.3.1 **Picture Word Articulation** Test (PWAT) in Kannada

The purpose of this test was to identify the misarticulation of phonemes in terms of substitution, omission, addition and distortion. A picture-word articulation test in Kannada which had been developed by the experimenter and which had been tried on normal subjects for reliability and validity, was employed to evaluate misarticulations in the speech of the subjects of this study. This test consisted of 59 color-picture cards, to test 21 consonants in two positions (initial and final), 12 vowels and 5 consonant clusters. The pictures and words were selected in the test in such a way that each consonant appeared in the initial and middle position of word. In Kannada, there are no words ending with consonants although such words can be heard in the spoken form. Therefore, words and pictures were selected to include the test consonants in the word-initial and word-middle position only. Consonant clusters were tested in the word-initial position only. Misarticulation of vowels in word-final position were analysed from the responses of the patients on one or more of these 59 picture cards and words (See Appendix 3)

2.3.3.2 All-phoneme Passage

An all-phoneme passage, 395 syllables in length, in Kannada (Sec Appendix 3) in which all phonemes of the language occurred at least 3 times in the word-initial position was used to collect reading samples from the subjects. This reading sample was used to

a) analyse articulatory errors

b) measure consistency of articulatory errors, and

c) measure reading rate

The subjects were asked to read the first three sentences of the passage for a second time, but this time in the whispered mode. Whispered speech samples were collected on the premise that analysis of the same would help in understanding the contribution of laryngeal factors to dysarthric speech.

2.3.3.3 Voice and Speech Samples for Latency Measurements

The dysarthric subjects may exhibit difficulty with the rapid initiation and termination of speech. This difficulty may be because the patients cannot coordinate the laryngeal actions with the respiratory components, or (b) they cannot activate the supraglottal structures for articulation, or (c) because the central control mechanism mediating the laryngeal, articulatory and respiratory functions is faulty. Furthermore, the patients may have difficulty in the quick initiation and termination of speech only when (a) phonation is involved or, (b) when supralaryngeal articulation is involved. The following voice and speech samples were collected to assess the difficulty that the subjects may have in the rapid initiation and termination of voice/speech:

a) phonation of vowel /a/ and it's termination in response to click, and

b) production of the following two sentences:

Sentence 1 'Kh' enðu heḷu
Sentence 2 a: cup esi

Sentence 1 starts with a voiceless sound whereas sentence 2 starts with a voiced sound.

2.3.3.4 Voice Onset Time (VOT)

VOT is the time interval between the plosive burst and the onset of vowel (voicing). The speech of dysarthrics may be characterized by abnormal VOTs such as invariable prevoicing (negative VOTs) or excessive voice lag. Dysarthrics often have poorly defined plosive bursts due to their inability to quickly and completely halt the air stream or to release the burst due to neuromuscular disorder.

Speech samples consisting of 36 'words' were recorded from each subject. The Kannada 'words' were of CVCCV type, with each of the six stop-piosives of /p/, /t/, */k/,* /b/, /d/, and /g/ occurring in the word-initial position (first C in CVCCV sequence) in the vowel environment of /a/, /i/ and /u/ (first V in CVCCV). The consonant succeeding the vowel (second and third consonant in the CVCCV series) was again a voiced or a voiceless stop-plosive. Thus, for each stop-plosive in the word-initial position, there were six 'words' as follows.

PAKKA, PAGGA, PIKKA, PIGGA, PUKKA, PUGGA

The strict criteria adopted in forming the words (stop-plosive in the word-initial position followed by one of the 3 vowels /a/, *I'll, or Inl,* and this followed by a voiceless or voiced stop-plosive), left us with no choice but to use some meaningless 'words'.

2.3.3.5 Diadorhokinctic Repetitions

Rapid repetition of a syllable requires alternating articulatory movements, usually from a completely closed vocal tract to a completely open vocal tract. It is believed that information on rate and regularity of repetition on a DDK task provides insight into the adequacy of the patients neuromotor maturation and integration. DDK was analysed on the following speech tasks:

a) repetition of vowels /a/, /i/ and /u/ in isolation - to assess the rate of phonatory onsets and offsets,

b) repetition of vowel combinations /a-i/, /i-u/ and /u-a/ - to assess and understand the difficulty the dysarthrics may have in achieving the transitions required between two vowels requiring different tongue positions,

c) repetition of syllables /pa/, /ta/, /ka/, /ba/, /da/ and /ga/ in isolation, and without bite block. This task assesses alternate motion rate (AMR),

d) repetition of syllables /pa/, /ta/, /ka/, /ba/, /da/, and /ga/ with bite block to eliminate the influence of jaw movement,

e) repetition of syllable /ja/ to assess the rate of production of a palatal affricate,

f) repetition of bisyllabic sequences /pa-ta/, /pa-ka/, /ba-da/ and /ba-ga/ to assess the ability of the subjects to move from one articulatory position to another,

g) repetition of trisyllabic sequences with consonants requiring different place of articulation. One sequence comprised of voiceless bilabial, velar and alveolar consonants (/pa ta ka/) while the other sequence consisted of voiced consonants (/ba da ga/),

h) repetitions of trisyllabic sequences (CVCVCV). This sequence was formed by using the same stop-plosive consonant in different vowel contexts. For

a) repetition of vowels /a/, /i/ and /u/ in isolation - to assess the rate of phonatory onsets and offsets.

b) repetition of vowel combinations /a-i/, /i-u/ and /u-a/ - to assess and understand the difficulty the dysarthrics may have in achieving the transitions required between two vowels requiring different tongue positions,

c) repetition of syllables /pa/, /ta/, /ka/, /ba/, */da/* and */ga/* in isolation, and without bite block. This task assesses alternate motion rate (AMR),

d) repetition of syllables /pa/, /ta/, /ka/, /ba/, /da/, and /ga/ with bite block to eliminate the influence of jaw movement,

e) repetition of syllable /ja/ to assess the rate of production of a palatal affricate,

f) repetition of bisyllabic sequences /pa-ta/, /pa-ka/, /ba-da/ and /ba-ga/ to assess the ability of the subjects to move from one articulatory position to another,

g) repetition of trisyllabic sequences with consonants requiring different place of articulation. One sequence comprised of voiceless bilabial, velar and alveolar consonants (/pa ta ka/) while the other sequence consisted of voiced consonants (/ba da ga/),

h) repetitions of trisyllabic sequences (CVCVCV). This sequence was formed by using the same stop-plosive consonant in different vowel contexts. For example, /pi pa pu/. The sequences elicited were /pi pa pu/, /ti ta tu/, /ki ka ku/, /bi ba bu/, /di da du/ and /gi ga gu/.

Tasks(f)and(g) above assess sequential motion rate (SMR) which measures the ability to move quickly from one articulatory position to another.

2.3.4 Prosodic Parameters

Abnormalities at any level of central or peripheral neural control can alter one or more aspects of prosody. Most often, dysarthric subjects exhibit deviations in prosodic features such as variation of the vocal fundamental frequency (perceptually - pitch variations), intensity (perceptually - loudness variations) and duration (perceived as variations in either rate or rhythm). Material for testing prosodic aspects included

2.3.4.1 Spontaneous Speech Sample

Spontaneous speech sample was elicited from subjects by asking them to speak a story based on a series of 6 pictures given to them. The series of pictures describe a simple story. The same series of pictures were presented to all the subjects to keep the content of speech constant. These speech samples were used for the analysis of speaking rate, speech rate, speaking fundamental frequency, the perceptual assessment of speech intelligibility and for rating the severity of dysarthria.

The subjects were asked to tell the story, or part of the story for a second time, but this time in the whispered mode. Whispered speaking rate was computed from this sample. The task of whispering throws light on the laryngeal problems that the patients may have.

2.3.4.2 Material for Sentence Production

Studies on speech production at different rates reveal on how speakers accomplish variations in rate, how these changes are signalled to listeners, and how these alterations affect various classes of speech sounds. When a subject speaks faster, the overall duration of an utterance decreases. This can be accomplished in two ways; the duration of pauses between word and syllables can be decreased; or the duration of sounds/words themselves could be reduced.

Therefore, to assess the subject's ability to control speaking rate in sentences, the following two sentences, with two clauses in each were recorded at normal and a fast rate from the subjects: one sentence contained only voiceless sounds in the word-initial position while the other sentence contained only voiced sounds in the word-initial position.

Sentence 1 : ʃiva ṭi: kuḍiðano
sebu θinðano: ?

Sentence 2 : avanu edakke ho:ðano
balakke ho:ðano: ?

Table 2.4 summarizes the speech material used and the purpose for which it was employed in the study.

Speech Material	Purpose
Phonatory Parameters	
1. Sustained phonation sample of isolated vowels /a/, *I'lI* and /u/ after deep inspiration	Maximum phonation duration
2. Sustained phonation of vowels /a/, */i/* and /u/ in isolation	Frequency and intensity measurements, frequency and intensity decay, jitter, shimmer, voice tremors and pitch breaks.
3. Pitch glide - phonation of /a/ from low to high pitch level.	Measurement of frequency range
4. Intensity glide - phonation of /a/ from soft to loud voice.	Measurement of intensity range
5. Sustained production of /s/ and /z/ sound after deep inhalation	For s/z ratio.
Resonatory Parameters	
6. Phonation of vowels: /a/, /i/ and	Measurement of resonatory

Table 2.4 continued....

/u/, consonants /m/ and /z/; and two sentences, one with nasal sounds and the other without any nasal sounds	parameters : Nasalance and Tonar
<u>Articulatory Parameters</u>	
7. Rapid repetitions of consonants : /p/, /t/, /k/, /b/, /d/, /g/ and /j/, in isolation and with and without bite block; CVCV combinations /paka/, /pata/ and trisyllabic combination like /pataka/.	For the evaluation of oral diado-chokinetic rate, mean syllable duration, peak intensity and peak frequency variations; and rate of growth of repetitions,
Rapid repetition of vowels /a/, /i/, and /u/ in isolation and in combination like /a-i/, /i-u/ and /u-a/.	For the measurement of rate of vowel repetition as well as the rate of phonatory onsets and offsets.
8. Repetition of CVCVCV combinations like /pi-pa-pu/, /ti-ta-tu/, /ki-ka-ku/, /bi-ba-bu/, /di-da-du/ /gi-ga-gu/	To understand the transition from a completely closed vocal tract to a completely open vocal tract in different vowel contexts
9. Initiation and termination of vowel /a/ in response to a click sound	For measurement of voice initiation time and voice termination time

Table 2.4 continued....

	as a measure of voice reaction time
Initiation of two sentences: one beginning with voiceless sounds and the other with voiced sounds.	For the measurement of speech initiation time
10. 36-CVCCV words embedded in a carrier phrase	For the measurement of voice onset time and other temporal and spectral measures.
<u>Prosodic Parameters</u>	
11. Two sentences with 2 clauses	For the measurement of rate of sentence production at normal and fast rates.
12. Picture word articulation test in Kannada, containing familiar pictures to represent different sounds.	For assessment of articulation in terms of substitution, omission distortion and addition of phonemes
13. Picture story chart to elicit spontaneous speech	For speaking rate, speech rate speaking fundamental frequency, average intensity (dB avg), and consistency of misarticulation

Table 2.4 continued.....

14. Reading of an all-phoneme passage.	For measurement of reading rate, whispered reading rate, and articulatory errors in read ing and consistency of errors.

Table 2.4 : Material used to elicit voice and speech samples and the variables studied.

2.4 Procedure

2.4.1 Neurological Examination

Dysarthric subjects were first evaluated by a neurologist who made the diagnosis of the problem. The neurologic examination included a whole range of tests including examination of cranial nerves, motor and sensory functions, extrapyramidal, pyramidal and cerebellar systems, higher order mental functions, as well as speech (Appendix 2). The subjects were subjected to CT scan evaluation to get more objective information on the site and extent of lesion.

2.4.1.1 CT Examination

CT scans were done on GE-9000 scanner. Contiguous 10 mm sections were taken parallel to the orbitomeatal line from base to the vertex. All CT sections were magnified on a magnifier and measurements made on them with the use of a vernier caliper (accuracy of 0.02 mm). Both qualitative and quantitative assessments were done (Appendix 4).

Following this, dysarthria speech evaluation was done by the experimenter to assess the functioning of speech mechanism and the voice and speech characteristics.

2.4.2 Instrumentation and Procedure of Recording

The voice and speech samples of the subjects were recorded on a spool audiotape recording system (Uher 630 SG Logic), using a high fidelity AKG39 microphone with a constant mic-to-mouth distance of 10 cms (see Figure 2.1 for the instrumentation setup). The recording levels were monitored on the VU meter of the tape recorder. The audiotape recording was carried out in a sound treated room at the department of Speech Pathology NIMHANS, Bangalore.

2.4.3 Method of Administration of Tests

Subjects were suitably instructed before recording the voice and speech samples. Instructions were specific to the task at hand. Besides, subjects were given demonstration, whenever required. At least two trials were given to ascertain that the subject has correctly understood the task. On the tasks where reading was involved, and in case, where the subject was unable to read, a repetition task was used (where the examiner read the stimuli, that is, test materials to the subject and it was repeated by the subject). Presentation of tasks in the voice-speech protocol and audiotape recording was done in a random order for each subject to nullify the order effects. All patients knew that their speech samples were being recorded and in fact, they could all see the recording equipment and the recording process. Speech sample recording was done in one or two sessions, depending upon the comfort and convenience of the patients.

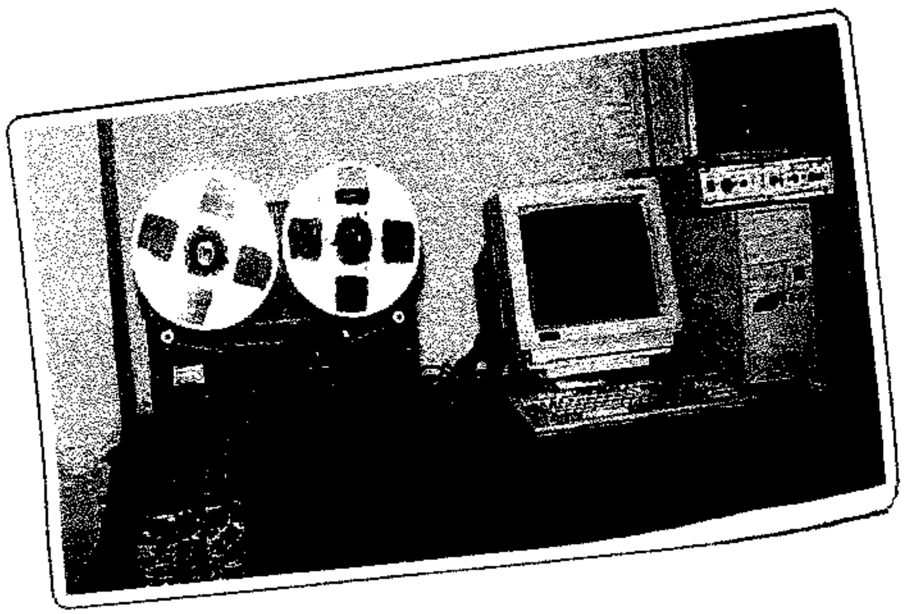

Figure 2,1: Instrumentation Set-up of the present study showing-

a) Uher spool tape recorder

b) PCS Computer- Pentium I

c) Speech interface unit (for Vaghami & SSL speech Softwares)

d) Dual microphone assembly (for nasality recording)

e) AKG- 39 Microphone (for speech-voice recording)

f) Ear phones (for auditory feedback)

2.4.3.1 Sustained Phonation of Vowels

The subjects were instructed to phonate vowel /a/ as long as possible after a deep inhalation and at a comfortable loudness level. Three trials were recorded. The duration of the longest of the three trials was considered the maximum phonation duration.

Sustained phonation of vowels /a/, /i/ and /u/ were recorded in another way. This time the subjects were instructed to maintain phonation of a given vowel for a comfortable duration and at a comfortable intensity level. This second of phonation samples were used for voice analysis.

2.4.3.2 Frequency Glide

Subjects were asked to sustain the phonation of vowel /a/ at a comfortable loudness level. They were instructed to change the frequency of vibration from low to high that they are capable of as in the demonstration tape and as per the demonstration by the experimenter. They were asked to maintain the intensity as constant as possible throughout phonation. First the subjects listened to a demonstration tape of a variable tone varying from 80 Hz to 500 Hz and recorded at 50 dB. The experimenter also demonstrated the task. Three recordings were done and the sample which gave the widest frequency range was selected for analysis.

2.4.3.3 Intensity Glide

Similarly, the subjects first listened to a tape on which a variable intensity . tone from 20 dB to 1 10 dB SPL (keeping the frequency constant at 150 Hz) had been recorded. After a demonstration by the experimenter and two practice trials, the subjects recorded phonation of vowel /a/ in which they varied intensity from the lowest to the highest, keeping frequency as constant as possible. No specific method was adopted to monitor the variation in frequency, or variation in intensity in the earlier task on frequency glide. Three recordings were done and the sample which gave the widest intensity range was selected for analysis.

2.4.3.4 S/Z Ratio

Subjects were first demonstrated the sustained production of /s/ and /z/ sounds. They were then instructed to produce the hissing noise /s/, at a comfortable loudness level for as long as possible. Similarly, /z/ sound was produced by the subjects. Each sound was produced twice. The higher of the two ratios was considered for further analysis.

2.4.3.5 Resonatory Parameters

Resonatory parameters, TONAR and nasalance, were measured on the 'Nasality indicator' of VAGHM1 software. This is an on line program wherein the output from two microphones, one pertaining to the oral output and the other to the nasal output, was inputted to the computer through a speech interface unit (S1U). The two microphones are held in a disc-like holder which when placed just above the upper lip effectively separates the nasal and oral outputs.

The output from the microphones is processed by the SIU to provide measures of oral and nasal intensity. The intensities are represented by the height of a filled display.

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The output from the microphones is processed by the SIU to provide measures of oral and nasal intensity. The intensities are represented by the height of a filled display.

The subjects were asked to sustain each of the three vowels and the consonants /m/ and /z/, one at a time, at a comfortable level, for at least 4-5 seconds. Subjects were also asked to speak the two sentences, one with both nasal and non-nasal sounds and the other with no nasal sounds. The tasks were presented and the subjects' response recorded in a random order. The display on the video screen gives the two measures of TONAR and nasalence.

2.4.3.6 Administration of Picture Word Articulation Test (PWAT)

Pictures in the PWAT in Kannada were presented to the subjects who were instructed to name each picture. The pictures were presented one at a time and randomly. There was gap of at least 30 seconds after the subjects responded and before the presentation of the next picture card. If the subjects could not get the right word, then the experimenter gave the correct word and the subjects were encouraged to repeat the same. There were a total of 5 instances when the experimenter had to supply the right word for the picture. Each response of the subjects was audiotape recorded as described earlier.

2.4.3.7 **All-phoneme** Passage

The all-phoneme passage was written in bold letters on a 12" x 10" thick card and was presented to the subjects for them to read aloud. Subjects were instructed to read the passage at a comfortable loudness level and in their habitual reading rate and style.

The subjects also read the first three sentences of this passage for a second time, but this time in the whispered mode. The interest here was to see if the performance of the dysarthrics would be any different when laryngeal vibration is eliminated. After a demonstration by the experimenter, actual recording of the reading was done.

2.4.3.8 Spontaneous Speech

A serial picture-story chart was made used to elicit spontaneous speech. The picture-story chart contained six pictures of postcard size and were numbered in such a way that when the sequence was followed with narration, the story could be completed. Subjects were presented the pictures and were asked to tell the story. Subjects were given a preparatory time of one minute. No time restriction was placed on the subjects regarding the length of their narration.

As in whispered reading, the subjects narrated the story for a second time, but whispered this time. Subjects were asked to whisper only the first three or four sentences.

2.4.3.9 Samples for Voice Initiation Time (VIT) and Voice Termination Time (VTT)

The subjects were instructed to close their eyes and initiate phonation of /a/ as soon as they hear a click sound and terminate phonation when they hear a second click. After demonstration, when the subjects had closed their eyes, the tester made a click sound near the microphone. Both the click and the phonation of subjects were audiotape recorded. After phonation was started, the tester made a click sound near the microphone for a second time and the subjects stopped phonation. The second click was automatically audiotape recorded Totally three recordings were made for each vowel, and the spacing between the two clicks (for initiation and termination of phonation) was varied in each trial. The aver- . age of the three trials was considered the initiation and termination time.

2.4.3.10 Measurement of Speech Initiation Time (SIT)

A similar procedure as used for the measurement of VIT was employed for this task too. However, there were two differences from the VIT procedure. First, the subjects initiated a sentence as soon as possible after they heard the click. Second, there was no second click as measurement of speech initiation time (akin to voice termination time) is illogical.

2.4.3.11 Speech Sample for Voice Onset Time (VOT)

Each of the 36 words for the measurement of VOT were embedded in a carrier phrase 'i:ga——endu heli',written one each on a 6" x 3" card and were presented to the subjects for reading at a comfortable loudness level. The cards were presented to the subjects in a random order and the subjects were asked to read them in their natural reading rate and style.

2.4.3.12 Diadochokinetic Repetitions

The subjects were instructed to repeat a given phonetic sequence as quickly, clearly and regularly as possible after taking a deep inhalation. Subjects were encouraged to repeat each syllable or sequence of syllables, presented in a random order, for at least 6 to 7 seconds or even longer. Altogether 3 1 combinations of syllables were recorded in a random order. The DDK repetitions were recorded with and without block bite.

2.4.3.13 Rate of Sentence Production

Subjects were instructed to first speak the two sentences at their normal rate and style and at a comfortable loudness level. Following this, they were asked to speak these two sentences at a fast rate. Subjects were given suitable demonstration of the task. The subjects were encouraged to memorize the sentences, and as each sentence had 5 words of 2 or 3 syllables, the subjects did not find it difficult to memorize.

2.5 Analysis of the Recorded Data

2.5.1 Analysis of Spontaneous Speech

2.5.1.1 Perceptual Analysis of Speech Intelligibility

Each subject's speech sample was evaluated by three judges consisting of three speech-language pathologists including the experimenter. The recorded speech samples were played on a tape recorder connected to an external speaker. The speech samples were played at a comfortable loudness level for the judges. The judges were encouraged to ask for replay of any segment of speech and any number of times that they wanted.

The term speech intelligibility refers to the degree to which a person's speech is understandable clinically. A 45-second speech sample, from each subject, was played to the judges who were asked to rate the speech on a 7-point speech intelligibility scale given in Table 2.5. Subject order was randomized. The judges had no information on the diagnostic category of the subject whose speech sample they were rating.

Speech Intelligibility Factors	Rating
Normal speech without errors	01
Speech is intelligible although occasional errors are noticed	02
Speech is intelligible although errors are distinctive	03
Speech is intelligible with careful listening	04
Speech intelligibility is difficult Only some words can be recognized	05
Speech is generally not unintelligible and with errors	06
Speech is unintelligible	07

Table 2.5 : Rating scale for speech intelligibility

2.5.1.2 Perceptual analysis of Severity of Dysarthrics Speech

Similarly, a severity rating scale was employed to rate the seventy of the dysarthric speech productions. Again, spontaneous speech samples (elicited on the picture-chart story) were used to rate the speech for dysarthric severity by three judges. Judges for this task were different from those in the intelligibility rating task, but the experimenter was a common judge in both the tasks. Table 2.6 gives the severity scale, an adaptation from Langmore and Lehman (1994).

	Severity	Speech description
1.	Normal :	No dysarthria evident, articulation, resonance, voice, speech rate, and prosody not impaired.
2.	Mild:	Just barely dysarthric, and completely intelligible. Articulation impaired for < 10 % of words, with errors involving a few consonants only. Voice and/or resonance may also be slightly impaired.
3.	Mild-Moderate :	Definitely dysarthric, but intelligible except for occasional words. Articulation impaired for 10 to 30 % of words, with errors involving a few consonants only. Voice and/or resonance may also be impaired.

4.	Moderate:	Speech is sometimes difficult to understand. Articulation impaired for 30 to 50 % of words, with errors involving many consonants and occasionally vowels. Some combination of resonance, voice, speech rate, and prosody will be impaired.
5.	Moderate-Severe:	Speech is often difficult to understand. Articulation impaired for 50 to 70 % of words. Resonance, voice, speech, rate and prosody are probably all affected.
6.	Severe :	Speech is often unintelligible. Articulation impaired to 70 to 90 % of words, with errors involving nearly all consonants and some vowels. Resonance, voice, speech rate, and prosody arc all affected.
7.	Profound:	Speech is unintelligible. Articulation impaired for >90 % of words with errors involving all consonants and most vowels. Resonance, voice, speech rate, and prosody profoundly impaired.

Table 2.6 : Rating scale for the judgment of severity of dysarthric speech (Langmore and Lehman, 1994).

2.5.1.3 Reliability of the Judgments

An interjudge correlation of the judgments of intelligibility of the three judges was computed by asking the judges to rate a portion of speech, selected at random from three subjects for a second time. There was a high product-moment correlation of 0.95 between the two sets of intelligibility judgments. Similarly, another measure of interjudge reliability, this time between the tester and other two judges was computed by repeating judgments on a portion of speech selected at random. Again a high product-moment correlation of 0.96 was obtained between the judgments of the two judges and those of the experimenter for the relevant portion of the speech sample. Therefore, only the ratings given by the experimenter were used in all statistical analysis.

Similarly, Product-moment correlations were computed for the judgment of severity of dysarthria. This time a correlation of 0.96 for interjudge reliability and 0.96 for the reliability between the judgments of the experimenter and two other judges was obtained. Again, only the judgments of the experimenter were considered while analysing results.

2.5.1.4 Judgment of Articulatory Errors

The tester analysed spontaneous speech and reading of an all-phoneme passage for the articulatory errors. The audiotape was played as many times as required until the experimenter was sure that all articulatory errors have been identified. The reliability of the experimenter's evaluation of articulatory errors was determined by asking one of the judges (who had participated earlier in the intelligibility study) to analyse a portion of the recorded speech and readings, selected at random from five subjects and mark the articulatory errors. As there was a very high Product-moment correlation of 0.98 between the evaluation of the experimenter and those of the second judge, the experimenter's evaluation was considered in all further analysis.

2.5.1.5 Speaking Rate

Speaking rate, expressed in syllable per second, was obtained by dividing the total number of syllables uttered by the patient by the total speaking time.

$$\text{Speaking rate} = \frac{\text{Number of syllables uttered}}{\text{Total speaking time}}$$

2.5.1.6 Speech Rate

A complementary measure of speech rate was obtained by dividing the total speaking time by the total number of syllables. Speech rate is expressed in seconds per syllable.

$$\text{Speech rate} = \frac{\text{Time taken (Secs.)}}{\text{Number of syllables uttered}}$$

Speaking rate gives the average number of syllables spoken per second while speech rate gives the average duration of each syllable uttered.

2.5.2 Reading Material : All-phoneme passage

2.5.2.1 Reading Rate, Syllable rate, Consistency of Misarticulation

Reading rate and syllable duration (akin to speech rate) was computed for reading sample in the same manner as it was done for spontaneous speech sample. Further, the reading sample was also used for computing consistency of misarticulatory errors. As each phoneme in the passage occurred more than 3 times in the initial position, percentage of time each phoneme was misarticulated was computed by dividing the number of articulatory errors on a given sound by the number of times that particular sound occurred in the initial position and multiplying this result by 100.

$$\text{Consistency of Misarticulation (\%)} = \frac{\text{Number of times a particular sound was misarticulated}}{\text{Number of times this particular sound occurred in the initial position}} \times 100$$

Misarticulations in the reading sample were evaluated by the experimenter in the same way as with the spontaneous speech sample (sec Section 2.5.1.4).

2.5.3 Identification of Articulatory Errors on PWAT

The occurrence of misarticulation was assessed using picture word articulation test. Audiotaped speech samples of PWAT were presented to the same three judges for assessment of misarticulation. The judges were allowed to listen to the speech samples as many times as required to identify all the misarticulations. Judges were asked to judge and write down the misarticulations in terms of omission, distortion, substitution and addition. An interjudge correlation of the judgments of the three judges was computed. A Product-moment correlation of 0.98 was obtained between the three judges in their ratings. Therefore, only the ratings given by the tester were used in all further computation.

2.6 Acoustic Analysis

Acoustic analysis of the voice and speech samples was accomplished by using the software Vaghmi and Speech Science Lab (Voice and Speech systems, Bangalore, IndiaJ

The required segment of the speech sample was low-pass filtered at 7.5 kHz and then digitized using a PC Pentium 150 (PCS make) on a 12- bit A/D converter at a sampling rate of 16,000 Hz for phonatory measurements, and at 12,000 Hz for spectrographic measurements. Speech samples were digitized at 8000 Hz for diadochokinetic rate analysis, voice initiation and termination time, and speech initiation time measurements.

The voice and speech samples were digitized at the same level of volume setting in the tape recorder as it was for original recording at the time of collection of speech samples from the subjects.

2.6.1 Phonatory Parameters

Analysis of phonatory parameters was done using the submodule 'voice' of the 'Diagnostics' module of VAGHM1 software. The following voice parameters were analysed and measured:

2.6.1.1 Maximum Phonation Duration (MPD)

MPD is the maximum duration for which phonation of vowel /a/ was sustained. The cursors were placed at the beginning and end of the displayed voice sample and the interval between them was measured. The duration of the longest of the three trials was considered the MPD. MPD is expressed in seconds.

2.6.1.2 Vocal Fundamental Frequency (FO) and Intensity

FO is the number of vocal cord vibrations per second and is expressed in cycles/second or Hz. Frequency measures were obtained for 4 segments of the voice sample as shown below:

* the entire sample of phonation
* first 1.5 segment of the sample
* last 1.5 seconds of the sample
* middle portion (excluding the first and the last 1.5 secs.)

The dysarthrics may have difficulty in initiating and terminating phonation and therefore, the initial and the final segment of their voice sample might be different from the rest of the sample. Separate analysis of the four segments was done to offset this feature. This procedure was repeated for all the three vowels /a/, /i/ and /u/.

Intensity of voice is its power and is dependent on an interplay of subglottal air pressure, aerodynamics at the level of the glottis, and shape and volume of the supraglottal cavities. Intensity of voice was also analysed for the 4 segments of the sample as described under 2.6.1.2.

FO extraction was done on FOINT package of VAGHMI software. Auto correlation technique was employed. The analysis settings were :

FO in blocks of 32 msecs duration

Successive block interval = 10 msecs

Sampling rate - 16000 Hz

FO limits between 80 Hz to 500 Hz.

Intensity was measured as RMS value dB.

The following measurements were made :

i) Mean (Average) of F0 and intensity
ii) Maximum and minimum F0, and intensity
iii) Range of F0 and intensity
iv) Number and extent of fluctuations of F0 and intensity

A variation of more than 8 Hz or 3 dB is considered a fluctuation of F0 and intensity, respectively. The average of all the deviations in frequency greater than 8 Hz or 3 dB in intensity is the number of fluctuation in frequency and intensity, respectively. The maximum variation in frequency or intensity, beyond 8 Hz or 3dB respectively, is the extent of fluctuations.

2.6.1.3 Jitter Measurements

Jitter refers to a short-term (cycle to cycle) perturbation in the fundamental frequency of voice. Jitter reflects the short-term stability of the vocal fold vibration. Jitter measurement was used to quantify short term instability of the vocal signal.

Following were the seven jitter measurements obtained based on number of cycles or periods for analyses on a moving average :

i) Jitter ratio
ii) Jitter factor
iii) Period variability index (PVI),
iv) Relative average perturbation (RAP) or Frequency perturbation quotient (FPQ)
v) Deviation from linear trend (DLT), and
vi) Directional perturbation quotient (DPQ)

i) Jitter Ratio

The simplest form of F()-adjusted perturbation index is the mean perturbation divided by mean waveform duration. When done in terms of period, the measure is called the jitter ratio (Horii, 1979). By definition, it is calculated by dividing the sum of the absolute values of the difference between the successive periods by the number of the differences measured (N-l) and multiplying by 1000. Multiplication by 1000 is to make the obtained ratio a large number, as a matter of convenience.

ii) Jitter Factor

The frequency based equivalent of jitter ratio is known as jitter factor (Hollien, et al, 1973). It is the mean difference between the frequencies of adjacent cycles divided by the mean frequency, multiplied by 100.

iii) Period Variability Index (PVI)

It is another approach to the quantification of period perturbation that requires computation of a coefficient of variation (Dean and Emanuel, 1975).

iv) Relative Average Perturbation (RAP) of Frequency Perturbation Quotient (FPQ)

RAP is the deviation of the period from the average period and its immediate neighbours. It is calculated by dividing the average difference between actual periods and their three point estimates by the mean period (Koike, 1972; Takahashi and Koike, 1975).

v) Deviation from Linear Trend (DLT)

It is the difference between a given period and the average of the period, two cycles away from it in each direction (Ludlow, Coulter and Gentger, 1983).

vi) Directional Perturbation Factor (DPF)

It is a percentage based on the total number of differences for which there

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v) Deviation from Linear Trend (DLT)

It is the difference between a given period and the average of the period, two cycles away from it in each direction (Ludlow, Coulter and Gentger, 1983).

vi) Directional Perturbation Factor (DPF)

It is a percentage based on the total number of differences for which there is a change in algebraic sign, that is, the number of times the frequency change shifts direction (Hecker and Kreul, 1971).

2.6.1.4 Shimmer Measurements

Amplitude-related perturbation factor is known as shimmer. A short term (cycle-to-cyclc) variation in the amplitude of vocal signal is shimmer. It is a measure based on the peak amplitude of each phonatory cycle. It is supposed to be as important a factor as jitter in the perception of hoarseness (Wendahl, 1966a, b).

Following are the four intensity-related shimmer factors computed. These arc based on the number of cycles of waveform amplitude considered on a point moving average.

i) shimmer in dB
ii) Amplitude Variability Index (AVI)
iii) directional perturbation factor (DPF)
iv) amplitude variability index (AVI), and
v) amplitude variability quotient (APQ)

i) Shimmer in dB

It is convenient to use dB scale for quantifying shimmer because the decibel scale is based on a ratio of amplitudes (Horii, 1980). This approach to the quantification of shimmer is advantageous because it frees the measurement of shimmer from absolute threshold.

ii) Amplitude Variability Index (AVI)

The **AVI** is based on a coefficient of variation that can be applied to either period or amplitude.

iii) Amplitude Perturbation Quotient (APQ)

Long term analysis of vocal intensity is not used in the evaluation of shimmer, but it is bound to increase its measured magnitude. Eliminating the effects of amplitude drift in order to get a new index of the underlying shimmer itself has been attempted by many. Average perturbation index (Takahashi and Koike, 1975; Koike, Takahashi and Calcatera, 1977) is one such measure which is analogous to the relative average perturbation of Koike (1973). APQ uses an 1 1-point average for computation. This can be measured either from the speech signal or from the inverse filtered signal (Bakcn, 1981).

iv) Directional Perturbation Factor (DPF)

This measure is analogous to DPF (Hecker and Kreul (1971) discussed under the frequency perturbation measure.

All the pitch and intensity perturbation measures including histogram were done using JITSHIM' program (Jitter and Shimmer) - offline - from the main menu of VAGHMI software.

2.6.1.5 Harmonic-to-Noisc Ratio (HNR)

A vocal signal is quasi-periodic in nature. However, the quasi-periodic wave may be contaminated with random noise. The degree of contamination can be expressed as a periodic to noise amplitude ratio. The noise level associated with each vocal period can be determined by averaging the waveform. Harmonic to noise ratio is the ratio of the mean amplitude of the average wave divided by the mean amplitude of the isolated noise components for the trains of waves and is expressed in dB. Harmonic to noise ratio is expressed as the ratio of harmonic energy to noise energy and is believed to be a good index of glottal efficiency.

Therefore, HNR is the ratio of the total acoustic energy contained in the harmonic frequencies (representing the energy due to periodic glottal closure) to the total energy of all the other frequencies (the non-harmonic frequencies at which the aperiodic energy is found - Yumoto et al, 1982).

HNR can be expressed either in percentage or dB. HNR is a good index of glottal efficiency. Greater the phonatory instability, lesser the HNR. HNR is considered as a perturbation measure, and this measure correlates best with an overall perception of 'noisiness and roughness' in the voice. HNR was measured, offline, using HNR program of Vaghmi software.

2.6.1.6 Long Term Average Spectrum (LIAS)

It is used as an index of vocal quality. Spectrum of voice is the product of the voice signal and the filter characteristics of the vocal tract. The spectral analysis provides a window through which laryngcal function and articulatory movements can be understood. The LTAS, uses the mean of all spectra of sounds of a relatively long sample (Carr and Trill, 1964). LTAS was analysed as follows .

Speech signal from a specified file was read in blocks or frames of about 16 msec. FFT technique was used to compute magnitude squared spectrum of this block of 16 m.sec. Spectra were accumulated pertaining to successive blocks or frames which overlap by 8 msec. At the end of the specified duration, the average was determined. Alpha, Beta and Gamma parameters were calculated both for magnitude squared spectrum and log spectrum. Finally, the graph of LTAS was displayed. LTAS measurements were done - off line - using the LTAS program.

2.6.1.7 Intensity Decay (dB)

This is a measure of progressive decrease or decay of intensity of voice during sustained phonation of vowel sound. Intensity decay measurement was done on a display of intensity curve, similar to frequency decay. As shown in Figure 2.2, intensity decay is the difference between the intensity level at the beginning and end of sustained phonation sample.

2.6.1.8 Fluctuations in Frequency and Intensity

It is the rhythmic or non-rhythmic, regular or irregular change in pitch and intensity during sustained phonation. Any variation of more than 8 Hz or 3 dB in intensity were counted as an instance of frequency or intensity fluctuation. Figure 2.3 illustrates the analysis of fluctuations.

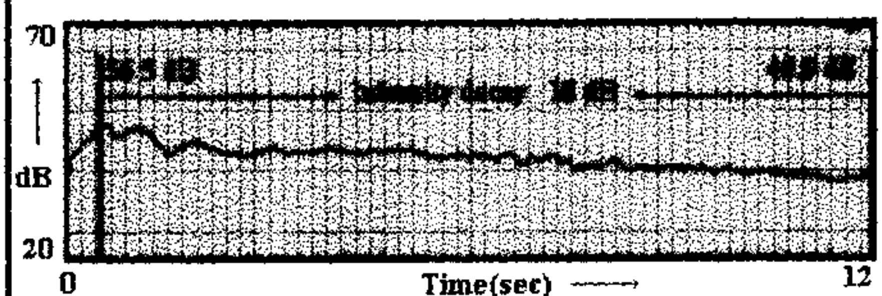


Figure 2.2 . Illustration of the measurement of intensity decay observed in a normal speaker during the production of vowel / a /.

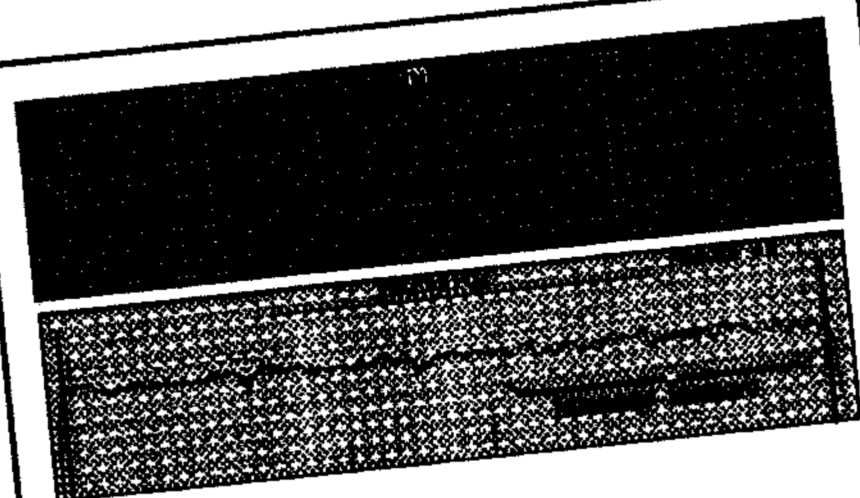


Figure 2.3 : Illustration of frequency and intensity tremors in a normal voice sample.

2.6.1.9 Rise Time

Acoustically different types of vocal attack can be discriminated on the basis of vocal rise time, among other factors. This is the interval between the onset of voice and the point at which intensity reaches a stable value. Measuring the vocal rise time has significance in therapy, like modification of vocal onset characteristics. Tremor analysis was done only in respect of patients with essential voice tremor. Figure 2.4 illustrates the measurement of rise time.

2.6.1.10 Fall Time

Fall time (FT), on the other hand, is the time taken to descend from a stable level to zero intensity at the time of termination of phonation. The rise and fall time of intensity basically denotes on the abruptness of initiation and termination of phonation. Figure 2.4 illustrates the measurement of rise time and fall time.

The rise and fall times for intensity were measured from the intensity display window of the FO1NT program of VAGHM1.

2.6.1.11 Frequency Range

It is a task to determine whether a patient has the capacity to alter fundamental frequency, in a range adequate for speech intonation.

The pitch glide sample was digitized at 16000 Hz and the pitch and intensity were extracted in the range of 50 Hz to 800 Hz using the 'FOINT program

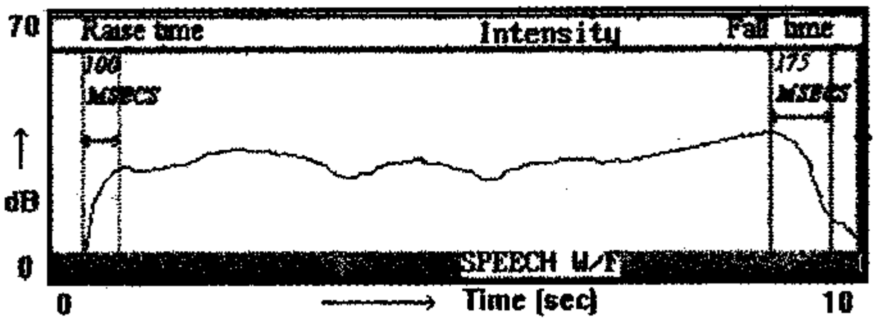


Figure 2.4 : Illustration of raise time at the initiation and fall time at the termination of voice (measured in msecs).

- off line - diagnostic program of Vaghmi software. Figure 2.5 depicts the measurement of frequency range.

2.6.1.12 Intensity Range

It is a task to determine whether a patient has the capacity to achieve a range of intensity in phonation. Similar to the imitation of a pitch glide, subjects were required to produce /a/ and change the intensity continuously from low to high levels, achieving their highest vocal intensity towards the end of phonation. Figure 2.6 illustrates the measurement of intensity range.

Intensity range was determined from the 'FOINT' program of VAGHMI. This was measured with reference to a 1000 Hz calibration tone recorded earlier where sound pressure level in decibels (dB SPL) was read at the face of the microphone with a sound level meter.

2.6.1.13 S/Z Ratio

It is a ratio of the duration of maximum sustained production of hissing sound /s/ to the maximum duration of a sustained /z/ sound. Duration of /s/ divided by the duration of */z/* gives the s/z ratio. Boone (1977) proposed this method as a clinical means of separating the contribution of respiratory and laryngeal factors to a phonation problem. Boone noted that subjects with vocal fold pathology (for example, thickening, polyps, or nodules) generally performed normally on the voiceless sound /s/, but abnormally on the voiced /z/. That is, s/z ratio will be around unity (1) in speakers with normal phonatory mechanism, but larger than 1 for persons with laryngcal pathology. The sustained samples

Figure 2. 5 : Illustration of frequency range (pitch glide) of a normal female voice sample.

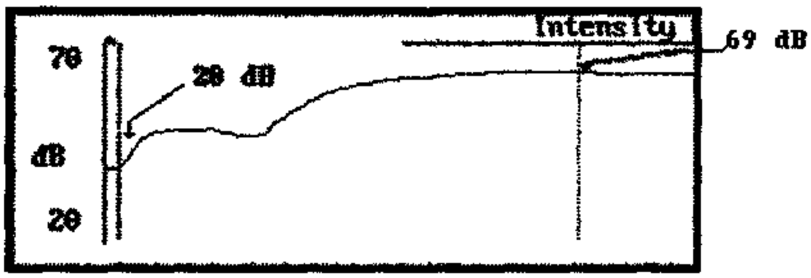


Figure 2. 6: Illustration of intensity range (loudness glide) of a normal female sample.

of /s/ and /z/ were displayed on the intensity display graph and with appropriate cursor placement, the interval between the two cursors for each production was measured.

2.6.2 Resonatory Parameters

Resonance is nothing but the modification of the vocal tone in the vocal tract cavities as the air stream travels supraglottally. This modulation or amplification results in a unique quality of voice for each individual. The supraglottal transmission also includes passage through the nasal cavities. This study analysed only the nasal resonance.

2.6.2.1 TONAR

TONAR, the oral-nasal acoustic ratio, as the term denotes, is the ratio of the oral and nasal sound pressures at different frequencies (Fletcher, 1970). Inputs from nasal and oral microphones (from a dual-channel recording) are individually amplified and conditioned by identical bandpass filters. Rectification and smoothing of the filtered signals results in DC voltages proportional to the amplitude of the portion of each input within the filter's bandpass. A special circuit performs an analog division function. Its output is the ratio of the (filtered) nasal amplitude to the (identically filtered) oral amplitude. The variable filters may be electronically controlled by the user to provide for different bandwidths in the frequency range of 10 to 65 kHz. Alternatively, the filters can be automatically swept across several frequency ranges at various rates. Figure 2.7a to 281, illustrate the measurement of TONAR and nasalance on different phonetic and language units.

Nasalcnce: 8.66 % and TONAR: 10.54 on vowel /a/

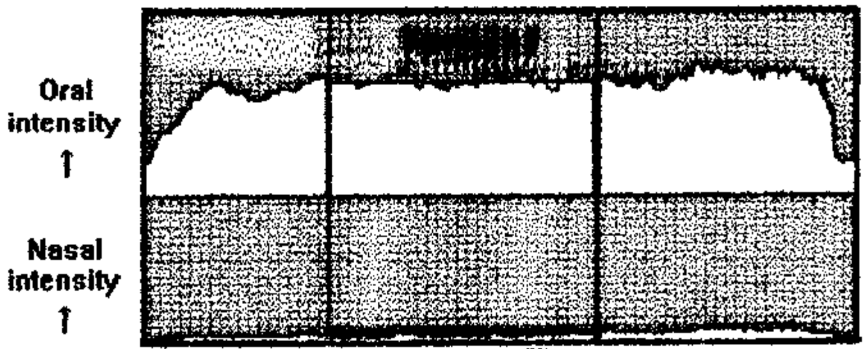


Figure 2. 7a ⟶ Time

Nasalence : 62.98 % and TONAR : 0.59 on /m/ sound

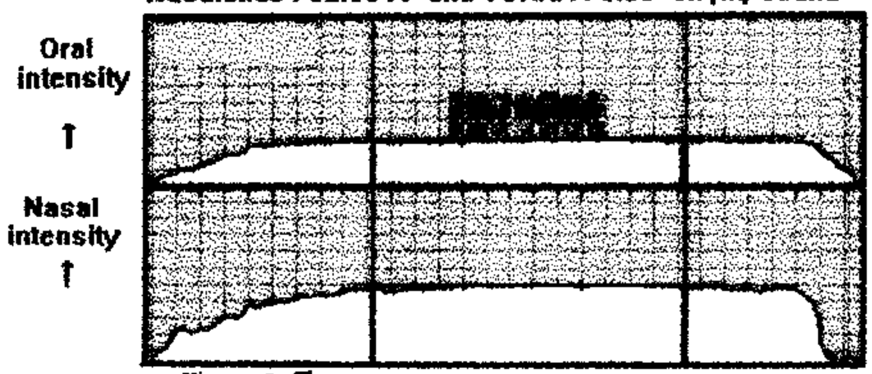
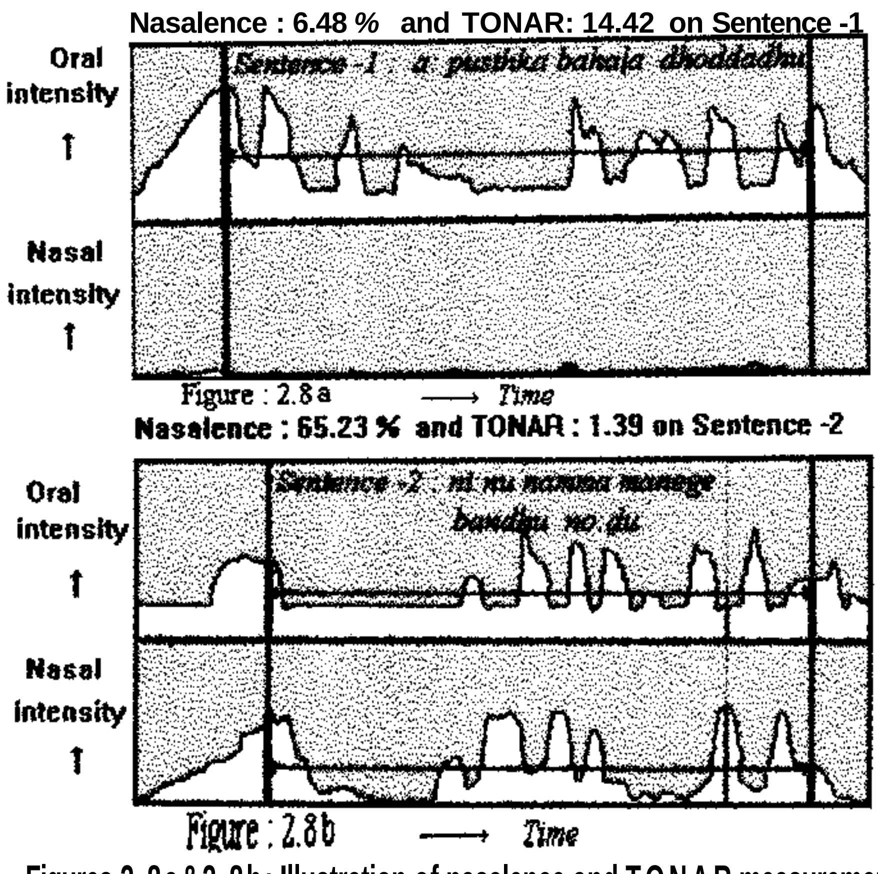


Figure 2. 7b ⟶ Time

Figures 2. 7a and 2.7b. Illustration of the measurement of nasalence and TONAR during the phonation of /a/ & /m/ sounds respectively.



Figures 2.8a & 2.8b: Illustration of nasalence and TONAR measurements during the production of sentences 1 & 2, respectively.

2.6.2.2 Nasalance

Nasalence, expressed in percentage, is a complementary measure of TONAR. The instrument may be used with the filters inactivated, in which case the output is a simple nasal/oral ratio. But, filtering results in a more complex output product: the ratio of the amplitude in a limited range of the speech frequency spectrum. Nasalance has been found to correlate moderately with perceived nasality (Fletcher and Bishop, 1973).

2.6.3 Articulatory Parameters

The following articulatory parameters were studied :

a) Voice onset time

b) Voice initiation time and voice termination time

c) Speech initiation time

d) Diadochokinetic repetitions

2.6.3.1 Voice Onset Time (VOT)

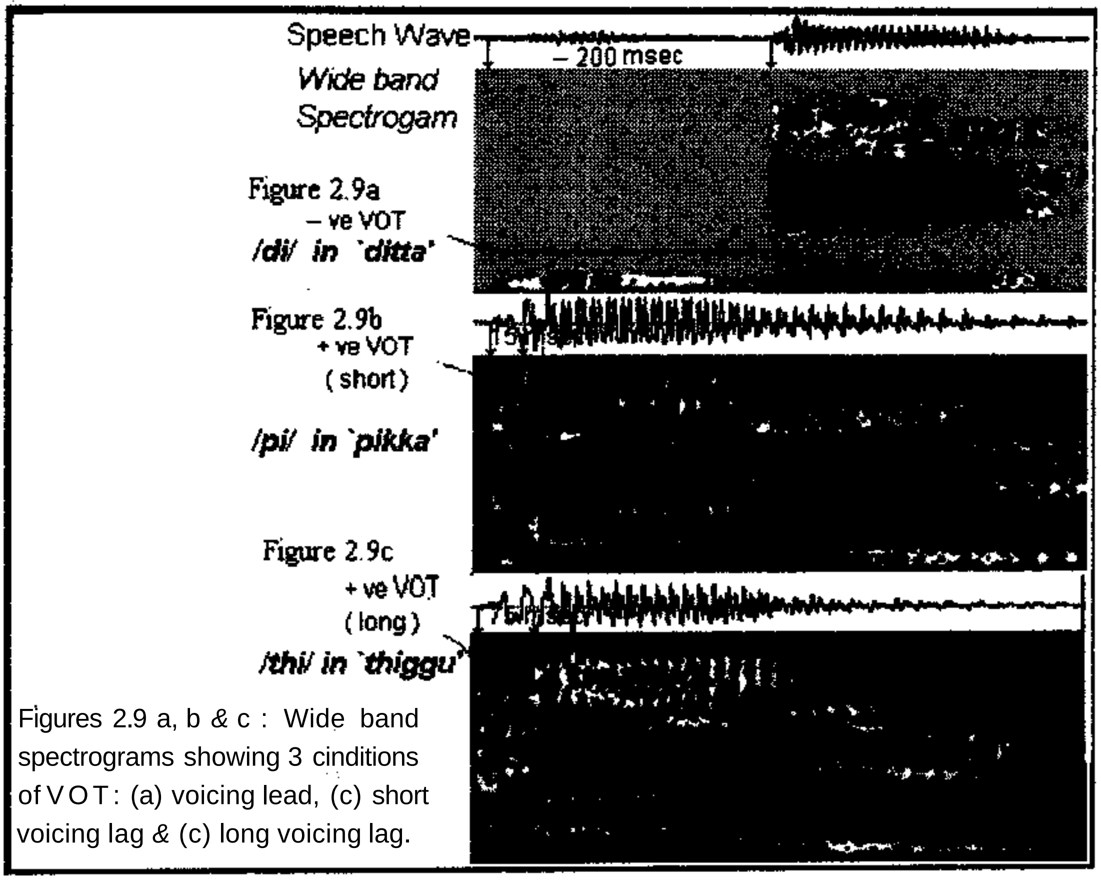
Voice onset time is defined as the interval between the release of an oral constriction and the start of glottal pulsing (Lisker and Abramson, 1964). VOT is generally measured from a wideband spectrogram. On a spectrogram, VOT is defined as the time equivalent of the space from the onset of the stop-release burst to the first vertical striation representing glottal pulsing (Lieberman, Delattre, and Cooper, 1952; Lisker and Abramson, 1964, 1967). Stops, depending on their voicing status, may have negative or positive VOTs.

VOT was measured from wideband spectrogram (300 Hz bandwidth) on the SPGM program of SSL software package. Figure 2.9a illustrates the measurement of negative VOT (as in the case of voiced plosive-stop) while Figures 2.9b and c illustrate the measurement of positive VOTs (as in the case of voiceless plosive-stops),Table 2.7 gives the software settings for the analysis and measurement of VOT. Number of LPC's was selected at 16 as the sampling rate was 12 kHz.

Material for spectrographic analysis were the 36 CVCCV 'words' (Appendix 3) which were digitized at a sampling rate 12000 Hz. VOT measurement was done by moving and placing the cursors on the wideband spectrogram as per the definition of VOT given above. Audio playback of the relevant speech segment was done while fixing the cursors for identifying the correct speech segment.

Start at (sec) : As required	End at: As required
Block duration (msec) :	32 (30 in case of females)
Block shift interval (msec) :	10
No. of LPCs : 14 (16 in case of females)	
Pre-emphasis factor :	1
Scale factor .	1
Window type :	2 (Hanning)
FFTsize:	512

Table 2.7 : Software settings for the analysis of VOT



Figures 2.9 a, b & c : Wide band spectrograms showing 3 cinditions of V O T : (a) voicing lead, (c) short voicing lag & (c) long voicing lag.

2.6.3.2 Voice Initiation Time (VIT) & Voice Termination Time (VTT)

VIT is the time interval between the onset of the first click and the onset of the voice. Similarly, VTT is the time interval between the onset of the second click and end of the voice production. These two durations were measured using the 'Display[1] program of the 'Wavespec' module of SSL package with the settings given in Table 2.7. However, in this case, the number of LPC's selected were 10 (12 in the case of females) because the sampling rate was 8 kHz.

Material for VIT and VTT measurement were the recorded samples of vowel /a/ in response to click sounds which were digitized at a sampling rate of 8kHz

The relevant durations were obtained by moving the vertical cursor on the displayed sample. Movement of the cursor highlights the traversed space to give the time interval in msecs. Measurements from three samples were averaged to arrive at one initiation and one termination time. VIT and VTT are expressed in milliseconds. Figure 2.10 illustrates the measurement of VIT and VTT.

2.6.3.3 Speech Initiation Time

This is the time interval between the onset of the click sound and the onset of the first syllable of the sentences. SIT was measured in the same way as VIT and the material for analysis was the sample of two sentences recorded with clicks. The average of three samples for each sentence was taken as the speech initiation time. Software settings for the analysis of speech initiation time were as given in Table 2.7 except the number of LPC's which was 10 (12 in the case of

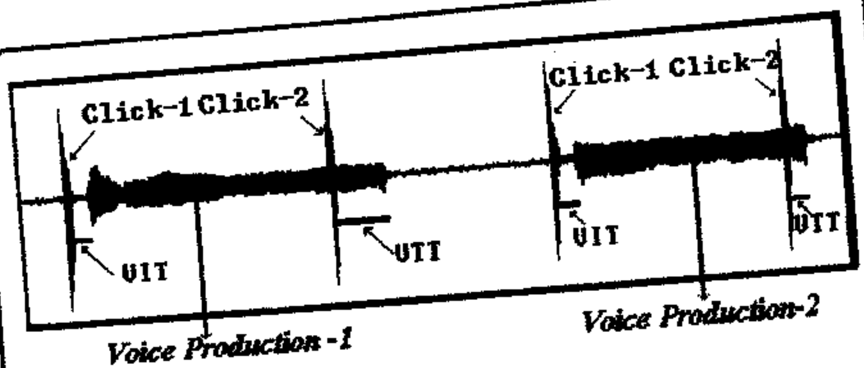


Figure 2.10 : Illustration of the measurement of voice initiation time (VIT) and voice termination time (VTT) for the production of vowel /a/ (in msec) in response to click-1(to start phonation) and click -2 (to stop the phonation).

females) in this instance. Figures 2.11 illustrates the measurement of SIT for two sentences in which words started with a voiced sound and voiceless sound, respectively.

2.6.3.4 Diadochokinetic Repetition Analysis

The various samples of diadochokinetic repetitions of syllables and syllable sequences were digitized at a sampling rate of 12000 Hz. Digitized samples were analysed in 3 stages : in the first stage, display program of the 'wavespec' module of SSL was used with the settings shown in Table 2.7. Figure 2.12 illustrates the measurement of rate of repetition.

In the second stage, spcctrographic analysis was done using SPGM program of the VSS-spectrograph module of SSL for the following measurements:

a) syllabic duration of each repeated syllable, and
b) intcrsyllabic duration between two syllables Figure 2I3 a & b illustrate the measurement of syllable and intersyllabic gap durations.

In the third stage, peak frequency and peak intensity measurements were made for each repetition. The measurements were made on the 'Analysis' module of the 'VSLP-SUBMODULE' of ACOPHON-I Module of SSL package with the settings shown in Table 2.8.

After the analysis of the sample for peak frequency and intensity information, the FOEDIT program of the submodule VSLP' (in ACOPHON-I module) was used to get digital display of actual measurements. Figure 2.14 illustrates

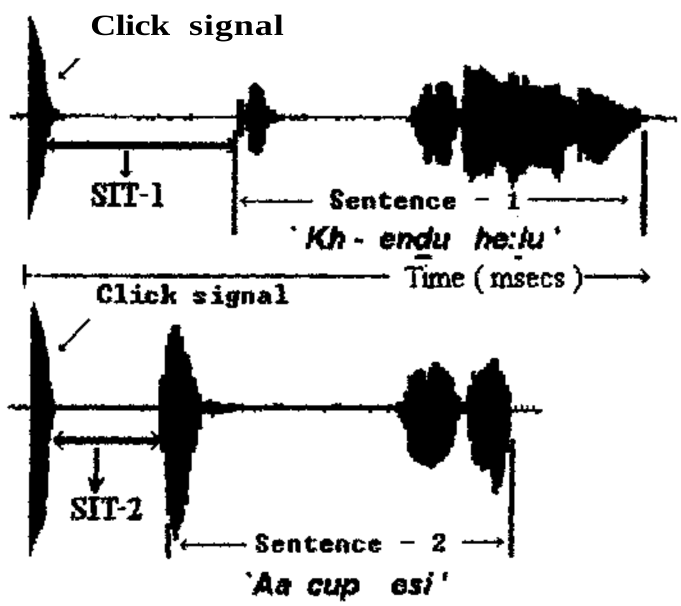


Figure 2.11: Illustration of the measurement of speech initiation time {SIT} for the productions of sentence - 1 kh - endu hehi' which begins with voiceless sound (upper part) & sentence - 2 'a: cup esi', which begins voiced sound (lower part) in response to click signal. SITs were measured in msecs.

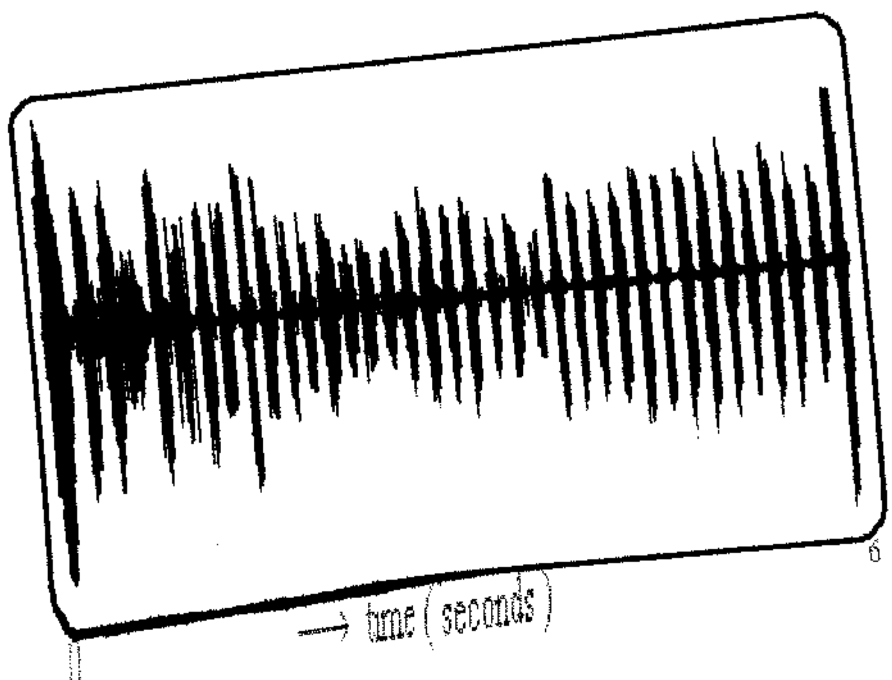


Figure 1.12 : Showing the number of DDK repetitions of /ṭa/ for a duration of 6 seconds. There are 37 repetitions in 6 seconds in this particular illustration.

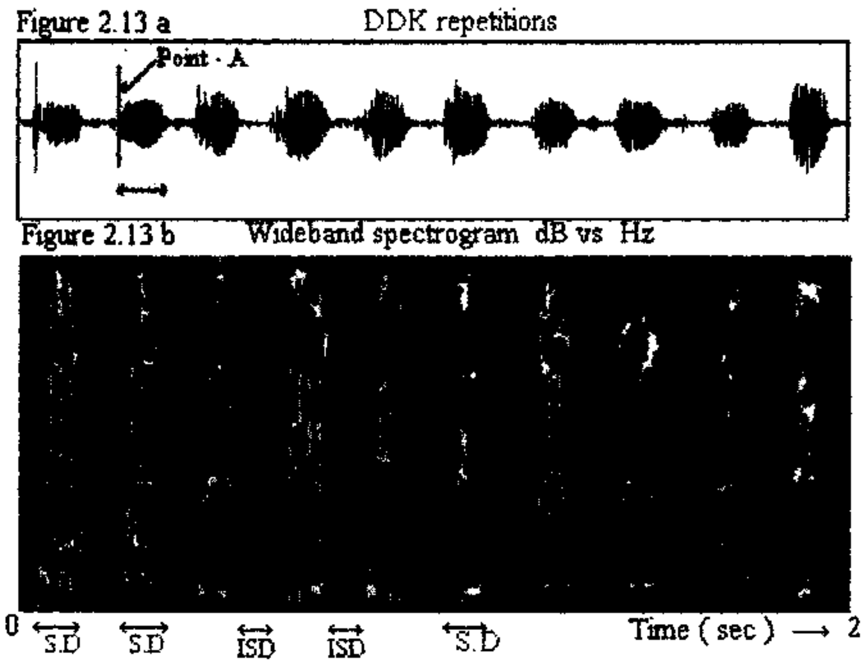


Figure 2.13a & b : Showing the measurement of syllable duraion (S. D) from the onset of the burst to the closure of vowel-cognate and inter syllable duration (ISD) of a DDK repetitions of /ta/ using a wideband spectrogram. Figure 2.13b is the spectrogram of the same DDK repetitions shown in Figure 2,13a. Corresponding to point - A in Figure 2.13a, there is a burst even in Figure 2.13b.

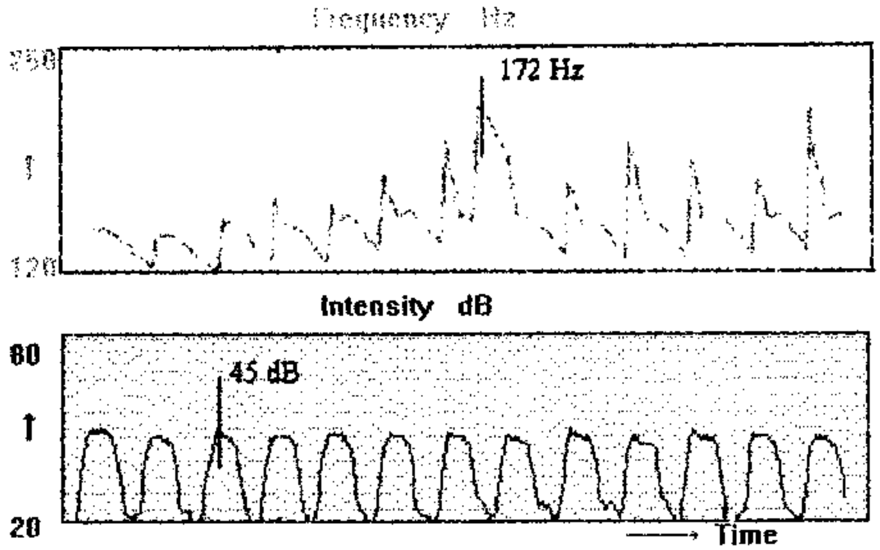


Figure 2.14 : Showing the measurement of peak frequency (in Hz) and peak intensity (in dB) of each repetitions of a monosyllable in a DDK sequence.

the measurement of peak frequency and intensity measurements of repetitions. The following diadochokinctic measurements were made

Block duration (m sec) :	32 (30 in case of females)
Block shift interval (msecs) :	10
No. of LPCs :	14 (16 in case of females)
Pre-emphasis factor :	1
Window type :	2 (Manning)
Low frequency (Hz) :	75
High frequency (Hz)	450

Table 2.8 : Software settings for the analysis of different aspects of diadochokinetic measurements

a) total duration of the sample (in seconds),

b) total number of repetitions - number of repetitions were counted from the display layout,

c) number of syllables repeated per second : number of repetitions in each second were separately counted to analyse the rate of growth of syllable repetitions over the entire sample,

d) syllable duration (in msecs). It is the interval between the onset of the plosive, which includes burst, and the closure of it's vowel cognate,

e) intersyllabic interval (in msecs). It is the interval between two successive syllables,

f) peak intensity (in dB) - peak amplitude of each and every repetition to analyse the rate of change over the entire sample.

g) peak frequency (in Hz) - peak frequency of all repetitions, and

h) diadochokinetic rate (DDK rate) in syllables/second

All these measurements were made only in respect of repetitions of monosyllables (/pa/, /ta/, /ka/, /ba/, /da/, /ga/ and /ja/ - without bite block). For the remaining 24 phonetic sequences, measurements (d) to (g) were not made.

Other than the above measures, the following measures were made from the spectrogram:

a) the number of vowel and syllable productions in 5 seconds,

b) number of gaps in vowel repetitions in 5 seconds

c) the number of vowels or syllables produced in the first 1 second and the last 1 second. This measure is made to determine whether the subjects were able to maintain the same rate of repetitions over 5 seconds and over the entire duration.

2.6.4 Prosodic Parameters

2.6.4.1 Speaking Fundamental Frequency (SFO)

Speaking fundamental frequency is the fundamental frequency of a long stretch of speech. In this study, SFO was measured on a speech segment of 9 seconds, digitized at 16000 Hz. Furthermore, nine second sample was selected beginning from the end of the first sentence. This frees the measurements from contamination by any violent fluctuations that might be present in the first sentence of the speech when subjects are initiating their speech. Extraction of SFO was done using 'FOINT program of 'Diagnostic-speech module' of VAGHMI software.

Similarly, extraction of reading fundamental frequency (RFO) was done by using a 12 second sample, again starting from the second sentence. The speech sample for this analysis was the reading of the all-phoneme passage.

2.6.4.2 Rate of Speech Production

The digitized speech samples of the two sentences (with two clauses), for the measurement of rate of production at normal and fast rate were subjected to spectrographic analysis. Figure 2.15 illustrates the analysis of rate of speech production. The speech samples were digitized at 12000 Hz for spectrographic display. The following measurements were made from the spectrographic display:

a) sentence duration : duration of the spoken sentences,
b) word duration,
c) gap duration : interval between any two words. Word duration and gap duration were measured in the same way as it was done under the diadochokinctic measures using the SPGM module of SSL,
d) word-pause duration, that is, interval between the two clauses and interval between the words within the clause,
e) formation of syllable group in both rates of production
f) number of syllables produced,
g) speaking rate,
h) speech rate,

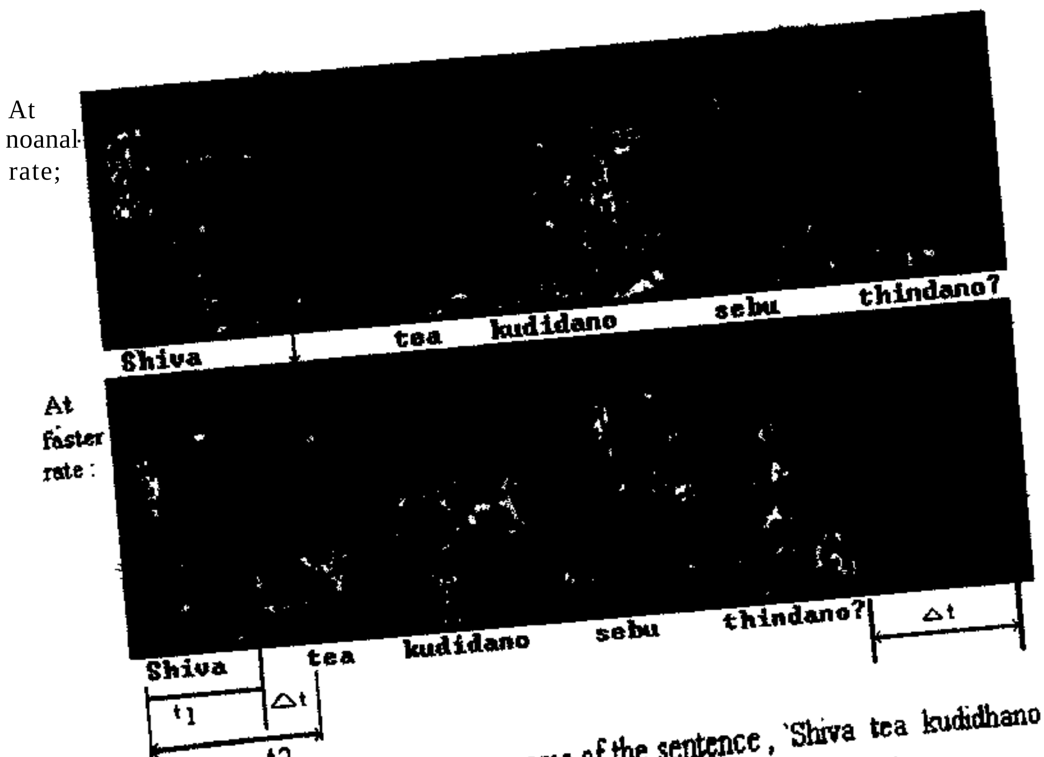


Figure 2.15 : Wideband spectrograms of the sentence , 'Shiva tea kudidhano sebu thindhano ' at normal rate and faster rate by a normal speaker.

i) articulation rate : Articulation rate was obtained by subtracting the total gap duration (interval between the words and interval between the clauses) from the total speaking time and dividing the result by the number of syllables uttered,

$$\text{Articulatory rate} = \frac{\text{Number of syllables uttered}}{\text{Total duration - Total duration of gaps}}$$

j) frequency measurements including mean, maximum, and minimum frequency as well as frequency range, and

k) intensity measurements including mean, maximum, and minimum intensity as well as intensity range.

Chapter 3

RESULTS

The purpose of this study was to investigate the

a) deviant speech-voice dimensions in hypokinetic and hyperkinetic dysarthrias and further in the subcategories of hyperkinetic dysarthrias, namely, chorea, essential voice tremor, dystonia and tardive dyskinesia,

b) speech-voice deviant dimensions which arc important in the diagnosis of hypokinetic and hyperkinetic dysarthrias, and the subcategories of the latter,

c) phonatory, articulatory, rcsonatory and prosodic deviations in the speech of the hypokinetic and hyperkinetic dysarthrias and the subcategories of the latter, and

d) to understand the neurological basis of the speech-voice dimensions in these two types of dysarthrias.

3.1 Subjects

A total of 24 dysarthrics were selected for the study based on the inclusion and exclusion criteria enumerated in Chapter 2. All subjects were literate, mono- or bilinguals and had dysarthria for at least 1 year, but the duration of the speech problem itself varied from 4 months to 7 years, with one patient having speech problem for as long as 16 years. Only those patients who were diagnosed as dysarthrics, following a neurological evaluation, were included in the study.

The dysarthrics were classified into an hypokinetic dysarthric group with 8 patients and an hypcrkinetic dysarthric group with 16 patients. The latter group was further categorized into 4 groups of chorea, essential voice tremor, dystonia and tardive dyskinesia with four subjects in each group.

3.1.1 Hypokinetic Dysarthria Group

All the 8 subjects in this group were diagnosed to have Parkinson's disease. These patients were in the age range of 20 to 60 years with a mean age of 40.7 years. Mean duration of the problem (speech) in these patients was 2.75 years. The Parkinson's disease group had 6 males and 2 females. Tables 3.1 and 3.2 give some of the characteristics of the patients selected for this study.

All of these patients had tremors of the upper limbs, weakness of either upper or lower limb(s), and rigidity. DTR's were brisk in 6 of these patients, normal in one patient and depressed in one another patient. Plantars were flexor in all 8 patients. Cranial nerves were normal except in one patient who had left UMN facial palsy. Half of these patients had some disturbance of gait. Seven of the 8 patients presented masklikc face, a typical characteristic of extrapyramidal syndromes. Ccrcbellar system was normal in 7 of the 8 patients. CT scan examination revealed a normal study in 6 of these patients. In one patient, MRI scan showed multiple lacunar infarcts while in another patient, the CT scan revealed bilateral basal ganglionic infarcts. There was no family history of the problem in any patient.

Pt. No.	Name	Age/ Sex	Duration of illness	Duration of speech	Family History	Symptoms	HMF	Speech
1.	KRI	58/M	2	9/12	-ve	Tremor of Lt. limbs at rest. Difficulty in walking.	Normal	Mild dysarthria
2.	GON	40/M	2	1	-ve	Tremors of all 4 limbs. Difficulty in combing hair. Inability to grasp objects.	Normal	Slurring
3.	GID	60/M	1	9/12	-ve	Difficulty to speak. Weakness of LUL Tremors.	Normal	Slurring
4	CHA	49/M	6	1	-ve	Tremors of both ULs Weakness of LL	Normal	Slurred

5.	CHI	60/M	3	4	-ve	Speech difficulty. Weakness of LL.	Normal	Dysarthria
6.	BAL	20/M	6/12	4/12	-ve	Speech difficulty. Walking difficulty.	Normal	Slurred
7.	RJM	60/F	3	1	-ve	Tremors of Lt. LLs	Normal	Slurred
8.	VIJ	32/F	6/12	4/12	-ve	Tremors of RLs.	Normal	Dysarthric
9.	MKS	46/M	4	1	+ve	Difficulty in walking. Clumsiness of hands Forgetfulness. Loss of weight.	Affected	Dysarthric
10.	RKP	32/M	4	1	+ve	Jerky movements of limbs. Change in personality.	Affected	Slurred

11.	WAS	60/M	7	2	-ve	Involuntary movements of all limbs & neck. Loss of memory. Hearing problem.	Affected	Affected
12.	RAJ	39/F	4	1	+ve	Involuntary movements of all limbs. Fatiguability	Affected	Abnormal
13.	KRS	60/M	8	16	+ve	Slowness. Difficulty to speak. Hearing loss in the Lt.ear. Tremulousness of hands at work.	Normal	Severe Dysarthric
14.	MAL	45/M	10	3	-ve	Movements of head. Movements of ULs. Movements of LLs. Defective speaking.	Normal	Slurred Voice tremor

15.	STB	60/F	5	5	-ve	Difficulty in speaking Swaying while walking.	Normal	Defective
16.	LAX	45/M	4	2	-ve	Difficulty in speaking. Movements of hands.	Normal	Defective
17.	MAD	60/M	2	2	-ve	Difficulty in speaking (Insidious onset and progressive).	Normal	Slurring
18.	ROH	30/M	6	6	-ve	Difficulty in speaking (Insidious onset and progressive). Increased pitch.	Normal	Spastic type of speech. Low volume.
19.	BAG	34/F	4	4	-ve	Speech difficulty following encepha- litis.	Normal	Dysarthria

20.	DAK	22/F	5	5	-ve	Speech difficulty following ence-phalitis. Rt. thumb weakness.	Normal	Dysarthria
21.	ABD	60/M	3	1	-ve	Abnormal movements of face since 1 year. Depression since 3 years. On Eskazine, clonipra-mine, Fludac THP, TFP Fluoxetin	Affected	Dysarthria
22.	VEN	27/M	10	1	-ve	Tremors of ULs. Difficulty to speak. Schizophrenia since 10 year. On clozopine, serence, THP. ATT	Affected	Affected

23.	PBK	50/M	20	. 1	-ve	Tremor of RUL. Mild difficulty to speak. Schizophrenia On Serenace, largactil. fludac	Abnormal	Affected
24.	TSS	35/M	10	7	-ve	Choreatic movements of tongue. Difficulty to speak. Schizophrenia & seizures. On Rx, DZM, THP. M-toin.	Abnormal	Affected

Table 3.1 : Table showing some general characteristics of the patients of the study

Patient. Number	Cranial Nerves	Motor System	Sensory System	EP & Pyr. System	Cerebellar system	Neuro Diag.	CT/MRI
1. KRI/M	Normal	DTR ^ (Brisk) Plantar. Mild weakness of left half of the body.	Normal	Resting tremor. Rigidity of left extremities. Dystonia of left foot. Bradykinesia. Masklike face	Normal	Parkinson's with dys- tonic foot	CT Normal Study
2. GON/M	Normal	DTR f (Brisk) Plantars f1exor	Normal	Tremors of all limbs. Cogwheel type of rigidity. Slowness of gait (brady kinesia) Masklike face	Normal	Juvenile Parkinsonism	CT Normal Study

3.	GID/M	Normal	DTR ↑ (Brisk) Plantar - flexors	Normal	Tremors at rest. Cogwheel type rigidity. Masklike face	Normal	Parkinsonism	CT Normal Study
4.	CHA/M	Normal	DTR ↑ (Brisk) Plantar - flexors	Normal	Tremors at rest. of both UL's Cogwheel type of rigidity. Masklike face	Normal	Hemi-Parkinsonism	CT Normal study
5.	CHI/M	Normal	DTR ↑ (depressed) Plantar-flexors Rt.side-motor weakness	Normal	Tremors at rest. Mild rigidity Hypokinesia Hypokinesia	Mild Incoor-dination. Broad based gait	Hemi-Parkinsonism	MRI - multiple lacunar infarcts

6.	BAL/M	Lt. UMN facial palsy Mild was- tongue	DTR ↑ brisk (L > R) Plantar Flexor on Lt. side)	Normal	Tremors of RUL Rigidity of lt. extremities. mities. Dystonia of LUL. Masklike face	Normal	Juvenile Parkinsonism	CT-Bilateral basal ganglionic infarcts
7.	RJM/F	Normal	DTR Normal Plantar ↓↓ (flexor)	Normal	Tremors Rigidity Bradykinesia (slow walking) Masklike face	Normal	Parkinsonism	CT Normal study
8.	VIJ/M	Normal	DTRs ↑ Bil. brisk Plantar ↓↓	Normal	Tremors of RUL & RLL. Cogwheel rigidity. Brady- kinesia. Masklike face	Normal	Parkinsonism	CT Normal study

9. MKS/M	Impaired saccades+	DTR ^ (Bil) Plantars	Normal	Choreiform movements of head, tongue & all 4 limbs. Generalized wasting. Hyper-tonia in LLs.	Normal	Huntington's chorea	CT- Diffuse cerebral atrophy
10. RKP/M	Impaired saccades - vertical> horizontal pursuits - normal	Tone in all 4 limbs Plantar	Normal	Chorieform movements. Slow tongue movements.	Normal	Huntington's chorea	CT Diffuse cerebral atrophy
11. WAS/M	Bil. high frequency hearing loss.	DTR t (in ULs) Plantar	Normal	Choreatic move-ments. Myoclonus Tremor at rest. Mild rigidity in 4 limbs.	Normal	Chorea	CT Diffuse cerebral atrophy

12. RAJ/F	Normal	Non-repetitive Nonpurposive movements at the shoulder joint	Normal	Chorieform movements. Fasciculation and wasting of tongue	Normal	Huntington's chorea	CT - Diffuse cerebral atrophy
13. KRS/M	Profound SN Hg. loss	DTR ↑ (Brisk) Plantar ↓↓	Normal	Tremors of extremities Tongue and soft palate	Incoor-dination. Mild tandem ataxia.	Essential voice tremor	CT Normal study
14. MAL/M	Normal	DTR - Normal Plantar ↓↓ flexor	Normal	Tremors of both UL & LLs. (Rest + ^ with action). Tituba-tion of head	Normal.	Essential voice tremor	CT Normal study
15. STB/F	Normal	DTR - Normal	Normal	Tremors of jaw	Tandem	Essential	CT- Diffuse

		Plantar ↓↓ flexor		Titubation of head	gait- Sweeps to both sides (Romberg's sign +ve) No limb ataxia	voice tremor	cortical & cerebellar atrophy
16. LAX/M	Normal	DTR ↑ (Brisk) Plantar: ↓↓ (Bil.extensor)	Normal	Tremors of ULs Titubation of head.	Tandem gait swaying to both sides (Romberg's sign +ve)	Essential voice tremor	CT - Diffuse cortical atrophy
17. MAD/M	Normal No tongue dystonia. Wasting/ fascicu- lation	DTR Normal Plantar ↑↑ Jaw jerk ↑ (Brisk)	Normal	Uvula > (Rt) side	Normal	Oro-pharyn- geal dysto- nia	CT Normal study

18. ROH/M	Normal	DTR Normal Gag reflex normal	Normal	Normal	Normal	Laryngeal dystonia	CT Normal study
19. BAG/F	Normal	DTR - Normal Plantar ↓ (Flexor)	Normal	Faciobuccal weakness. Lips protrusion, tongue elevation & protrusion are affected.	Normal	Lingual dystonia	CT Normal study
20. DAK/F	(?) Bil 6th cranial nerve palsy	DTR-Normal Plantar ↓↓ (flexor)	Normal	Faciobuccal weakness. Lips protrusion, tongue elevation protrusion are affected	Normal	Lingual dystonia	CT Normal study

21. ABD/M	Normal	DTR (N) plantar $\downarrow\downarrow$	Normal	Oro-lingual masticatory movements Oromandibular movements	Normal	Drug induced oromandibular lingual TD	CT Normal study
22. VEN/M	H/o Lt. UMN facial palsy	DTR $\uparrow$ (Brisk) (Lt > Rt) Plantar $\downarrow\downarrow$ Neck stiffness Gag reflex+	Normal	Lingual movements Lt. sided hypotonia with weakness	Normal	Drug induced dyskinesia Lingual TD	CT Normal study
23. PBK/M	Normal	DTR (N) Plantar $\downarrow\downarrow$ Lingual TD	Normal	Lingual movements	Normal	Drug induced dyskinesia	CT Normal study
24. TSS/M	Normal	DTR $\uparrow\uparrow$ Plantar $\downarrow\downarrow$	Normal	Lingual movements	Normal	Drug induced Lingual TD	CT Normal study

Table 3.2 : Table showing the neurological and CT characteristics of the patients of the study

3.1.2 Hyperkinetic Dysarthric Group

Patients in the hyperkinetic dysarthria group were in the age range of 22 to 60 years with a mean age of 49.5 years. There were 11 males and 5 female subjects in this group. As has been mentioned earlier, these subjects were categorized into 4 subgroups of chorea, EVT, dystonia and tardive dyskinesia. Tables 3.3 to 3.7 dwell on some of the characteristics of the patients of this study in terms of the neurological systems involved. There were 11 patients in whom the cranial nerve involvement was present. DTR's were brisk in 7, depressed in one and normal in 8 patients. Plantar responses were flexor in 15 of them and extensor in 1 patient. Cerebellar system was involved in 10 patients.

Abnormality	Hypo-Kinetic	Hyper-Kinetic
Number of patients with cranial nerve lesion	1	5
Unilateral 7th nerve paresis	0	1
Ocular movements impaired	0	2
Hearing loss	0	2
6th nerve palsy	0	1

Table 3.3 : Cranial nerve abnormalities in the hypokinetic and the hyperkinetic dysarthria groups.

3.1.2.1. Chorea

There were 3 male and 1 female subject in the chorea group. Age range of these subjects (combined) was 32 to 60 years, with a mean age of 44.2 years.

Movement disorders were present in all the 4 subjects. Higher mental functions (particularly memory) were affected in all the patients. Family history was positive for 3 of the 4 subjects. Cranial nerves were affected in 3 of the 4 subjects, and DTR's were brisk in all subjects. Choreiform movements were present in all the 4 subjects. Cerebellar system was not involved in any subject in this group. CT scan showed diffuse cerebral atrophy in all subjects. All these subjects were diagnosed as Huntingtons chorea.

Features	Hypo-kinetic	Hyper-kinetic
Deep tendon reflex		
Brisk	6	7
Depressed	1	1
Normal	1	8
Plantar response		
Flexor	8	15
Extensor	0	**1**

Table 3.4 : Pattern of deep tendon reflexes and plantar responses in patients with hypokineric and the hyperkinetic dysarthrias.

3.1.2.2 Essential Voice Tremor (EVT)

The patients with EVT were in the age range of 45 to 60 years with a mean age of 52.5 years. There were 2 male and 2 female subjects in this group. Positive family history was noted in only one subject. Cranial nerve abnormality was evident in only one patient. DTR's were brisk in 2 patients and normal in the other two patients. Tremors of upper limbs were present in all the 4 subjects while titubation of head was present in 3 of the 4 patients. Cerebellar involvement was reflected in the form of tandem gait (in 3 patients) with swaying to both sides. CT study was normal in 2 patients while it revealed diffuse cortical atrophy in 2 other patients with one of them having diffused cerebellar atrophy also. Patients in this group had speech problem for an average duration of 6.5 years, more than in any other subgroup.

Features	Hypo-kinetic	Hyper-kinetic
Number of patients with EP manifestations	8	16
Tremors		
Resting	8	2
Action	0	1
Mixed	0	1
Rigidity	8	1
Dystonia	2	6
Chorea	0	4
Masked face	6	0
Gait (Festinant, hypo- or bradykinesia)	5	1
Titubation of head	0	3
Bucco-lingual movements	0	4
Tremors of jaw, tongue or soft palate	0	2

Table 3.5 : Extrapyramidal manifestations in the hypokinetic and the hyperkinetic dysarthria groups.

3.1.2.3 Dystonia

There were 2 male and 2 female speakers in the dystonia group. These patients were in the age range of 22 to 60 years with a mean age of 46 years. The average duration of the speech problem, as well as dysarthria, in these patients, was 3.5 years. Cranial nerve involvement was evident in only one patient; DTR's were normal in all the 4 subjects; sensory system was not affected in any patient; weakness of orofacial musculature was evident in 2 of the four subjects; cerebellar system was not involved in any of these patients; and CT scan revealed an essentially normal study in all the four patients of this group. Two of these patients were diagnosed to have lingual dystonia, one as laryngeal dystonia and one to have oropharyngcal dystonia.

Features	Hypo-kinetic	Hyper-kinetic
Number of patients with cerebellar manifestations	I	4
Incoordination (finger-nose, heel-knee)	1	2
Gait (broad based, tandem)	1	4

Table 3.6 : Cerebellar manifestations in the hypokinetic and the hyperkinetic dysarthria groups.

3.1.2.4 Tardive Dyskinesia

Patients who were diagnosed to have tardive dyskinesia were all males and were in the age range of 27 to 60 years with a mean age of 43 years. Though these patients had dyskinesia for a mean duration of 10 to 15 years, speech problem itself was of 2.5 years duration, on an average. All patients showed some movement disorder in the form of either tremors or choreatic movements. Higher mental functions were affected in all the patients. There was cranial nerve involvement (history of UMN facial palsy) in only one patient. DTR's were normal in 2 patients and brisk in 2 patients. Extrapyramidal involvement was predominantly in the form of abnormal lingual movement. All patients were diagnosed to have drug induced lingual tardive dyskinesia. CT scan presented an essentially normal study in all patients.

Feature	Normal	Hypo-kinetic	Hyper-kinetic
Vermian atrophy	0	5(62%)	5(31%)
Cerebellar hemispheric atrophy	0	5(62%)	3(18%)
Visualization of CP angle cistern	0	8(100%)	7(43%)
Visualization of cistern magna	1	4 (50%)	8 (50%)
Visualization of SCC	0	3(37%)	0
Visualization of LCC	2	5(62%)	3(18%)
Visualization of QGC	0	6(75%)	11(68%)
Visualization of AC	2	8(100%)	16(100%)

Table 3.7 : Qualitative changes seen in the CT scan of patients and the percentage of patients in the hypo- and hyperkinetic dysarthria groups who manifested such CT changes (SCC = Superior Cerebellar Cistern; LCC = Lateral Cerebellar Cistern; AC = Ambience Cistern; QGC = Quadrageminal Cistern).

Subjects had not received any speech therapy for their speech problem. This was true even in those patients who had their speech problem for a longer duration than an year. However, many of the dysarthrics, particularly those who had dysarthriafor less than 2 years, were under medical treatment. Fourteen of the 16 patients came from lower socio-economic strata of the society while the remaining two were from middle socio-economic level.

3.1.2.5 Normals

A control group of 10 normal subjects, with 8 males and 2 females, was constituted to obtain normative data for comparison. They were in the age range of 25 to 45 years with a mean age of 24.7 years. All normal subjects were randomly selected and were subjected to a screening procedure with respect to both speech and neurological examination. All normal subjects were monolingual or bilingual speakers, were predominantly from lower socioeconomic section of the society, were literate, and educated.

Thus subjects in the normal and dysarthric groups compare favourably with each other with respect to such factors as age, sex, education, socioeconomic status etc. However, the patient groups differed in terms of neurological involvement, and the duration of dysarthria and the speech problem.

3.2 Statistical Analyses

All patients and normals were evaluated only once. Two types of statistical comparisons were made: one, between the three main groups of normals, hypokinetic and hyperkinetic dysarthrias and two, between the subgroups of hyperkinetic dysarthrias.

Generally, one-way ANOVA was employed for testing the significance of difference in mean values between the groups and the statistical significance was tested at 0.05 confidence level. Student-Newman-Keuls test for post hoc t-score comparison was performed to isolate the source of significance for any variable with ANOVA's that had p' values less than 0.05. Wherever the relationship between any two variables was of interest, Pearson's Product-moment correlations were computed. Spearman's Rank Order correlations were computed to understand the relationship between speech intelligibility and dysarthria severity, these two being essentially rating scales. As for as correlations were concerned, the significance of the correlation was not tested, except with regard to neuro and CT findings, because of the small sample size. All statistical analysis were performed on the SPSS package (Statistical Procedures for Social Sciences, Version 1)..

The hypokinetic group consisted of only those patients with Parkinson's disease. However, in all our discussion we have generally used the term hypokinetic dysarthria. Where the term hypokinetic dysarthria has been used, it refers to, and must be taken as Parkinson's disease. Similarly, all patients in the 'dyskinesia' group were tardive dyskinetics. But, throughout this and the succeeding chapters, the term 'dyskinesia' has been used to refer to tardive dyskinesia.

3.3 Phonatory Deviations

A number of phonatory parameters were investigated on the assumption that neurological involvement of laryngeal and/or respiratory muscles may affect these parameters.

3.3.1 Maximum Phonation Duration and Others Measures

Maximum phonation duration, rise time, fall time and intensity decay were all investigated on the phonation of vowels /a, i, u/ in isolation. Rise time refers to the duration between the onset of phonation and attainment of a steady intensity level. Similarly, fall time refers to the duration between the point at which the intensity of voice drops from its steady level to the point of termination of voice. Intensity decay refers to a drop in the intensity of voice from the beginning (steady level) to the termination of voice. The results for all these parameters are given in Table 3.8 to 3.10 for vowels /a/, /i/ and /u/, respectively.

Upper half of Table 3.8 (and all other tables), unless otherwise stated, gives the results of the analysis of differences in mean values between the main groups while the lower half gives the results of the comparison of means between the four subgroups of hyperkinetic dysarthria.

The results showed that none of the differences in mean values of either maximum phonation duration, or rise time, or fall time, or intensity decay, for any vowel, was significantly different between the main groups. The mean values of hypokinetic and hyperkinetic dysarthria groups were less than that of normals, (for example, maximum phonation duration) but the difference did not reach the point of statistical significance. These results implied that the hypokinetic and hyperkinetic dysarthrias can not be differentiated from each other or from normals, based on these parameters.

None of the mean differences in mean values for any vowel was significantly different between the subgroups of hyperkinetic dysarthria at 0.05 level.

An exception was the fall time in respect of vowel /u/. The mean fall time for the EVT group was significantly higher than that of the chorea and the dystonia groups. Such a tendency was visible even for vowel /a/ and / i /, but the difference in means was not statistically significant for these two vowels. However, it must be cautioned that the group performance on fall time of intensity was highly variable with high standard deviations.

		MPD (Sec)	Rise Time (msec)	Fall Time (msec)	Int. Decay (dB)
Normal (1)	M	10.56	139.00	103.00	7.84
	SD	3.31	65.00	120.00	7.49
Hypokinetic(2)	M	8.32	156.00	113.00	7.19
	SD	2.39	224.00	95.00	5.39
Hyperkinetic(3)	M	9.42	130.00	60.00	7.33
	SD	3.98	56.00	85.00	6.59
F. Ratio		0.93	0.12	0.99	0.26
F. Prob.		NS	NS	NS	NS
Subgroups of (3)					
Chorea (1)	M	8.72	140.00	42.50	6.48
	SD	4.45	64.80	85.00	7.40
EVT (2)	M	8.19	127.50	111.25	10.35
	SD	3.61	28.72	120.09	9.55
Dystonia(3)	M	10.40	127.50	51.50	9.37
	SD	5.68	51.23	85.00	6.30
Dyskinesia(4)	M	10.40	125.75	30.00	3.11
	SD	56.80	87.59	53.54	3.78

F. Ratio	0.27	0.04	0.64	0.84
F. Prob.	NS	NS	NS	NS

Table 3.8 : Means (M) and standard deviations (SD) of maximum phonation duration (MPD) rise time, fall time and intensity decay (int.decay) on the phonation of vowel /a/ and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study (normals, hypokinetic and hyperkinetic dysarthria) and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		MPD (Sec)	Rise Time (msec)	Fall Time (msec)	Int. Decay (dB)
Normal (1)	M	10.91	141.00	50.20	5.56
	SD	4.47	86.08	91.55	3.61
Hypokinetic (2)	M	8.98	153.75	62.00	4.49
	SD	3.52	173.61	63.74	4.00
Hyperkinetic (3)	M	8.10	145.50	76.25	7.75
	SD	3.13	94.23	118.90	7.08
F. Ratio		1.81	0.02	0.21	1.20
F.Prob.		NS	NS	NS	NS
Posthoc groups					

Subgroups of (3)

Chorea (1)	M	5.57	140.00	15.00	8.74
	SD	0.68	51.63	30.00	8.96
EVT(2)	M	6.93	133.50	61.25	9.31
	SD	2.37	51.46	81.62	8.73
Dystonia(3)	M	10.11	162.50	202.50	7.17
	SD	3.89	80.15	175.57	8.69
Dyskinesia(4)	M	9.81	146.17	26.25	7.17
	SD	2.88	80.15	49.22	8.69
F. Ratio		2.65	0.05	2.92	0.16
F.Prob.		NS	NS	NS	NS

Table 3.9 : Means (M) and standard deviations (SD) of maximum phonation duration (MPD), rise time, fall time and intensity decay (int.decay) on the phonation of vowel / i / and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study and the subcategories of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the 3 main groups) were 2,31 and 3,12 for the subcategory analysis.

		MPD (Sec)	Rise Time (msec)	Fall Time (msec)	Int. Decay (dB)
Normal (1)	M	10.62	157.00	78.80	6.62
	SD	3.39	97.07	101.61	6.10
Hypokinetic(2)	M	8.95	131.25	62.50	6.34
	SD	3.00	67.70	74.77	3.91

Hyperkinetic(3)	M	8.35	177.50	67.81	7.17
	SD	3.47	152.03	69.40	7.70
F. Ratio		1.42	0.38	0.09	0.04
F.Prob.		NS	NS	NS	NS

Subgroups of (3)

Chorea (1)	M	5.49	107.50	25.00	5.24
	SD	1.24	53.77	50.00	5.36
EVT(2)	M	6.92	145.00	147.50	9.54
	SD	2.15	111.20	41.93	10.14
Dystonia(3)	M	10.07	282.50	26.25	5.98
	SD	4.51	268.12	49.22	6.49
Dyskinesia(4)	M	10.93	0.97	72.50	7.93
	SD	2.73	0.43	64.48	10.36
F. Ratio		3.11	0.97	4.88	0.21
F. Prob.		NS	NS	0.05	NS
Post hoc - Groups				2&1, 2&3	

Table 3.10 : Means (M) and standard deviations (SD) of maximum phonation duration (MPD), rise time, fall time and intensity decay (int.decay) on the phonation of vowel /u/ and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,3 1 and 3,12 for the subcategory-analysis

3.3.2 Fundamental Frequency of Phonation

Fundamental frequency (FO) of voice on the phonation of vowels /a/, /i/ and /u/ was measured. The results are given in Tables 3.11 to 3.13 for vowels /a/, /i/ and /u/, respectively. The results can be summarized as follows:

a) There was no statistically significant difference in the mean FO values between the three main groups for any vowel. An exception was the hyperkinetic group where the mean FO was significantly higher than that of normals for vowel /u/. Maximum FO, minimum FO, and extent of fluctuations were also not significantly different between the groups. The general tendency was that the hyperkinetic dysarthria as a group had higher mean FO values than the hypokinetic group which in turn had higher FO values than the normals.

b) Mean values of fluctuation/second were significantly different between the groups for all the vowels. Again the hyperkinetic groups had significantly higher mean fluctuations/sec than the normal group, but it was not significantly higher than the hypokinetic group. There was a large difference between the hypokinetic and the hyperkinetic groups in the mean fluctuations per second, but the difference was significant for vowel /i/ only.

c) There was no significant difference in the mean FO, maximum FO, minimum FO, fluctuations per sec, or extent of fluctuations between the subgroups of hyperkinetic dysarthria for vowels /a/ and /i/. Mean FO and minimum FO were significantly different between the subgroups for vowel

/u/ only. The mean FO for the dystonia group was significantly higher than that of the dyskinesia group. The minimum FO of the dystonia group was significantly higher than that of all the other groups.

d) There was large variability in the group means with respect to these variables with high standard deviations.

Figure 3.1 is a pictorial representation of the FO of voice in different groups on the phonation of vowel /a/. The combined data for the male and female speakers have been plotted in the figure. It may be noted that the normal mean FO was 152 Hz. All the different groups of dysarthrics and their subcategorics have mean FO around the value of normals, except the dystonic group. It was a surprising result in the sense that the lingual system was focus of involvement in three of the four dystonics, yet they, and not patients with EVT, who showed a deviation on a laryngeal parameter like FO.

		Mean FO (Hz)	Max.FO (Hz)	Min. FO (Hz)	Fluct/ Sec	Ext.of Fluct.
Normal (1)	M	152.87	193.87	125.43	5.01	7.10
	SD	47.77	65.79	38.84	4.76	6.07
Hypokinetic (2)	M	166.37	247.20	101.03	14.79	22.10
	SD	47.59	65.36	60.72	11.72	20.00
Hyperkinetic (3)	M	178.63	253.70	111.05	26.23	15.00
	SD	52.93	80.21	54.70	23.64	17.00
F. Ratio		0.81	0.51	0.50	4.60	1.60
F. Prob.		NS	NS	NS	0.05	NS
Post hoc - Groups					1&3	

Subgroups of (3)

Chorea (1)	M	165.04	262.00	83.85	16.01	9.53
	SD	44.98	84.34	30.16	12.32	4.46
EVT(2)	M	167.74	300.55	88.69	41.18	14.35
	SD	49.45	89.39	10.92	9.67	9.23
Dystonia(3)	M	235.02	266.45	166.87	33.11	15.75
	SD	52.10	74.65	81.41	41.75	16.66
Dyskincsia(4)	M	146.16	185.80	104.76	14.64	20.38
	SD	26.68	45.90	38.03	11.25	32.51
F. Ratio		3.00	1.64	2.57	1.28	0.22
F. Prob.		NS	NS	NS	NS	NS

Table 3.11 : Means (M) and standard deviations (SD) of mean fundamental frequency (F0), maximum and minimum F0, fluctuations per second (Fluct/sec), and extent of fluctuation (Ext. of fluct) on the phonation of vowel /a/ and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study (normals, hypokinetic and hyperkinetic dysarthria) and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,3 1 and 3,12 for the subcategory analysis.

		Mean F0 (Hz)	Max.FO (Hz)	Min. F0 (Hz)	Fluct/ Sec	Ext.of Fluct.
Normal (1)	M	148.51	221.80	132.57	6.00	9.07
	SD	39.90	91.85	42.16	7.10	8.84

Hypokinctic (2)	M	181.80	282.21	104.02	11.61	17.61
	SD	43.08	84.31	26.77	6.29	15.40
Hyperkinetic (3)	M	217.67	301.25	122.71	20.65	30.53
	SD	71.34	64.06	52.02	12.32	41.33
F. Ratio		4.47	3.23	0.92	7.16	1.64
F.Prob.		0.05	0.05	NS	0.05	NS
Post hoc-Groups		1&3	1&3		1&3, 2&3	
Subgroups of (3)						
Chorea (1)	M	188.34	278.06	102.87	13.46	11.22
	SD	41.68	44.86	33.77	8.61	5.05
EVT(2)	M	214.07	308.10	90.68	32.53	23.39
	SD	115.95	103.41	19.98	14.44	21.12
Dystonia(3)	M	243.97	328.77	161.90	15.37	43.92
	SD	37.80	290.05	82.14	6.39	76.25
Dyskinesia (4)	M	224.29	290.05	135.36	21.26	43.61
	SD	81.70	58.90	32.97	11.89	34.98
F. Ratio		0.36	0.39	1.77	2.53	0.54
F.Prob.		NS	NS	NS	NS	NS

Table 3.12 : Means (M) and standard deviations (SD) of mean fundamental frequency (F0), maximum and minimum F0, fluctuations per second (Fluct/sec), and extent of fluctuation (Ext. of fluct) on the phonation of vowel /i/ and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study (normals, hypokinetic and hyperkinetic dys-

arthria) and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		Mean F0 (Hz)	Max.F0 (Hz)	Min. F0 (Hz)	Fluct/ Sec	Ext.of Fluct.
Normal (1)	M	165.27	229.23	101.75	10.19	31.79
	SD	58.10	83.16	31.74	14.48	36.61
Hypokinetic (2)	M	180.00	255.12	102.40	14.82	13.84
	SD	40.74	100.29	47.00	10.05	8.54
Hyperkinetic (3)	M	215.74	300.22	120.15	24.28	27.09
	SD	67.40	63.67	61.05	13.58	36.36
F. Ratio		2.41	2.64	0.53	3.81	0.72
F. Prob.		NS	NS	NS	0.05	NS
Post hoc - Groups					1&3	

Subgroups of Hyperkinetic dysarthria

Chorea (1)	M	190.95	308.47	77.57	21.10	19.98
	SD	52.94	16.84	33.13	14.03	5.28
EVT (2)	M	220.26	301.78	106.11	37.98	12.35
	SD	65.91	94.03	16.55	15.50	11.47
Dystonia (3)	M	285.31	323.35	197.02	16.72	37.69
	SD	62.39	61.32	69.07	5.57	66.19
Dyskinesia(4)	M	166.46	267.31	99.95	21.32	38.36
	SD	33.73	71.66	37.24	10.09	37.33

F. Ratio 3.46 0.49 5.90 2.46 0.45

F.Prob.	0.05	NS	0.05	NS	NS
Post hoc-Groups	4&3		3&1,2,4		

Table 3.13 : Means (M) and standard deviations (SD) of mean fundamental frequency (F0), maximum and minimum F0, fluctuations per second (Fluct/sec), and extent of fluctuation (Ext. of fluct) on the phonation of vowel /u/ and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study and the subcategories of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2.31 and 3.12 for the subcategory analysis

3.3.3. Intensity Measures

Relative intensity of phonation of vowels /a/, /i/ and /u/ was measured and the results are given in Tables 3.14 to 3.16 for vowels /a/, *I'll* and /u/, respectively. The results can be summarized as follows.

a) Mean intensity (in dB), maximum intensity and minimum intensity, were significantly different between the main groups for vowel /a/. Hypokinetic dysarthric group had significantly lower mean intensity than the normal group. Both the hypokinetic and the hyperkinetic groups had lower mean maximum and minimum intensities than the normals on vowel /a/.

b) Mean of the maximum and minimum intensities, fluctuations in intensity per second, and the extent of fluctuations were all significantly different between the main groups in respect of vowel /i/. Hypokinetic group had lower mean maximum intensity than normals: had lower minimum intensity than both the hypeikinetic dysarthria and normal group. The hyperkinetic group had significantly higher mean fluctuations per second than both the normal and the hypokinetic group; and the hyperkinetic group had significantly higher mean values for the extent of fluctuations than both the hyperkinetic and normal group.

c) None of the differences in mean values of intensity related factors was significant in respect of vowel /u/.

d) Subgroup analysis . The mean intensity and fluctuations/second in respect of vowel /a/, and mean fluctuations per second in case of vowel /i/ and /u/ were significantly different between the subgroups of hyperkinetic dysarthria. Dystonia group had significantly lower intensity for vowel /a/ than dyskinesia and the chorea groups. The EVT group had significantly higher mean fluctuations per second, compared to the chorea, dystonia and the dyskinetic groups on all vowels. None of the other differences in mean values with respect to maximum intensity, minimum intensity and extent of fluctuations between subgroups were significant for any vowel.

Figure 3.2 is a graphic representation of the distribution of vocal intensity on the phonation of vowel /a/ in different dysarthric groups. The difference in the mean intensities between the different groups are within a range of 6 dB and the difference in means was not statistically significant. The patients with chorea and dyskinesia have shown the highest values of mean intensity. The superimposition of choreiform movements might explain the high vocal intensity in this group, but, it was, again, a surprise to find high intensity in a group of lingual dyskinetics.

Mean Fundamental Frequency

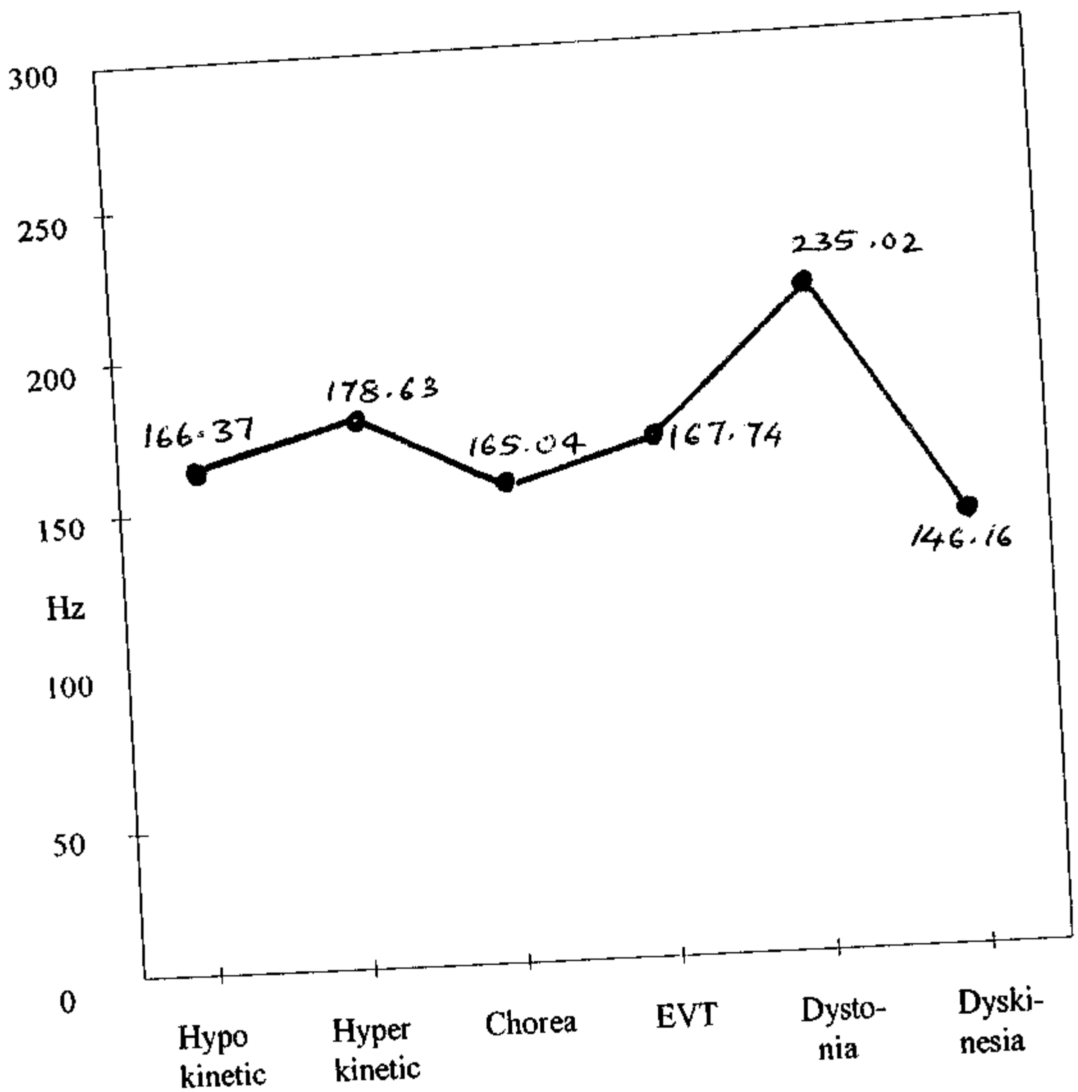


Figure 3.1: Graphic illustration of the mean fundamental frequency (in Hz) of the dysarthric groups on he phonation of vowel /a/.

Intensity of Voice

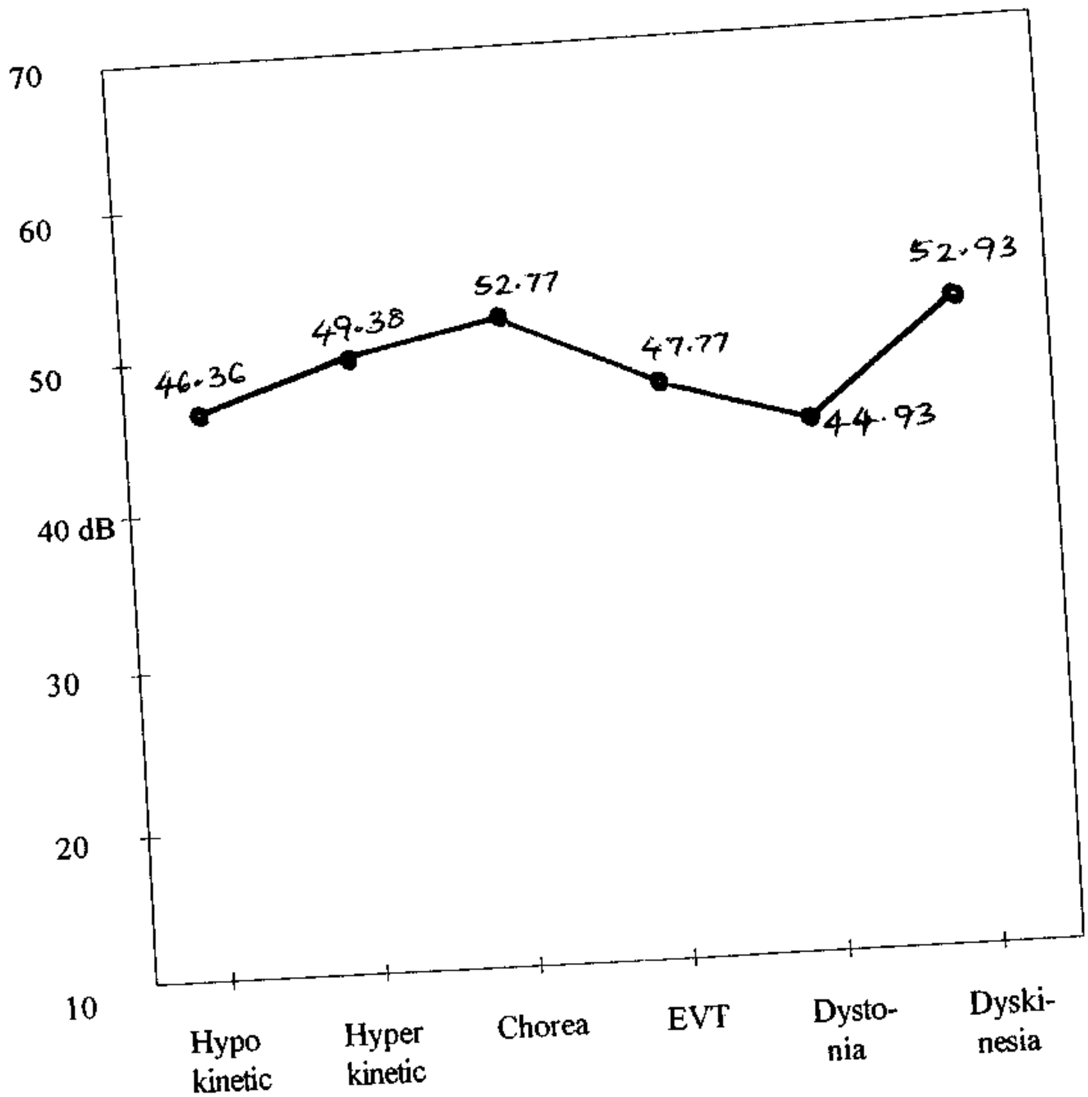


figure 3.2 : Graphic illustration of the mean intensity of voice (in dB) of the different dysarthrie groups on the phonation of vowel /a/.

		Mean Int (dB)	Max.Int (dB)	Min. Int (dB)	Fluct/ Sec	Ext.of Fluct.
Normal (1)	M	51.86	56.34	39.45	1.03	3.42
	SD	3.64	4.80	7.34	0.65	0.27
Hypokinetic (2)	M	46.36	51.83'	25.96	2.17	3.84
	SD	3.75	2.89	11.89	0.91	0.39
Hypcrkinctic (3)	M	49.38	53.36	29.29	4.49	3.63
	SD	5.07	3.84	11.88	6.17	0.51
F. Ratio		3.46	3.97	4.12	2.13	2.15
F. Prob.		0.05	0.05	0.05	NS	NS
Post hoc - Groups		2&1	2&1,	2&1,		
			2&3	**3&1**		
Subgroups of (3)						
Chorea (1)	M	52.77	59.89	33.58	3.36	3.69
	SD	3.55	2.02	2.57	2.63	0.20
EVT(2)	M	47.47	56.16	21.17	11.48	3.97
	SD	4.98	2.96	8.71	9.61	0.41
Dystonia(3)	M	44.93	53.25	29.84	1.67	3.50
	SD	3.70	4.60	15.03	1.06	0.43
Dyskinesia(4)	M	52.33	56.12	32.58	1.44	3.34
	SD	4.32	3.20	16.43	0.28	0.79
F. Ratio		3.31	2.66	0.87	3.57	1.13
F. Prob.		0.05	NS	NS	0.05	NS
Post hoc - Groups	3	&1			3&2,	
		3 &4			2&1,4	

Table 3.14 : Means (M) and standard deviations (SD) of mean intensity of voice, maximum and minimum intensity, fluctuations per second (fluct/sec), and extent of fluctuation (Ext. of fluct) on the phonation of vowel /a/ and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study (normals, hypokinetic and hyperkinetic dysarthria) and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		Mean Int. (dB)	Max.Int. (dB)	Min. Int. (dB)	Fluct/ Sec	Ext.of Fluct.
Normal (1)	M	44.73	52.08	40.37	0.63	3.26
	SD	10.53	3.21	4.63	0.52	0.15
Hypokinetic (2)	M	46.78	50.43	24.93	1.43	4.01
	SD	4.63	3.79	15.44	1.32	0.51
Hyperkinetic (3)	M	50.35	56.22	30.68	3.69	3.67
	SD	4.58	4.57	8.94	3.16	0.37
F. Ratio		2.18	6.49	5.70	6.08	9.39
F. Prob.		NS	0.05	0.05	0.05	0.05
Post hoc-Groups			2&3	2&1, 3&1	1&3, 2&3	1&3, 1&2, 3&2
Subgroups of (3)						
Chorea (1)	M	52.69	58.64	29.24	3.59	3.59
	SD	2.84	4.13	6.56	2.30	0.24

EVT(2)	M	49.68	56.67	32.22	7.34	3.47
	SD	5.00	4.80	10.22	4.06	0.06
Dystonia(3)	M	45.86	52.40	29.19	2.05	3.66
	SD	3.98	4.73	12.08	0.69	0.51
Dyskinesia(4)	M	53.16	57.16	32.06	1.79	3.95
	SD	3.28	3.65	9.74	1.30	0.45
F. Ratio		3.02	1.50	0.11	4.36	1.23
F. Prob.		NS	NS	NS	0.05	NS
Post hoc - Groups					4&2, 3&2	

Table 3.15 : Means (M) and standard deviations (SD) of mean intensity of voice, maximum and minimum intensity, fluctuations per second (fluct/sec), and extent of fluctuation (Ext. of fluct) on the phonation of vowel /i/ and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study (normals, hypokinetic and hyperkinetic dysarthria) and the subcatcgorics of hypcrkinctic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		Mean Int (dB)	Max.Int (dB)	Min. Int (dB)	Fluct/ Sec	Ext.of Fluct.
Normal (1)	M	49.53	53.40	39.50	1.10	3.38
	SD	4.09	5.55	6.74	0.79	0.27
Hypokinetic (2)	M	43.52	52.73	39.03	5.86	3.55
	SD	17.08	4.80	12.40	12.44	1.38

Hyperkinetic (3)	M	50.61	54.17	34.03	4.17	3.47
	SD	3.63	13.19	12.54	3.36	0.99
F. Ratio		1.80	0.05	0.95	1.33	0.07
F. Prob.		NS	NS	NS	NS	NS
Subgroups of (3)						
Chorea (1)	M	51.88	59.28	32.05	5.00	3.56
	SD	1.07	3.66	6.23	2.65	0.29
EVT(2)	M	48.83	56.64	30.36	8.66	3.90
	SD	3.03	5.52	14.14	1.20	0.43
Dystonia(3)	M	48.70	56.26	35.92	1.93	3.43
	SD	4.55	4.30	17.88	0.72	0.21
Dyskinesia(4)	M	53.02	56.26	37.82	1.11	2.98
	SD	3.99	4.30	13.45	0.74	2.00
F. Ratio		1.61	0.99	0.25	19.58	0.54
F. Prob.		NS	NS	NS	0.05	NS
Post hoc - Groups					4&1,3&1, 4&2, 3&2, 1&2	

Table 3.16 : Means (M) and standard deviations (SD) of mean intensity of voice, maximum and minimum intensity, fluctuations per second (fluct/sec), and extent of fluctuation (Ext. of fluct) on the phonation of vowel /u/ and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been shown for the three main groups of the study (normals, hypokinetic and hyperkinetic dysarthria) and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcatcgory analysis.

		Jitter T%	PVI	DPQ %	RAP3 Point	RAP5 Point	DLT	Jitter F0%
Normal (1)	M	1.30	0.89	51.04	0.01	0.01	0.11	1.32
	SD	0.73	0.80	6.71	0.01	0.01	0.19	0.78
Hypokinetic (2)	M	8.24	12.98	59.89	0.04	0.06	1.06	9.01
	SD	3.42	5.96	7.74	0.02	0.05	1.83	3.69
Hyperkinctic(3)	M	5.12	10.57	54.70	0.03	0.03	0.28	5.66
	SD	4.34	8.80	11.76	0.02	0.05	0.34	4.85
F. Ratio		9.16	8.82	1.02	4.61	2.85	2.72	9.23
F. Prob.		0.05	0.05	NS	0.05	NS	NS	0.05
Post hoc - Groups		1&3, 1&2, 2&3	1&3, 1&2		1&3, 1&2			1&3 1&2

Subgroups of (3)

		Jitter T%	PVI	DPQ %	RAP3 Point	RAP5 Point	DLT	Jitter F0%
Chorea (1)	M	3.98	10.31	51.04	0.02	0.02	0.16	4.24
	SD	2.94	5.91	8.10	0.01	0.01	0.12	2.99
EVT(2)	M	9.20	20.27	45.15	0.05	0.08	0.68	10.70
	SD	5.66	8.44	17.15	0.03	0.09	0.51	6.01
Dystonia(3)	M	5.41	10.05	61.13	0.03	0.03	0.17	5.69
	SD	3.77	7.66	0.93	0.02	0.02	0.12	4.09
Dyskinesia(4)	M	1.86	1.81	61.47	0.01	0.01	0.10	2.02
	SD	1.02	1.45	6.78	0.00	0.00	0.01	1.22
F. Ratio		2.72	5.73	2.34	2.16	2.05	3.94	3.42
F. Prob.		NS	0.05	NS	NS	NS	0.05	0.05
Post hoc - Groups			4&2, 1&2				4&2, 1&2, 3&2	4&2

Table 3. 17 : Means (M) and standard deviations of jitter factors in the phonation of vowel /a/ and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Jitter factors analysed included jitter in period (jitter T%), period variability index (PVI), directional perturbation quotient (DPQ), relative average perturbation (RAP3, and RAP5 - for 3-point and 5-point average), deviation from the linear trend (DLT), and jitter in frequency (jitter F0). Separate analysis of variance have been shown for the three main groups of the study and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		Jitter T %	PVI	DPQ %	RAP3 Point	RAP5 Point	DLT	Jitter F0%
Normal (1)	M	1.25	1.56	56.83	0.02	0.02	0.15	4.17
	SD	0.76	1.68	7.88	0.02	0.02	0.24	0.88
Hypokinctic(2)	M	4.36	8.01	58.09	0.03	0.08	0.36	4.69
	SD	4.19	8.75	9.43	0.02	0.11	0.80	4.40
Hyperkinetic (3)	M	8.31	16.99	60.33	0.05	0.43	0.40	9.25
	SD	10.82	23.68	14.92	0.07	1.55	0.71	13.73
F. Ratio		2.59	2.62	0.39	1.72	0.56	0.46	2.16
F. Prob.		NS	NS	NS	NS	NS	NS	NS
Subgroups of (3)								
Chorea (1)	M	7.80	13.77	54.09	0.04	0.04	0.27	4.59
	SD	7.46	9.65	5.00	0.04	0.04	0.24	2.99
EVT (2)	M	9.22	30.56	46.34	0.05	0.07	0.35	15.06
	SD	12.31	38.44	9.80	0.07	0.10	0.39	20.97

Dystonia(3)	M	3.92	8.26	62.68	0.02	0.02	0.11	4.61
	SD	2.49	8.19	1.61	0.01	0.01	0.09	4.26
Dyskinesia (4)	M	12.78	15.39	78.01	0.08	1.61	0.87	12.76
	SD	17.98	28.33	15.59	0.11	3.10	1.37	18.87
F. Ratio		0.35	0.59	7.85	0.42	1.02	0.81	0.57
F. Prob.		NS	NS	0.05	NS	NS	NS	NS
Post hoc - Groups				4&2,1,3				

Table 3. 18 : Means (M) and standard deviations of jitter factors in the phonation of vowel *HI* and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Jitter factors analysed included jitter in period (jitter T%), period variability index (PVI), directional perturbation quotient (DPQ), relative average perturbation (RAP3, and RAP5 - for 3-point and 5-point average), deviation from the linear trend (DLT), and jitter in frequency (jitter F0). Separate analysis of variance have been shown for the three main groups of the study and the subcategories of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		Jitter T %	PVI	DPQ %	RAP3 Point	RAP5 Point	DLT	Jitter F0%
Normal (1)	M	1.51	1.73	60.97	0.04	0.03	0.32	1.48
	SD	0.85	1.67	7.78	0.04	0.04	0.47	0.68
Hypokinetic(2)	M	4.07	6.08	53.20	0.02	0.17	0.96	3.48
	SD	2.81	3.07	22.19	0.01	0.34	2.29	3.11
Hyperkinetic(3)	M	6.91	11.39	62.12	0.04	0.04	0.27	7.31
	SD	6.19	9.69	17.62	0.03	0.03	0.24	6.35

F. Ratio		4.45	6.09	0.80	0.55	1.96	1.08	5.13
F.Prob.		0.05	0.05	NS	NS	NS	NS	0.05
Post hoc-Groups		1&3	1&3					1&3
Subgroups of (3)								
Chorea(l)	M	1.15	10.14	56.97	0.03	0.05	0.28	5.73
	SD	3.61	6.10	10.31	0.01	0.04	0.16	2.96
EVT(2)	M	10.32	19.76	64.00	0.06	0.05	0.28	11.37
	SD	7.10	11.93	24.54	0.04	0.03	0.09	6.81
Dystonia(3)	M	7.84	10.14	70.27	0.05	0.03	0.09	8.21
	SD	9.15	10.26	20.19	0.06	0.03	0.08	9.08
Dyskinesia (4)	M	3.34	5.53	57.26	0.02	0.04	0.41	3.92
	SD	3.14	6.47	16.63	0.01	0.04	0.42	4.71
F. Ratio		0.87	1.75	0.45	0.74	0.13	1.21	1.04
F.Prob.		NS	NS	NS	NS	NS	NS	NS

Table 3. 19 : Means (M) and standard deviations of jitter factors in the phonation of vowel /u/ and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Jitter factors analysed included jitter in period (jitter T%), period variability index (PVI), directional perturbation quotient (DPQ), relative average perturbation (RAP3, and RAP5 - for 3-point and 5-point average), deviation from the linear trend (DLT), and jitter in frequency (jitter F0). Separate analysis of variance have been shown for the three main groups of the study and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcatagory analysis.

3.3.4 Frequency Perturbations : Jitter

Jitter reflects on the short term instability in the frequency of vibration of the vocal cords. Several variations of perturbation factors like jitter (in period - T%), perturbation variability index (PVI), directional perturbation quotient (DPQ), relative average perturbation (RAP-3 point average and RAP5 - 5 point average), deviation from linear trend (DLT) and jitter (in frcquency-FO) were measured on vowels /a/, /i/ and /u/. All these jitter factors vary in terms of how ' they are calculated, but reflect on the same short term instability of frequency of vibration. Jitter T% and jitter FO are the standard forms of expression of frequency perturbation. The results given in Tables 3.17 to 3.19 for vowels /a/, /i/ and /u/ respectively can be summarized as follows:

a) Mean values of jitter T%, PVI, RAP3, and jitter FO in respect of vowel /a/ and mean values of jitter T% and PVI in respect of vowel /u/ were significantly different between the main groups. None of the differences in mean values for any perturbation factor was significantly different between the main groups in respect of vowel /i/.

b) The hypokinetic dysarthria group had significantly higher jitter T% than both the normal and the hyperkinetic groups, and the hyperkinetic dysarthric group in turn had significantly higher jitter T% than normals for vowel /a/. Both the hypokinetic and the hyperkinetic groups had higher PVI than normals for vowel /a/, whereas only the hyperkinetic group had higher PVI than normals for vowel /u/. Both the hypokinetic and the hyperkinetic groups had significantly higher jitter FO for vowel /a/, while only the latter group had significantly higher values than the normal group for vowel /u/

		/a/				/i/				/u/			
		A	B	C	D	A	B	C	D	A	B	C	D
		(dB)		%	(dB)	(dB)		%	(dB)	(dB)		%	(dB)
Normal (1)	M	0.3	1.6	56.6	2.4	0.8	1.4	61.1	2.5	1.1	1.7	64.5	7.7
	SD	0.1	0.3	7.5	1.0	0.1	0.2	5.3	0.9	1.0	0.6	2.6	7.1
Hypo-(2)	M	1.0	1.9	62.9	6.2	0.6	1.7	61.6	3.3	0.7	1.6	62.5	5.2
Kinetic	SD	0.5	0.2	5.4	3.4	0.6	0.3	5.6	3.7	0.5	0.4	6.5	3.6
Hyper-(3)	M	0.8	1.9	57.6	4.2	1.3	2.0	59.4	6.3	1.2	2.1	65.1	5.5
kinetic	SD	0.5	0.5	9.5	3.2	1.9	0.4	18.3	0.1	1.1	0.4	14.1	5.0
F. Ratio		5.4	2.4	1.4	4.0	1.4	6.6	0.0	0.9	0.5	2.6	0.1	0.6
F.Prob.		*	NS	NS	*	NS	*	NS	NS	NS	NS	NS	NS
Post hoc		1&3			1&2		1&3						
Groups		1&2											

Subgroups of (3)

		/a/ A	/a/ B	/a/ C	/a/ D	/i/ A	/i/ B	/i/ C	/i/ D	/u/ A	/u/ B	/u/ C	/u/ D
Chorea (1)	M	0.5	1.9	59.2	2.6	0.5	2.0	54.3	2.5	1.0	2.2	59.2	4.3
	SD	0.4	0.4	6.2	1.0	0.4	0.4	13.9	1.7	0.4	0.3	11.5	2.0
EVT(2)	M	1.5	2.3	4K.3	7.4	2.3	2.2	45.2	2.5	2.2	2.4	66.5	9.6
	SD	0.6	0.2	10.8	5.1	3.2	0.3	15.4	8.6	1.9	0.2	2 0.6	8.7
Dystonia(3)	M	0.8	2.2	65.4	4.2	0.5	2.1	66.0	2.5	0.9	2.1	72.3	3.7
	SD	0.2	0.4	3.7	1.7	0.3	0.4	7.4	1.0	0.9	0.3	16.1	3.9
Dyskinesia(4)	M	0.4	1.3	57.6	2.7	1.7	1.7	72.3	7.9	0.7	1.6	62.3	4.3
	SD	0.1	0.5	9.2	1.1	2.1	0.4	24.6	8.5	0.1	0.4	6.9	0.8
F Ratio		5.9	4.8	3.1	2.5	0.8	1.3	2.1	0.8	1.6	3.4	0.5	1.2
F.Prob.		*	*	*	. NS	NS	NS	NS	NS	NS	*	NS	NS
Post hoc		4&2	4&3	2&3							4&2		
		1&2,	4&2										
		3&2											

* Indicates that the difference was significant at 0.05 significance level

Table 3.20 : Means (M) and standard deviations of shimmer factors in the phonation of vowels /a, i, u/ in isolation and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Shimmer factors analysed included shimmer in dB (A), amplitude variability index (B), directional perturbation quotient (C), and amplitude perturbation quotient (D). Separate analysis of variance have been shown for the three main groups of the study (normals, hypokinetic and hyperkinetic dysarthria) and the subcategorics of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

c) A general trend was that the hypokinetic group had higher mean values pertaining to all the perturbation factors than the hyperkinetic group for vowel /a/, while the relationship was reversed in the case of vowels /i/ and /u/. However, only some of these differences in mean values were statistically significant.

d) Subgroup differences in mean values were significant in respect of PV1, DLT and jitter F0 for vowel /a/, and DPQ for vowel /i/. None of the other differences in mean values was significant between the subgroups.

e) EVT group had significantly higher mean PVI than the dyskinetic and the chorea groups for vowel /a/; significantly higher DLT than the chorea, dystonia and dyskinetic groups for vowel /a/; and significantly higher jitter F0 than the dyskinetic group for vowel /a/ (Table 3.17). The dyskinetic group had significantly higher DPQ values for vowel /i/ than the chorea, EVT and the dystonia groups.

f) The general trend with regard to the subgroups was that the EVT group had higher mean values on all the perturebation factors than the dyskinetic group for vowels /a/ and /u/ while the opposite relationship held good in respect of vowel /i/. However, only some of these differences in mean values were significant at 0.05 level.

3.3.5 Shimmer Factors

Shimmer reflects on the short term instability of the amplitude of vibration of the vocal cords. Shimmer (in dB), amplitude variability index (AVI), directional perturbation quotient (DPQ) and amplitude perturbation quotient (APQ) are all measures of shimmer. The difference between these factors lies in the way they are computed. Shimmer in dB is the standard form of representation of shimmer. Shimmer factors were measured on vowels /a/, /i/ and /u/. The mean values of different shimmer factors and the results of ANOVAs are given in Table 3.20. The results can be summarized as follows :

a) Mean shimmer in dB values were significantly different between the three main groups only for vowel /a/. Both the hypokinetic and the hyperkinetic dysarthric groups had significantly higher shimmer in dB than the normal group. Mean APQ for vowel /a/ and AVI for vowel /i/ were significantly different between the three main groups. None of the mean values in respect of any of the shimmer related factors was significantly different between the groups for vowel /u/.

b) Subgroup differences were significant in respect of mean shimmer in dB, AVI and DPQ only for vowel /a/. AVI was significantly different between the subgroups only in the case of vowel /u/. None of the other differences in means was significant for any vowel.

c) Mean shimmer in dB and mean AVI were significantly higher in the EVT group than dystonia, dyskinetic and chorea groups.

3.3.6 Harmonic to Noise Ratio and Long Term Average Spectrum

Harmonic to noise ratio (HNR), as the term denotes, is the ratio of the periodic energy at different harmonic frequencies to the noise energy present at these frequencies. The higher the HNR, better is the quality' of voice produced. **HNR** was measured on vowels /a/, /i/ and /u/ and the results are given on the left half of Table 3.21. Results showed that the differences in mean HNR value were not significantly different either between the three main groups or between the subgroups of hyperkinetic dysarthria for any vowel. However, the general trend was that the hyperkinetic dysarthria group had lower HNR than the hypokinetic group which in turn had lower values than the normal group, but the difference in mean values did not reach the level of statistical significance.

The right half of Table 3.21 shows the results of the analysis of long term average spectrum (LTAS) for the three vowels /a/, /i/ and /u/. LTAS gives the energy levels in specific range of frequencies. Energy levels in the frequency range between 0-1 kHz, 0-2 kHz, 4-5 kHz and 2-8 kHz can be computed, but in this study only the energy levels in the 0-1 kHz range was considered. The results on LTAS in Table 3.21 can be summarized as follows :

Mean energy levels between 0-1 kHz were not significantly different either between the main groups or between the subgroups for any vowel. A visual examination of the mean values indicated that the LTAS values for different groups and for different vowels were all in the range of 88.5 to 89.9 dB.

		HNR(in dB)			LTAS (0-lkHz - in dB)		
Vowels		/a/	/i/	/u/	/a/	/i/	/u/
Normal (1)	M	25.27	24.58	23.17	88.61	89.21	89.91
	SD	2.88	3.08	3.66	1.03	0.55	0.12
Hypokinetic(2)	M	22.99	23.95	21.68	87.75	89.62	89.82
	SD	2.33	1.75	3.15	1.12	0.44	0.14
Hyperkinetic(3)	M	22.75	22.56	20.03	88.61	89.63	89.94
	SD	3.83	3.73	4.16	1.09	1.00	0.07
F. Ratio		1.76	1.33	2.12	2.65	0.99	1.11
F. Prob.		NS	NS	NS	NS	NS	NS
Subgroups of (3)							
Chorea(l)	M	21.53	22.65	21.05	88.75	88.87	89.93
	SD	0.38	3.69	3.42	0.91	1.99	0.03
EVT(2)	M	20.79	22.73	17.28	88.25	89.87	89.89
	SD	2.73	2.46	3.27	1.57	0.07	0.11
Dystonia(3)	M	24.09	25.45	21.80	88.70	89.88	89.96
	SD	2.82	3.84	6.00	1.17	0.11	0.05
Dyskinesia(4)	M	24.57	19.43	20.01	88.54	89.91	89.98
	SD	3.87	3.30	3.53	0.34	0.08	0.02
F. Ratio		0.93	2.13	0.87	0.94	1.03	1.25
F. Prob.		NS	NS	NS	NS	NS	NS

Table 3.21 : Means (M) and standard deviations of harmonic-to-noise ratio (HNR) and long term average spectrum (LTAS : 0-1 kHz) in the phonation of vowels /a, i, u/ in isolation and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Separate analysis of variance have been shown

for the three main groups of the study (normals, hypokinetic and hyperkinetic dysarthria) and the subcategories of hyperkinetic dysarthria - chorea, essential voice tremor (EVT), dystonia and tardive dyskinesia (dyskinesia). Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

3.3.7 S/Z Ratio

The ratio of the duration of voiceless sound /s/ to the duration of a sustained voiced consonant /z/ which is supposed to differentiate the phonatory abnormality (vibration of vocal cards) and insufficiency of respiratory support was measured and the results are given in Table 3.22. There was no significant difference in the mean s/z ratios either between the main groups or between the subgroups of hyperkinetic dysarthria. Visual examination of the data showed that the chorea group had higher s/z ratios but the differences in mean values were not significant between the groups. Again, there was high variability in the individual data as reflected in higher standard deviations.

		S/Z Ratio
Normal (1)	M	0.99
	SD	0.19
Hypokinetic (2	M	1.01
	SD	1.28
Hyperkinetic (3)	M	0.20
	SD	0.57

F. Ratio 0.51
F. Prob. NS

Subgroups of (3)		
Chorea (I)	M	2.29
	SD	1.65
EVT (2)	M	0.99
	SD	0.27
Dystonia(3)	M	1.23
	SD	0.83
Dyskinesia(4)	M	0.60
	SD	0.31
F. Ratio		2.35
F. Prob.		NS

Table 3.22 : Means (M) and standard deviations (SD) of mean s/z ratios and the results of the analysis of variance for the significance of difference of means at the 0.05 confidence level. Separate analysis of variance have been made for the three main groups of the study and the subcategories of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		Max. Freq.	Min. Freq.	Freq. Range	Max. Int.	Min Int.	Int. Range
Normal (1)	M	299	110	189	61	32	29
	SD	76	32	75	2.92	6.76	7.75
Hypokinetic (2)	M	274	109	165	57	40	17
	SD	185	63	193	2.20	10.0	9.72
Hyperkinetic (3)	M	300	110	190	59	33	26
	SD	114	50	123	4.99	9.0	9.62
F. Ratio		1.13	0.00	0.03	3.23	2.45	4.02
F. Prob		NS	NS	NS	0.05	NS	0.05

Post hoc - Groups					2&1		2&3,1
Subgroups of (3)							
Chorea (1)	M	272	89	182	60	32	28
	SD	103	22	109	3.37	5.46	8.03
EVT(2)	M	372	79	293	63	36	27
	SD	173	22	189	4.61	13.9	14.2
Dystonia(3)	M	305	151	154	57	35	22
	SD	109	78	70	6.5	4.33	5.48
Dyskinesia(4)	M	251	119	131	57	29	28
	SD	35	32	51	4.13	9.43	11.0
F. Ratio		0.83	2.05	1.48	1.41	0.52	0.36
F. Prob		NS	NS	NS	NS	NS	NS

Table 3.23 : Means (M) and standard deviations (SD) of mean of maximum and minimum frequency and intensity and the frequency and intensity range on the phonation glide task and the results of the analysis of variance. Degrees of freedom were 2,31 for the main analysis (between the three main groups) and 3,12 for the subcategory analysis.

3.3.8 Frequency and Intensity Glide

Frequency range in the phonation of vowel /a/ was tested by asking the patients to initiate phonation at the lowest frequency that they are capable of and to continue phonation increasing the frequency to achieve the maximum frequency that they were capable of. Similarly the intensity range was tested. They were called frequency and intensity glide, respectively. Results are given in Table 3.23 and can be summarized as follows:

a) There was no significant difference in the mean maximum frequency, or minimum frequency, or frequency range between the main groups or between the subgroups of hyperkinetic group. A visual examination of the data revealed that the performance of the hypokinetic dysarthric patients was depressed compared to the normal and the hyperkinetic groups. Among the subgroups, the mean values of the EVT group were increased in relation to other subgroups of hyperkinetic dysarthria.

b) Mean of the maximum intensity and mean intensity range were significantly different between the groups, but not the mean minimum intensity. The hypokinetic dysarthric group had lower maximum intensity and intensity range values than the other two groups.

c) None of the differences with respect to intensity glide was significantly different between the subgroups of the hyperkinetic group.

Variable	Sex		Normal 1	Hypo-Kinetic 2	Hyper-kinetic 3	F.Ratio	F.Prob
MPD	Male	M	12.5	9.07	10.1	0.22	NS
		SD	2.11	2.29	4.09		
	Female	M	14.5	6.06	7.84	3.16	NS
		SD	5.27	0.29	3.64		
Mean F0	Male	M	133	150	157	0.99	NS
		SD	24.6	39.0	44.5		
	Female	M	234	217	225	0.11	NS
		SD	1.29	37.7	40.2		

Mean Intensity	Male		M	51.3	45.4	49.6	3.63	0.05[A]
			SD	3.85	3.97	4.39		
	Female		M	53.8	49.0	48.7	0.59	NS
			SD	2.4	0.95	6.88		
Fluctuations/ Sec.	Male		M	1.07	2.62	4.76	1.29	NS
			SD	0.63	0.40	7.39		
	Female		M	0.81	0.84	3.91	2.67	NS
			SD	0.99	0.46	2.35		
Jitter-Period	Male		M	1.35	9.83	3.81	25.8	0.05[B]
			SD	0.77	1.88	2.94		
	Female		M	1.09	3.49	7.99	1.66	NS
			SD	0.79	2.06	5.84		
Jitter-Frequency	Male		M	1.38	10.73	4.2	24.1	0.05[C]
			SD	0.83	1.97	3.41		
	Female		M	1.07	3.87	8.88	1.78	NS
			SD	0.76	2.35	6.35		
Shimmer -indB	Male		M	0.38	1.15	0.78	5.55	0.05[D]
			SD	0.14	0.53	0.51		
	Female		M	0.36	0.85	1.00	0.74	NS
			SD	0.25	0.60	0.71		
HNR (dB)	Male		M	24.9	22.4	21.9	1.57	NS
			SD	3.16	3.71	4.13		
	Female		M	26.6	24.7	24.5	0.69	NS
			SD	0.76	0.79	2.61		
Freq. Glide	Male	Low	M	103	96	108	0.07	NS
			SD	20.7	33.7	43.9		
		High	M	272	270	296	1.02	NS
			SD	50.8	18.5	33.7		
	Female	Low	M	135	146	115	0.07	NS
			SD	17.5	16.2	17.1		

		High	M	407	286	318	1.02	NS
			SD	19.1	11.6	19.3		
Int.	Male	Low	M	32	40	31	2.57	NS
Glide			SD	6.6	10.1	7.5		
		High	M	61	57	59	0.42	NS
			SD	2.99	2.42	5.74		
	Female	Low	M	32	42	40	2.57	NS
			SD	10.1	7.6	8.2		
		High	M	64	55	59	0.42	NS
			SD	0.5	0.9	3.3		

A : 2&1 B : 1&3, 1&2, 3&2

C : 1&3, 1&2, 3&2 D : 1&2

Table 3.24 : Differences between the three main groups on a number of phonatory parameters as a function of sex of the speakers. Separate analyses have been carried out for factors like maximum phonation duration (MPD), mean F0, mean intensity, fluctuations/second (frequency), jitter period, jitter frequency, shimmer (in dB), harmonic-to-noise ratio (HNR), frequency and intensity glide. Degrees of freedom for all intergroup analyses were 2,22 (for males) and 2,6 (for females).

3.3.9 Male-Female Differences in Phonatory Factors

In the analysis of phonatory factors, a combined analysis of the data from males and females was carried out hitherto. However, it is an established fact that male and female speakers differ on such factors as fundamental frequency, intensity of voice, maximum phonation duration, among others. Therefore, a separate analysis of the phonatory parameters may be of significance in characterizing or identifying different dysarthrias. A separate analysis of male and female speakers was done with respect to maximum phonation duration, mean FO, mean intensity, fluctuations in frequency/second, jitter (period), jitter (frequency), shimmer (in dB), HNR (dB), frequency glide and intensity glide on vowel /a/. Only, between-the-groups comparisons were made. These results given in Table 3.24, can be summarized as follows :

a) Mean MPD values for male and female speakers were not significantly different between the groups. However, the normal speakers, both males and females, had longer MPD's than the dysarthric groups.

b) Mean FO for male and female speakers was not significantly different between the groups. The mean FO of dysarthric males was high compared to normal males while the dysarthric females had slightly lower FO than normal females, but the difference was not significant.

c) Mean intensity of the voice of male speakers was significantly different between the groups with the hypokinetic male speakers having significantly lower intensity than normals. Differences in intensity were not statistically significant between the groups for female speakers.

d) Mean frequency fluctuations/second (8 Hz variations) were not significantly different between groups for either males or females. However, the mean value of hypokinetic and hyperkinetic groups were much higher than normal males. A significant difference was not obtained only on account of higher individual variability in the data.

e) Mean jitter (TO), mean jitter (FO), and shimmer (dB) were significantly different between the groups for male speakers, but not for the female speakers. The hypokinetic male group had significantly higher mean values in respect of all these parameters, than the hyperkinetic and normal males.

f) The differences in mean HNR values were not statistically significant between groups in respect of either males or females. However, the normal group (both males and females) had higher values of HNR compared to the hypokinetic and the hyperkinetic dysarthric groups. But, the differences were all within 1-2 dB range.

g) There was no significant difference between the groups, for either male speaker or female speakers, in the mean frequency glide and intensity glide values either with respect to low or high glide.

h) A consistent observation with regard to all these parameters and for both male and female speakers was that there was high individual variability in the mean values for patients in the hyperkinetic dysarthric group.

Var.	Seg.		Normals	Hypo-kinetic	Hyper-kinetic	F.Ratio	F.Prob.	Post hoc
FO	/a/	M	154.0	166.0	179.0	0.81	NS	
		SD	47.9	47.5	52.9			
	/al/	M	153.0	167.0	180.0	0.84	NS	
		SD	46.7	47.8	54.5			
	/a2/	M	153.0	171.0	179.0	0.75	NS	

		SD	47.7	54.8	54.8			
	/a3/	M	153.0	175.0	182.0	1.04	NS	
		SD	45.8	54.7	50.7			
F.Ratio			0.08	0.96	0.27			
F.Prob				NS	NS	NS		
Intensity	/a/	M	51.8	46.3	49.3	3.46	0.05	2&1 .
		SD	3.64	3.75	5.07			
	/al/	M	52.3	48.2	51.5	1.68	NS	
		SD	5.43	5.23	4.60			
	/a2/	M	51.8	49.4	53.5	2.04	NS	
		SD	3.23	3.53	4.77			
	/a3/	M	48.0	40.5	47.8	2.70	0.05	2&3
		SD	3.56	14.9	6.46			
F.Ratio			3.31	1.55	5.09			
F.Prob				0.05	NS	0.05		
Jitter	/a/	M	1.32	9.01	5.66	9.23	0.05	1&3,
(infreq)		SD	0.78	3.69	4.85			1&2
	/al/	M	1.01	6.12	4.34	4.09	0.05	1&3,
		SD	0.41	4.95	4.49			1&2
	/a2/	M	0.70	6.80	4.77	4.14	0.05	1&3,
		SD	0.32	4.83	5.82			1&2
	/a3/	M	1.02	10.8	9.12	4.40	0.05	1&3,
			0.80	8.13	4.80			1&2
F.Ratio			2.49	1.57	3.25			
F.Prob				NS	NS	0.05		
Shimmer	/a/	M	0.35	1.08	0.85	5.43	0.05	1&3,
(dB)		SD	0.15	0.52	0.56			1&2
	/al/	M	0.31	1.10	0.66	3.12	NS	
		SD	0.18	1.04	0.71			

	/a2/	M	0.35	1.40	0.64	2.69	NS	
		SD	0.25	1.24	0.53			
	/a3/	M	0.97	1.53	1.11	3.22	0.05	1&2
		SD	0.41	1.19	0.96			
F.Ratio			1.36	0.51	4.62			
F.Prob				NS	NS	0.05		
Freq. fluct.	/a/	M	5.01	14.8	26.24	4.60	0.05	1&3
		SD	4.76	11.7	23.6			
	/a1/	M	4.31	14.1	10.9	1.61	NS	
		SD	2.11	19.57	10.9			
	/a2/	M	3.54	12.8	19.9	4.39	0.05	1&3
		SD	3.71	9.01	18.5			
	/a3/	M	4.87	16.2	18.7	5.16	0.05	1&3
		SD	6.79	5.55	18.7			
F.Ratio			1.17	1.70	0.82			
F.Prob				NS	NS	NS		
Intensity fluct.	/a/	M	1.03	2.17	4.49	2.13	NS	
		SD	0.65	0.91	2.17			
	/a1/	M	0.99	7.12	4.00	6.77	0.05	1-3,2
		SD	0.40	4.37	4.07			3&2
	/a1/	M	0.48	0.91	2.54	1.06	NS	
		SD	0.58	1.23	1.39			
	/a3/	M	2.03	6.21	6.06	1.41	NS	
		SD	2.16	5.06	4.45			
F.Ratio			2.61	7.61	4.37			
F.Prob				NS	0.05	0.05		

Table 3.25 : Means (M) and standard deviations (SD) of a number of phonatory parameters in different segments of the phonation of vowel

/a/ and the results of the analysis of variance for the significance of difference of means for each segment between the three groups, /a/ = entire sample; /al/ = first 1.5 seconds of the sample; /a3/ = last 1.5 seconds of the sample; and /a2/ = entire sample - (/al/ + /a3/). Degrees of freedom : Between the segments : 3,36 (normal); 3,24 (hypokinetic) and 3,60 (hyperkinetic): Between groups : 2,31.

3.3.10 Phonatory Parameters - Analysis of Segments of Phonation

Separate analysis of the different segments of phonation samples of vowels /a/ were analysed with respect to phonatory parameters. The segments considered were : the full sample (a), first 1.5 seconds of the sample (al), last 1.5 seconds of the sample (a3) and middle portion of the sample |a3 = a - (al + a2)|. Fundamental frequency, intensity, jitter in frequency, shimmer in dB, frequency fluctuations/second and intensity fluctuations/second were computed. One-way ANOVA was tested for the difference in mean values between the four segments. A separate one-way ANOVA was carried out, for each segment, for the difference in means between the three groups. This segmental analysis has been done only on the phonation vowel /a/. The results tabulated in Table 3.25 can be summarized as follows :

a) The results of one-way ANOVA for difference in the mean values between the four segments of the sample did not show any significant difference between the four segments for any parameter. This implied that all the four segments of the phonation sample were similar except the duration.

b) Results of between-group analysis showed that :

i) there was no significant difference between the groups in the mean FO of any segment as it was for the whole sample,

ii) there was no significant difference between the groups in mean intensity for segment /aI/ and /a2/, but the mean values for /a3 /segment were different between the groups as was the case with whole sample. However, the whole sample showed a significant difference between normal and hypokinetic dysarthrias while the /a3/ segment showed a significant difference between the hypokinetic and the hyperkinetic dysarthria,

iii) the mean jitter in frequency for segments /aI/, /a2/ and /a3/ was significantly different between the groups as it was the case with the whole sample. The hypokinetic and the hyperkinetic dysarthrias were significantly different from the normals on these phonatory parameters and on all segments.

iv) the mean shimmer in dB values were not significantly different between groups in respect of segments /aI/ and /a2/, but the values on the /a3/ segment were significantly different between the groups.

Analysis of the entire sample (/a/) showed significant difference between the normal and the hyperkinetic, and normal and the hypokinetic dysarthrias while results on segment /a3/ showed significant difference only between the normal and the hypokinetic dysarthric group.

v) mean number of frequency fluctuations was significantly different between the normal and the hyperkinetic dysarthria groups. Similarly, mean number of frequency fluctuations was significantly different between the normal and hyperkinetic dysarthria groups for the /a2/ and /a3/ segments. The /a1/ segment did not yield any significant difference between the groups.

vi) mean number of fluctuations in intensity was significantly different between the groups for the /a1/ segment while none of the differences on the whole sample /a/, /a2/ or the /a3/ segments was significantly different. The implication is that intensity of voice at the time of initiation of phonation is more volatile, particularly in the hypokinetic group (mean number of fluctuations was 7.12) and that an analysis of only the initial portion of phonation may lead to invalid results or additional information, depending upon how one prefers to view them.

3.4. Articulation

3.4.1 Misarticulation of Speech Sounds

Misarticulation of speech sounds was investigated on three tasks : on a picture word articulation test in Kannada, on a reading of an all-phoneme passage and in spontaneous speech. Separate analysis of misarticulation was made for word-initial and word-medial position in PWAT and in the reading task, but not in spontaneous speech. Nature of articulatory errors were analysed in terms of substitution, omission, addition and distortion errors, but we did not come across any addition type errors.

		(A)	(B)	(C)	(D)	(E)	(F)	(G)	F.R	F.P
Hypo-(l)	M	24.8	33.2	27.5	16.5	37.5	16.0	4.13	0.99	NS
kinetic	SD	3.59	5.32	3.12	7.64	4.42	13.1	1.67		
Hyper-(2)	M	24.8	26.1	29.1	22.9	26.0	24.0	8.31	0.84	NS
kinetic	SD	5.76	5.07	3.05	7.99	9.88	10.0	1.96		
t-score		2.87	6.80	4.02	2.13	2.88	7.75	1.03		
t-prob.		NS	0.05	0.05	NS	NS	0.05	NS		

Subgroups of Hyperkinetic dysarthria

		(A)	(B)	(C)	(D)	(E)	(F)	(G)	F.R	F.P
Chorea (1)	M	33.0	13.2	10.0	0.0	0.0	15.7	0.0	9.98	0.05[A]
	SD	0.0	6.19	7.55	0.0	0.0	3.50	0.0		
EVT(2)	M	8.25	33.2	12.5	0.0	0.0	46.7	25.0	3.23	0.05[B]
	SD	6.50	7.35	9.86	0.0	0.0	21.5	13.2		
Dystonia(3)	M	41.5	41.7	68.7	75.0	83.2	25.0	8.25	3.06	0.05[c]
	SD	9.99	3.87	37.5	32.0	33.5	21.3	9.61		
Dyskinesia(4)	M	16.5	16.5	25.0	16.7	20.7	8.75	0.0	0.66	NS
	SD	9.05	9.05	20.4	13.5	14.9	8.81	0.0		
F. Ratio		1.53	1.23	5.49	9.44	14.2	4.78	1.71		
F. Prob.		NS	NS	0.05	0.05	0.05	0.05	NS		
Post hoc - Groups				1&3	1&3	1&3	2&4			
				2&3	2&3	2&3	1&2			
				3&4	3&4	3&4				

A: A&D, A&E, A&G, A&C, A&B, A&F

B : D&F, E&F   C : E&G

Table 3.26 : Mean (M) percentage of misarticulations and standard deviations (SD) on different group of sounds in the word-initial po-

sition on the picture word articulation test, t-scores were computed for the significance of difference between the main groups and 1-way ANOVA was run for the significance of difference of means between the subgroups of hyperkinetic dysarthrias as well as between the groups of sounds within each group. Degrees of freedom = Main group - between different groups of sounds in each group : 6,49; Subgroups analysis - between different groups of sounds in each group = 6,21; between group comparisons = 3,12. Sounds considered were bilabials (A), linguodentals (B), alveolars (C), palatals (D), velars (E), vowels (F) and nasals (G).

		(A)	(B)	(C)	(D)	(E)	(F)	(G)	F.R	F.P
Hypo-(l)	M	8.25	25.0	25.0	45.8	31.2	27.0	29.1	0.99	NS
kinetic	SD	5.28	9.66	5.63	15.4	15.8	19.7	17.5		
Hyper-(2)	M	10.4	22.8	28.4	34.5	23.9	32.5	10.3	1.71	NS
kinetic	SD	3.56	15.9	11.3	13.5	20.3	20.3	15.7		
t-score		1.07	2.39	4.26	6.66	2.05	11.8	4.36		
t-prob.		NS	NS	0.05	0.05	NS	0.05	0.05		
Subgroups of (2)										
Chorea (1)	M	0.0	0.0	5.0	33.2	0.0	25.5	0.0	5.22	0.05[A]
	SD	0.0	0.0	5.0	17.3	0.0	15.0	0.0		
EVT(2)	M	0.0	8.25	20.0	21.5	8.25	54.2	16.5	3.89	0.05[B]
	SD	0.0	6.5	18.2	15.8	6.5	16.2	9.01		
Dystonia(3)	M	33.5	66.5	63.7	75.0	75.0	37.5	8.25	2.22	NS
	SD	18.6	38.6	33.0	32.0	50.0	15.8	6.25		
Dyskinesia(4)	M	8.25	16.7	25.0	8.25	12.5	12.7	16.5	0.58	NS
	SD	6.5	13.5	20.4	6.51	10.5	8.5	9.05		

F. Ratio	2.27	4.94	4.16	5.82	5.58	6.14	1.00
F. Prob.	NS	0.05	0.05	0.05	0.05	0.05	NS
Post hoc - Groups		1&3	1&3	2&3	1&3	2&4	
		2&3		1&3	2&3	1&2	
		3&4		3&4	3&4		

A : A&D, B&D, D&E, D&G, C&D

B : F&A, B, C, **D,** E, G

Table 3.27 : Mean (M) percentage of misarticulations and standard deviations (SD) on different group of sounds in the word-medial position on the picture word articulation test, t-scores were computed for the significance of difference between the main groups and 1-way ANOVA was run for the significance of difference of means between the subgroups of hyperkinetic dysarthrias as well as between the groups of sounds within each group. Degrees of freedom = Main group - between different groups of sounds in each group : 6,49; Subgroups analysis - between different groups of sounds in each group = 6,21; between group comparisons = 3,12. Sounds considered were bilabials (A), linguodentals (B), alveolars (C), palatals (D), velars (E), vowels (F) and nasals (G).

3.4.1.1 Picture Word Articulation Test (PWAT)

Mean percentage of misarticulations on different groups of sounds and the results of analysis of ANOVA for the significance of difference in means are given in Table 3.26 and 3.27, for the PWAT, on word-initial and word-medial positions, respectively. Normal subjects had no misarticulatory errors (0 %) and hence their scores arc not shown. The results can be summarized as follows :

i) Word-Initial Position

a) Both the hypokinetic and the hyperkinetic dysarthrics misarticulated on all types of sounds and there was no significant difference in the mean articulatory errors on different groups of sound for either group.

b) The hyperkinetic dysarthrics misarticulated more on alvcolars and vowels than the hypokinetic dysarthrics, while the hypokinetic dysarthrics misarticulated more on linguodentals than the hyperkinetic dysarthrics, the difference in means being significant at 0.05 level.

c) Among the subgroups of hyperkinetic dysarthrias, the chorea group misarticulated more on bilabials than any other group of sounds; the EVT group misarticulated more on vowels than on other sounds; and the dystonic dysarthric group misarticulated most on alveolar, palatal and velar group of sounds. There was no significant difference in the mean percentage of articulation on different groups of sounds for the dyskinetic group.

d) As far as between-group differences were concerned, there was no significant difference between the four subgroups of hyperkinetic dysarthria on bilabial, linguodental, and nasal sounds; on alveolars, palatals and velars, the dystonia group had the highest misarticulatory errors in comparison with the other dysarthria groups; on vowels, the EVT group had significantly higher percentage of misarticulation than the other three hyperkinetic groups.

ii) Word-Medial Position

a) The results of analysis of variance on the mean percentage of misarticulation on different sounds in the word-medial position yielded results which were similar to those on word-initial sounds. There was no significant difference in the mean articulation scores on different sounds in either hypo- or hyperkinetic dysarthric groups.

b) Between-group differences showed that the hypokinetic dysarthrics misarticulated more on palatals and nasals than the hyperkinetic groups, while the hyperkinetic group misarticulated more on alveolars and vowels compared to the hypokinetic dysarthric group.

c) Among the subgroups of hyperkinetic dysarthrias, the chorea group misarticulated more on palatals than on other sounds; the EVT group misarticulated more on vowels than on other sounds. There was no significant difference in the mean articulatory errors on different groups of sounds for the dystonic and the dyskinetic groups.

d) Linguodentals, alveolars, palatals and velars were misarticulated significantly higher by the dystonic group while vowels were significantly affected in the EVT group.

Figure 3.3 is a visual illustration of the mean percentage of articulatory errors on the PWAT for word-initial and word-medial errors combined. Note the high and low percentage of articulatory errors in the dystoniaand the dyskinetic groups, respectively. In both these groups, the lingual system was the focus of involvement.

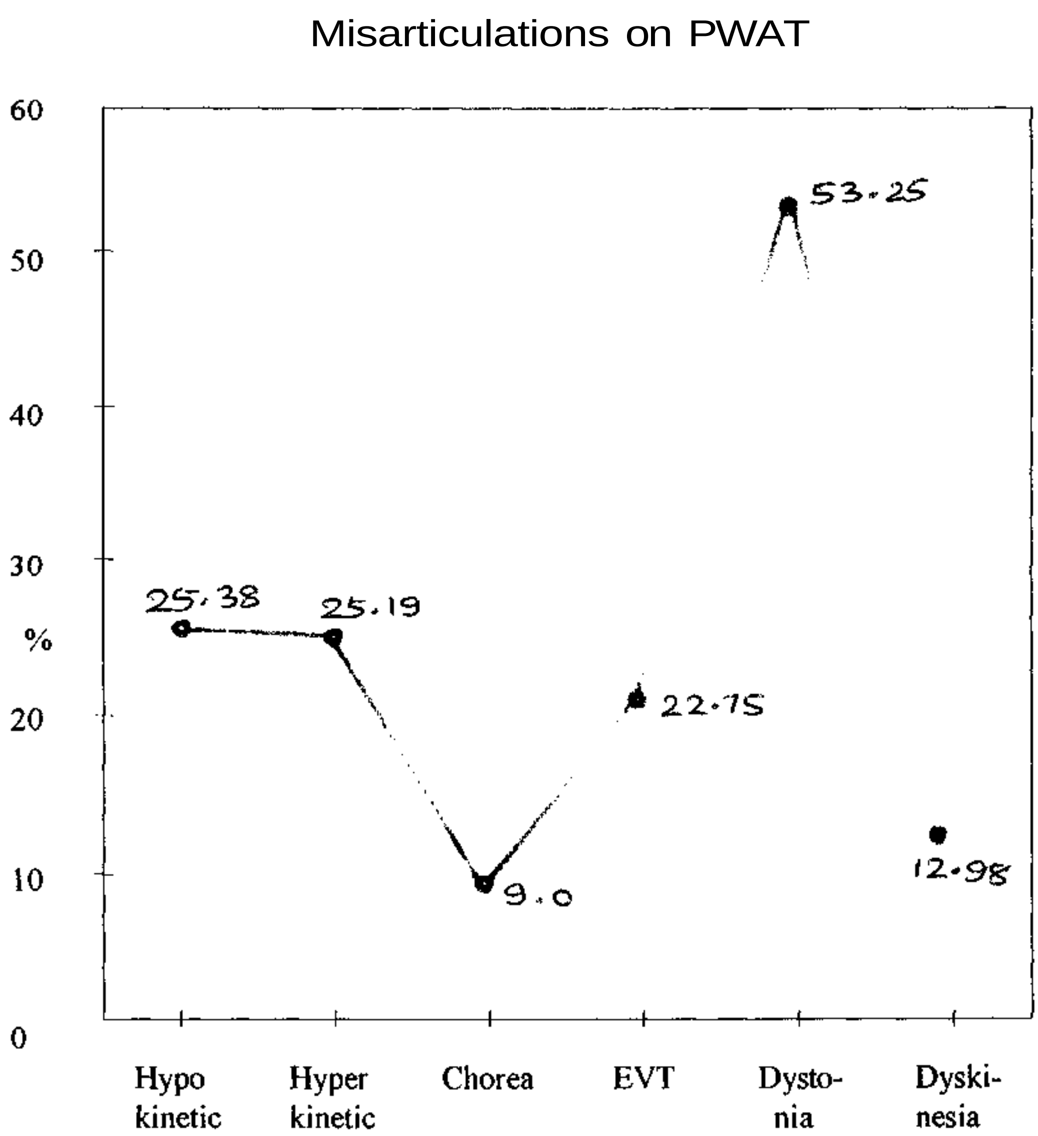


Figure 3.3 : Graphic illustration of the mean percentage of misarticulations on the picture word articulation test (PWAT) in different dysarthric groups.

		(A)	(B)	(C)	(D)	(E)	(F)	(G)
Hypokinetic(l)	M	11.0	2.7	24.7	4.1	9.7	0.0	0.0
	SD	9.9	1.7	4.0	1.6	3.5	0.0	0.0
Hyperkinetic (2)	M	9.5	6.8	27.7	21.0	19.8	40.8	5.1
	SD	4.5	2.8	2.7	8.9	4.1	3.8	2.4
t-scorc		0.26	0.36	0.24	1.57	0.80	0.05	1.2
t-prob.		NS	NS	NS	NS	NS	NS	NS
Subgroups of (2)								
Chorea (1)	M	12.5	0.0	4.0	11.5	0.0	46.0	7.7
	SD	4.64	0.0	2.0	3.2	0.0	4.9	2.2
EVT(2)	M	3.0	11.5	10.5	20.5	13.5	85.2	4.7
	SD	2.1	3.01	2.1	7.06	7.01	6.7	2.9
Dystonia(3)	M	19.2	15.7	55.2	52.0	60.5	32.2	0.0
	SD	2.6	3.1	3.7	3.7	4.3	4.3	0.0
Dyskinesia(4)	M	3.2	0.0	41.2	0.0	5.5	0.0	8.2
	SD	2.5	0.0	3.2	0.0	1.1	0.0	5.2
F. Ratio		1.22	0.68	3.24	3.61	4.39	25.1	0.3
F. Prob		NS	NS	0.05	0.05	0.05	0.05*	NS
Post hoc - Groups				3&1	4&3	1&3		
				3&2		4&3		
				4&1		2&3		

* : 4&3, 4&1, 4&2, 3&1, 3&2, 1&2

Table 3.28 : Mean (M) percentage of misarticulations and standard deviations (SD) on different group of sounds in the word-initial position on the reading of the all-phoneme passage. t-scores were computed for the significance of difference between the main groups and 1-way ANOVA was run for the significance of difference of means between the subgroups of hyperkinetic dysarthrias as well as between the groups of sounds within each group. Degrees of freedom for the subgroup analysis = 3,12. Speech sounds considered were bilabials (A), linguodentals (B), alveolars (C), palatals (D), velars (E), vowels (F) and nasals (G).

		(A)	(B)	(C)	(D)	(E)	(F)	(G)
Hypokinetic (1)	M	2.25	1.5	23.1	5.4	17.6	0.0	0.0
	SD	1.61	1.2	13.7	2.5	1.6	0.0	0.0
Hyperkinetic (2)	M	5.0	5.6	33.6	23.3	19.6	34.4	3.3
	SD	3.9	2.7	8.2	9.1	3.7	3.4	1.6
t-score		0.54	0.66	0.99	1.68	0.16	2.89	1.0
t-prob.		NS	NS	NS	NS	NS	0.05	NS

Subgroups of Hyperkinetic dysarthria

Chorea (1)	M	0.0	0.0	10.0	11.5	0.0	15.7	2.5
	SD	0.0	0.0	3.2	3.0	0.0	2.6	1.2
EVT (2)	M	3.0	5.7	20.0	28.7	13.5	80.2	2.5
	SD	1.2	1.5	7.6	10.5	7.1	9.5	1.2
Dystonia (3)	M	13.7	17.0	65.7	53.0	59.5	33.7	0.0
	SD	7.5	3.4	10.8	8.4	4.6	4.3	0.0
Dyskinesia (4)	M	3.2	0.0	39.0	0.0	5.5	0.0	8.2
	SD	0.5	0.0	3.1	0.0	1.9	0.0	6.5

F. Ratio	0.69	0.79	6.11	4.01	4.28	69.1	0.6
F. Prob	NS	NS	0.05	0.05	0.05	0.05*	NS
Post hoc-Groups			3&1,2	4&3	3&1,4,2		

* : 4&1,4&3,4&2, 1&3, 1&2, 3&2

Table 3.29 : Mean (M) percentage of misarticulations and standard deviations (SD) on different group of sounds in the word-medial position on the reading of the all-phoneme passage, t-scores were computed for the significance of difference between the main groups and 1-way ANOVA was run for the significance of difference of means between the subgroups of hyperkinetic dysarthrias as well as between the groups of sounds within each group. Degrees of freedom for the subgroup analysis = 3,12. Sounds considered were bilabials (A), linguodentals (B), alveolars (C), palatals (D), velars (E), vowels (F) and nasals (G).

3.4.1.2 **All-phoneme** passage

Mean percentage of articulatory errors, on different groups of sounds in the reading of an all-phoneme passage are given in Tables 3.28 and 3.29 for the word-initial and word-medial sounds, respectively. These results can be summarized as follows :

i) **Word-Initial**

a) There was no significant difference in the mean articulatory errors between the hypokinetic and the hyperkinetic dysarthric groups with respect to any group of sounds. However, outside statistical significance, the hyperkinetic dysarthrics showed higher percentage of misarticulation on all sounds than did the hypokinetic group.

b) There was higher percentage of misarticulation in the reading of the dystonia group, compared to the other subgroups of hyperkinetic dysarthria, on all sounds except vowels, but the difference was statistically significant only in respect of palatal and vowel sounds. The EVT group misarticulated significantly higher on vowels than the other three subgroups of hyperkinetic dysarthria.

ii) Word-medial

a) The results on misarticulatory errors in the word-medial position appeared to be similar to those in the word-initial position. There was no significant difference in the mean percentage of articulatory errors between the main groups of dysarthria on any group of sounds.

b) Like in the word-initial position, the dystonia group misarticulated significantly higher on alveolars, palatals and velars in comparison . to the other three subgroups while the EVT group misarticulated higher on vowels than the other subgroups of hyperkinetic dysarthria.

3.4.1.3 Spontaneous Speech

The results on misarticulation of speech sounds in spontaneous speech are given in Table 3.30. Results can be summarized as follows.

a) The hyperkinetic group evidenced a higher percentage of misarticulatory errors than the hypokinetic dysarthric group, but the difference was not statistically significant.

b) Among the subgroups of hyperkinetic dysarthria, the dystonia group had significantly higher mean percentage of misarticulations than the other three subgroups.

Group	M	SD	Group	M	SD
Hypokinetic (2)	35.65	12.34	Subgroups of (3)		
Hyperkinetic (3)	44.95	16.27	Chorea (1)	22.25	11.61
			EVT (2)	39.60	17.28
			Dystonia (3)	85.75	36.76
			Dyskinesia (4)	32.22	16.53
t-score	2.01		F. Ratio	6.54	
t-prob	NS		F. Prob	0.05	
			Post-hoc	1&2.1&3	
				2&3,3&4	

Table 3.30 : Mean (M) percentage of misarticulations and standard deviations (SD) in spontaneous speech, and the results of t-score (between the main groups) and 1-way ANOVA for the significance of difference in means (between the subgroups, df = 3,12).

3.4.1.4 Types of Mis articulation

The type of misarticulatory errors and the nature of sounds misarticulated by the hypo- and the hyperkinetic dysarthric groups in the word-initial and word-medial positions was analysed and the results are given in Table 3.31. Nature of misarticulations was analysed in terms of substitution, distortion and omissions and as there was only one type of error on some of the sounds, the data were not subjected to statistical tests. The results in Table 3.31 from the picture word articulation test, can be summarized as follows :

A prominent result was that misarticulatory errors were predominantly distortion type errors although a substantial percentage of substitution errors also occurred. The exceptions were : articulatory errors on alveolars (hyperkinetic group) and on velars (hypokinetic group) were not of substitution type.

3.4.1.5 Consistency of Misarticulations

Table 3.32 touches upon the aspect of consistency of misarticulation. It may be recalled that in the all-phoneme passage, each of the consonants of the language occurred at least 3 times in the word-initial position. Number of times each sound is misarticulated is a measure of the consistency of misarticulation (refer to section 2.5.2.1).

No strict criteria are available, or have been developed here, to measure consistency or inconsistency of misarticulation. However, if we have to adopt a criterion of 50% to characterize misarticulation consistency (a given sound should be misarticulated 50% of the time, or more, that it occurs for it to be characterized as consistently misarticulated), then the hyperkinetic dysarthrics seem to be more consistent than the hypokinetic dysarthrics in their misarticulations. Hyperkinetic dysarthrics seemed to be consistent in their misarticulation of linguodental, velar and vowel sounds and came nearer to consistency level stipumedial positions was analysed and the results are given in Table 3.31. Nature of misarticulations was analysed in terms of substitution, distortion and omissions and as there was only one type of error on some of the sounds, the data were not subjected to statistical tests. The results in Table 3.31 from the picture word articulation test, can be summarized as follows :

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Sounds	Type	Hypokinetic		Hyperkinetic	
		Initial	Medial	Initial	Medial
Bilabial	Substitution	33.33	0.00	50.82	0.00
(p, b)	Omission	33.33	0.00	19.67	0.00
	Distortion	33.33	0.00	29.51	100.00
(m)	Distortion	100.00	100.00	100.00	100.00
	Substitution	28.74	0.00	19.35	0.00
(th, dh)	Omission	0.00	0.00	19.35	0.00
	Distortion	71.26	100.00	61.29	100.00
(n)	Distortion	100.00	100.00	100.00	100.00
Alveolar	Substitution	62.00	65.50	0.00	0.00
(s, sh)	Omission	0.00	0.00	18.00	28.00
	Distortion	38.00	34.50	82.00	72.00
(r, 1)	Substitution	21.00	33.00	28.00	55.00
	Distortion	79.00	67.00	72.00	45.00
Retroflex	Substitution	50.00	0.00	16.22	16.22
(t, d, 1)	Omission	0.00	0.00	16.22	0.00
	Distortion	50.00	100.00	67.56	83.78
(n)	Substitution	0.00	0.00	0.00	50.00
	Distortion	0.00	100.00	0.00	50.00

Palatal	Substitution	19.35	16.22	14.00	14.00
(ts, dz)	Omission	0.00	0.00	14.00	14.00
	Distortion	80.65	83.78	72.00	72.00
Velar	Substitution	0.00	0.00	14.00	0.00
(k, g)	Omission	0.00	0.00	14.00	16.22
	Distortion	100.00	100.00	72.00	83.78
Vowels	Substitution	25.00	37.00	11.43	13.10
	Distortion	75.00	63.00	88.57	69.90

Table 3.31 : Mean percentage of misarticulations and the nature of misarticulations on different groups of sounds in the picture word oysarticulation test. No statistical analysis has been made.

Group	Bil.	Linguo-dentals	Alveo-lars	Pala-tals	Velars	Vowel	Nasals
Hypokinctic	12	17	24	38	37		
Hyperkinetic	26	50	49	47	63	50	23
Subgroups of Hyperkinetic dysarthria							
Chorea	20	-	19	46	--	81	21
EVT	12	35	25	28	54	83	15
Dystonia	44	66	68	66	80	28	
Dyskinesia	13	--	53	--	22	--	33

Table 3.32 : Mean percentage of misarticulations on bilabials (Bil), Hnguodcntals, alveolars (alv), palatals (pal), velars, vowels and na-

sals on reading of the all-phoneme passage. No test for statistical significance was run.

Among the subgroups of hyperkinetic dysarthrias, the dystonics generally seemed to be more consistent in their misarticulations compared to the other three groups. The dystonics misarticulated, more than 50% of the time, on linguodentals, alveolars, palatals and velars and came nearer to this level on bilabials. Patients with chorea and EVT were consistent in their misarticulations on only vowels while the dyskinetic group was consistent in their misarticulation of alveolars. However, whether these mean percentages of misarticulation (as far as consistency of misarticulations was concerned) was significantly different between the groups, was not tested. According to the criterion used here, consistency of misarticulation on more number of sounds means higher severity of the problem, or lower severity, depending on how one interprets.

3.4.2 Diadochokinesis

3.4.2.1 Dindochokinetic Rate

Repetition tasks of syllables were analysed in respect of 10 monosyllabic, 7 bisyllabic and 8 trisyllabic sequences. DDK rate was measured for all the sequences. Mean and standard deviations of monosyllabic repetitions and results of analysis of variance for the significance of difference in means are summarized in Table 3.33, both for the main and subgroup comparisons. The results are summarized below :

a) Repetition rate of syllables involving stop consonants and /ja/ were all significantly different between the groups. The performance of both the dysarthric groups were depressed compared to that of normals, but there was no significant difference between the hypokinetic and the hyperkinetic groups themselves although the repetition rate was less in the case of hyperkinetic dysarthrias. There was no significant difference between the groups with respect to the rate of repetition of vowels.

b) Within each group, there was significant difference between the repetition rate of vowels on the one hand and the repetition of stop consonants on the other hand. The repetition rate for vowels was significantly different from that of consonants in each group.

c) The subgroup analysis showed that

i) There was a significant difference in the mean repetition of different monosyllables in the chorea and the dyskinesia groups. Vowel repetitions, in both these groups, were less than that of bilabial /pa/ and retroflex /ta/ and the difference was significant at 0.05 level.

ii) There was no significant difference in the mean repetition rate of any monosyllable between the four subgroups. However, outside statistical significance, the repetition rate of all monosyllables in the dystonia group were less than those of the three other groups.

d) Analysis of repetition rates for different sounds in each subgroup showed significant difference in the repetition rate of syllables for the chorea and the dyskinesia groups. In both the groups, there was a significant difference between the repetition rate of vowels and consonants.

		/pa/ (1)	/ta/ (2)	/ka/ (3)	/ba/ (4)	/da/ (5)	/ga/ (6)	/ja/ (7)	/a/ (8)	/i/ (9)	/u/ (10)	F.R	F.P
Normal (1)	M	5.84	5.99	5.53	5.68	5.70	5.30	5.29	3.84	3.37	3.15	18.07	0.05[A]
	SD	0.85	0.88	0.84	0.72	1.03	0.94	0.94	0.60	0.55	0.78		
Hypo- (2)	M	4.88	4.51	4.27	4.51	4.10	3.94	3.91	3.22	3.41	2.94	2.25	0.05[B]
kinetic	SD	1.21	1.12	0.89	1.11	0.99	0.97	1.00	0.73	0.77	0.66		
Hyper - (3)	M	4.44	4.11	4.01	3.99	3.67	3.86	3.79	3.59	3.42	2.87	4.64	0.05[C]
kinetic	SD	1.30	1.12	1.08	0.90	1.15	1.05	1.00	0.95	0.98	0.75		
F. Ratio		4.41	9.94	7.73	10.62	11.03	7.09	7.84	2.80	2.19	2.54		
F. Prob.		0.05	0.05	0.05	0.05	0.05	0.05	0.05	NS	NS	NS		
Post hoc		3&1	3&1	3&1	3&1	3&1	3&1	3&1					
		2&1	2&1	2&1	2&1	2&1	2&1	2&1					
Sub-groups of (3)													
Chorea (1)	M	4.73	4.62	3.40	4.25	3.39	3.77	3.66	2.47	2.60	2.69	3.55	0.05[D]

	SD	1.27	0.79	0.70	0.49	1.04	0.90	0.77	0.81	0.47	1.01		
EVT (2)	M	4.16	3.85	4.06	4.09	3.95	4.07	3.69	2.75	3.16	2.95	1.87	NS
	SD	0.93	0.57	0.60	0.71	0.71	0.71	1.09	0.84	0.79	0.68		
Dystonia (3)	M	4.11	3.32	3.04	3.32	2.94	3.04	3.34	2.28	2.76	3.02	0.43	NS
	SD	2.17	1.79	1.82	1.45	1.72	1.32	1.13	0.30	0.72	0.95		
Dyskinesia (4)	M	4.75	4.84	4.60	4.29	4.41	4.58	4.49	3.42	3.34	2.89	2.73	0.05[E]
	SD	0.89	0.96	0.85	0.68	0.71	0.95	1.01	0.99	0.64	0.31		
F. Ratio		0.24	1.42	0.69	0.99	1.30	1.66	2.80	0.59	0.68	2.24		
F. Prob.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		

A 8&1, 8&2, 8&3, 8&4, 8&5, 8&6, 8&7:
9&1, 9&2, 9&3, 9&4, 9&5, 9&6, 9&7
10&1, 10&2, 10&3, 10&4, 10&5, 10&6, 10&7

B 8&1, 8&2, 8&3, 8&4, 8&5, 8&6, 8&7:
9&1, 9&2, 9&3, 9&4, 9&5, 9&6, 9&7
10&1, 2, 3, 4, 5, 6, 7

C 10&5, 10&1, 10&2; 9&1, 9&2, 9&4; 8&1, 8&2, 8&4

D 8&1, 8&2; 9&1, 9&2; 10&1, 10&2

E 10&1, 10&2, 10&3; 9&1, 9&2

Table 3.33 : Means (M) and standard deviations (SD) of rate of repetition of monosyllables (syllables/second) and the results of ANOVA for the significance of difference between means. Comparisons have been made between sounds within each group and between groups for each syllable. Degrees of freedom - between syllables within each group = 9,90 (normals), 9,70 (hypokinetic) and 9,150 (hyperkinetic); between groups for each syllable = 2,31. Subgroup analysis - between syllables within each grouup = 9,30; between subgroups for each syllable = 3,12.

		/a-i/	/i-u/	/u-a/
Normal (1)	M	3.53	3.44	3.49
	SD	0.53	0.49	0.53
Hypokinetic (2)	M	4.38	3.91	3.74
	SD	1.71	0.89	1.36
Hyperkinetic(3)	M	3.01	3.03	2.96
	SD	0.55	0.66	0.40
F. Ratio		4.54	4.54	2.39
F.Prob.		0.05	0.05	NS
Post hoc - Groups		3&2	3&2	

Subgroups of (3)

		/a-i/	/i-u/	/u-a/
Chorea (1)	M	2.93	2.93	2.73
	SD	0.46	0.30	0.57
EVT(2)	M	3.10	2.85	2.85
	SD	0.38	0.10	0.10
Dystonia(3)	M	2.30	2.60	2.95
	SD	0.42	0.69	0.42
Dyskinesia(4)	M	3.60	3.30	3.10
	SD	0.69	0.62	0.38
F. Ratio		2.76	1.28	0.57
F. Prob.		NS	NS	NS

Table 3.34 : Means (M) and standard deviations (SD) of rate of repetition of bisyllables (units/second - vowels) and the results of ANOVA for the significance of difference between means. Degrees of freedom - difference between the main groups = 2,3 1 and for subgroup analysis = 3,12.

		/pata/	/paka/	/bada/	/baga/	/pataka/	/badaga/
Normal (1)	M	7.11	8.01	9.00	7.57	8.41	7.74
	SD	3.58	1.80	0.96	1.44	1.33	1.35
Hypokinetic (2)	M	6.58	6.43	6.55	6.22	7.21	6.94
	SD	1.47	1.30	1.64	1.22	1.57	1.59
Hyperkinetic(3)	M	5.61	4.76	5.33	5.28	4.75	5.86
	SD	1.91	1.43	1.37	1.46	1.23	1.72
F. Ratio		1.09	14.27	24.28	8.2	12.27	4.41
F. Prob.		NS	0.05	0.05	0.05	0.05	0.05
Post hoc - Groups			3&2	3&2	3&1	3&2	3&1
			3&1	3&1		3&1	
			2&1	2&1			

Subgroups of (3)

Chorea (1)	M	7.26	5.40	6.20	6.10	5.86	6.70
	SD	0.83	0.60	0.70	0.14	0.23	0.14
EVT (2)	M	4.90	5.30	5.50	5.60	3.75	5.90
	SD	1.89	1.11	1.22	1.65	1.49	1.27
Dystonia (3)	M	5.00	3.06	4.15	6.62	6.40	6.20
	SD	2.77	1.22	1.12	0.42	3.95	1.67
Dyskinesia (4)	M	5.86	5.53	5.33	5.86	6.06	5.90
	SD	1.54	1.27	1.27	0.08	1.54	0.92
F. Ratio		1.13	3.56	0.85	0.19	0.06	0.11
F. Prob.		NS	0.05	NS	NS	NS	NS
Post hoc - Groups			3&2				
			3&1				
			3&4				

Table 3.35 . Means (M) and standard deviations (SD) of rate of repetition of bisyllables (units/second) and trisyllables (with the same vowels) and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,3 1 and for subgroup analysis = 3,12.

		/pipapu/	/titatu/	/kikaku/	/bibabu/	/didadu/	/gigagu/
Normal (1)	M	5.19	4.79	4.65	5.37	5.34	4.57
	SD	0.86	0.35	0.37	0.31	0.29	0.44
Hypokinetic (2)	M	4.41	4.14	4.18	9.34	4.36	3.92
	SD	0.96	1.09	0.87	0.75	0.98	0.90
Hyperkinetic(3)	M	3.42	3.42	3.32	3.70	3.77	3.32
	SD	0.87	1.04	1.15	1.00	1.45	1.04
F. Ratio		12.38	7.04	6.91	13.04	5.95	6.27
F. Prob.		0.05	0.05	0.05	0.05	0.05	0.05
Post hoc - Groups		3&2, 3&1	3&1,	3&2, 3&1	3&1, 2&1, 3&2	3&1,	3&1,
Subgroups of (3)							
Chorea(l)	M	3.20	3.42	3.16	3.52	3.45	3.47
	SD	0.14	0.42	0.32	0.46	1.26	1.45
EVT (2)	M	3.42	3.58	3.47	3.44	3.96	3.53
	SD	0.31	0.49	0.46	0.26	1.43	0.42
Dystonia(3)	M	3.56	3.72	3.82	3.94	3.96	3.75
	SD	0.46	0.46	0.56	0.54	1.46	0.56
Dyskincsia(4)	M	3.85	3.92	3.94	3.99	3.99	3.92
	SD	0.36	0.12	0.26	0.26	1.24	0.95

F. Ratio	0.42	0.56	2.46	1.45	1.53	2.64
F. Prob.	NS	NS	NS	NS	NS	NS

Table 3.36 : Means (M) and standard deviations (SD) of rate of repetition of trisyllables (units/second - with different vowels) and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

The results of the analysis of DDK rate for bisyllabic vowel sequences are given in Table 3.34. The results can be summarized as follows :

a) The mean repetition rates for /a-i/ and /i-u/ sequences were significantly different between the hypokinctic and the hyperkinetic groups. The hypokinetic group had higher rates. There was no significant difference between the groups for the /u-a/ sequence.

b) There was no significant difference between the subgroups of hyperkinetic dysarthrias in the mean repetition rate of any vowel sequence. However, a visual inspection indicated that the rates were higher in the case of dyskinetic group while they were lower in the case of dystonia group, for all vowel sequences.

The results of the analysis of DDK rate for bisyllablcs with stop consonants are given in Table 3.35. Here, the rate reflects the repetition of each sequence like /pata/ as a whole and not that of individual syllables in each sequence.

The results can be summarized as follows :

a) The mean rate of repetition of /paka/ /bada/ and /baga/ was significantly different between the groups with the normals having the highest rate followed by hypokinetic and hyperkinetic dysarthrics, in that order. However, on the /baga/ sequence, only the difference between the hyperkinetic dysarthrics and the normals was statistically significant.

b) Analysis of subgroups showed that only the repetition rate in respect of /paka/ sequence was significantly different between the subgroups with the dystonia group having the lowest repetition rate on this sequence. None of the other differences in mean rates, for any sequence, was statistically significant between the subgroups.

The mean rates of repetition of the trisyllabic sequences and the results of ANOVA are shown in Table 3.36. Part of the results on trisyllables (/pa-ta-ka/ and /ba-da-ga/) are given in Table 3.35 also. The results can be summarized as follows :

a) The mean rate of repetition of all trisyllabic sequences was significantly different between the groups with the normals having the highest rate followed by hypokinetic and hyperkinetic groups in that order. This was true even in respect of those trisyllable sequences for which the differences in mean rate was not significantly different between the hypokinetic and the hyperkinetic dysarthric groups.

b) The normal and the hypokinetic dysarthric groups were significantly different only with respect to the mean rate of repetition of /bi-ba-bu/ sequence with the hypokinetic group showing an higher rate than the normals.

c) None of the differences in the mean rate of repetitions of the syllables was significantly different between the 4 subgroups of hyperkinetic dysarthria. However, a visual inspection showed that the rate for the EVT group was slightly suppressed, especially for the /pa-ta-ka/ and the /badaga/ sequences.

d) Although statistically not compared, the rates for the trisyllables with the same consonant but different vowels (for example: /pi-pa-pu/) was depressed compared to the rate of repetition of trisyllables with the same vowel but different consonant (for example: /pa-ta-ka/). This was true for the normal speakers also, and hence may not be clinically significant.

3.4.2.2 DDK-Syllabic Duration

Results of the analysis of syllable duration of DDK repetitions are given in Table 3.37. As said earlier, syllable duration was measured only in respect of monosyllabic repetitions. The results can be summarized as follows .

a) Within group analysis showed that the mean duration of different syllables were significantly different in the case of normal speakers, but not significantly different in the case of hypo- and hyperkinetic dysarthric groups. Generally, the duration of syllables with voiced consonants were longer than those involving voiceless consonants, irrespective of statistical significance.

b) Between the group analysis showed that none of the differences in syllable duration, for any syllabic, was significantly different between the groups. However, the syllabic duration was longer in the hyperkinetic group compared to the hypokinetic group which in turn had longer duration than the normals, but the difference was not statistically significant.

c) Subgroup analysis showed that the differences in syllable duration were statistically significant between the subgroups only with respect to /ta/ and /ga/ syllables. In both these, the syllabic durations in the case of dystonia group were significantly longer than in the other groups.

		/pa/ (1)	/ta/ (2)	/ka/ (3)	/ba/ (4)	/da/ (5)	/ga/ (6)	/ja/ (7)	F.R	F.P
Normal (1)	M	112.4	118.2	138.2	135.6	143.1	158.5	45.7	6.74	0.05[A]
	SD	48.8	18.8	16.1	16.6	18.2	22.7	20.9		
Hypokinetic (2)	M	141.8	165.2	169.7	162.7	198.3	198.4	185.8	2.06	NS
	SD	18.2	21.2	29.3	39.1	48.3	68.9	30.7		
Hyperkinetic(3)	M	157.0	144.2	182.7	187.9	218.2	204.2	208.9	1.17	NS
	SD	61.8	108.3	66.7	87.7	101.3	73.0	75.6		
F. Ratio		2.85	0.9	0.5	3.0	3.1	1.7	3.5		
F. Prob.		NS	NS	NS	NS	NS	NS	NS		
Subgroups of (3)										
Chorea (1)	M	148.0	152.0	212.0	163.0	242.0	217.0	203.0		
	SD	38.3	23.3	86.0	53.9	107.4	95.0	75.1		
EVT (2)	M	162.0	137.0	167.0	179.9	194.0	189.6	230.0		

	SD	25.3	17.0	27.4	42.3	48.1	55.4	78.4
Dys(onia(3)	M	186.0	236.0	197.2	241.0	266.0	227.0	234.0
	SD	117.0	126.6	102.4	161.2	166.7	106.2	110.3
Dyskincsia (4)	M	131.0	163.0	153.4	167.0	169.7	182.0	168.0
	SD	33.0	22.4	26.0	49.4	43.4	36.5	30.8
F. Ratio		0.5	9.8	0.6	0.6	0.7	10.3	0.6
F. Prob.		NS	0.05	NS	NS	NS	0.05	NS
Post hoc - Groups			3&1, 3&2, 3&4				3&1, 3&2, 3&4	

A : 1&3, 1&4, 1&5, 1&6, 2&6, 3&6

Table 3.37 : Means (M) and standard deviations (SD) of duration of monosyllabic repetitions (milliseconds/syllable) and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

		/pa/ (1)	/ta/ (2)	/ka/ (3)	/ba/ (4)	/da/ (5)	/ga/ (6)	/ja/ (7)	F.R	F.P
Normal (1)	M	75.1	58.5	62.6	63.3	48.9	51.2	49.0	3.69	0.05A
	SD	11.9	20.2	8.2	12.3	21.2	14.3	20.2		
Hypokinetic(2)	M	88.0	77.4	74.9	74.9	66.5	80.0	89.2	0.76	NS
	SD	14.9	19.1	15.7	11.7	19.3	17.7	33.8		
Hyperkinetic	M	100.9	82.5	107.6	80.4	99.3	78.2	80.8	0.57	NS
	SD	27.4	70.5	69.4	23.1	95.5	76.6	26.3		

F. Ratio		4.3	0.7	2.9	2.0	1.8	0.9	2.4
F.Prob.		0.05	NS	NS	NS	NS	NS	0.05
Post hoc - Groups		1&3						1&3 1&2
Subgroups of (3)								
Chorea (1)	M	88.0	79.0	91.0	63.0	54.0	49.0	73.0
	SD	35.0	17.3	18.7	16.3	27.2	21.6	28.8
EVT(2)	M	115.0	110.0	101.0	91.0	93.0	87.0	98.0
	SD	30.1	2.2	16.6	19.7	26.3	15.7	27.4
Dystonia(3)	M	108.0	140.0	135.0	100.0	181.0	116.8	84.0
	SD	25.6	99.6	104.3	25.0	75.9	57.2	28.7
Dyskincsia(4)	M	91.0	82.0	102.0	66.0	67.0	58.0	66.2
	SD	15.5	18.4	44.6	9.0	9.8	15.0	17.2
F. Ratio		0.9	5.7	0.3	3.7	1.6	0.6	1.1
F. Prob.		NS	0.05	NS	0.05	NS	NS	NS
Post hoc - Groups			2&1, 4&2, 4&3 1&3		2&1 4&2 4&3			

A : Groups 5&1, 7&1, 6&1

Table 3.38 : Means (M) and standard deviations (SD) of duration of gaps between the monosyllabic repetitions (milliseconds) and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis=3,12.

3.4.2.3 DDK - Intersyllabic Gap Duration

The mean intersyllabic gap duration and the results of ANOVA for the significance of difference in means are given in Table 3.38. Again, the intersyllabic gap duration was measured only in respect of monosyllabic repetitions. The results can be summarized as follows :

a) The mean intersyllabic gap durations were significantly different between different syllables for the normal and the dysarthric groups.

b) The mean intersyllabic gap duration was significantly different between the three main groups only with respect to syllables /pa/ and /ja/. The gap durations were significantly longer in the hyperkinetic group compared to normals, for both these syllables, but there was no significant difference between the hypokinetic and the hyperkinetic groups. Generally, the intersyllabic gaps were longer in the hyperkinetic group than the hypokinetic groups which in turn had longer gaps than the normal speakers.

c) The subgroup analysis (between the 4 subgroups of hyperkinetic dysarthrias) showed that the mean intersyllabic gap durations were significantly different between the groups in respect of syllables /ta/ and /ba/. None of the other differences was significant. In general, the intersyllabic gaps were longer in the dystonia group followed by the EVT group.

3.4.2.4 Peak Intensity of DDK Repetition

Results in Table 3.39 on mean peak intensity levels of DDK repetitions and the results of ANOVA can be summarized as follows :

a) Mean peak intensity levels were significantly different between the main groups only in respect of syllable /ga/. Both the hypokinetic and the hyperkinetic dysarthrics had higher peak intensity levels than the normal . speakers. None of the other differences was significant.

b) Mean peak intensity levels were different between the four subgroups of hyperkinetic dysarthrias only for syllable /ta/. None of the other differences was statistically significant.

c) No general trends could be seen either in the main group or in the subgroups analysis except that, generally, the peak intensity levels in the DDK repetitions of the hyperkinetic dysarthria group was higher compared to those of the normals.

		/pa/ (1)	/ta/ (2)	/ka/ (3)	/ba/ (4)	/da/ (5)	/ga/ (6)	/ja/ (7)
Normal (1)	M	43.9	45.3	44.6	44.3	43.9	46.1	42.8
	SD	2.6	2.3	2.2	2.1	1.9	2.8	3.1
Hypokinetic(2)	M	43.6	46.4	47.5	45.7	45.9	47.0	46.2
	SD	4.6	2.2	3.3	2.3	2.8	2.4	3.1
Hyperkinetic(3)	M	45.7	35.1	48.1	48.9	47.0	47.6	46.3
	SD	5.4	21.3	5.2	7.15	4.0	3.9	5.1
F. Ratio		0.9	2.2	2.2	2.6	2.6	5.9	2.9
F. Prob.		NS	NS	NS	NS	NS	0.05	NS
Post hoc - Groups							1 &2, 1&3	

Subgroups of (3)

Chorea (1)	M	43.3	45.4	45.7	46.0	48.9	46.1	45.3
	SD	7.6	6.7	5.5	5.2	4.4	2.8	5.2
EVT(2)	M	45.3	47.8	47.0	47.0	46.6	48.2	43.2
	SD	5.7	4.7	5.1	4.6	4.8	4.2	6.5
Dystonia(3)	M	45.0	46.9	48.2	54.0	45.1	46.3	47.6
	SD	3.5	3.2	3.7	11.3	5.4	4.7	5.8
Dyskinesia(4)	M	49.3	47.2	51.2	47.0	47.4	49.7	49.2
	SD	4.2	5.3	6.6	4.5	0.9	3.8	1.0
F. Ratio		0.8	10.7	0.7	1.2	0.5	0.7	1.0
F. Prob.		NS	0.05	NS	NS	NS	NS	NS'
Post hoc - Groups			1&2,3,4					

Table 3.39 : Means (M) and standard deviations (SD) of peak intensity levels of monosyllabic repetitions (dB) and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

		/pa/ (1)	/ta/ (2)	/ka/ (3)	/ba/ (4)	/da/ (5)	/ga/ (6)	/ja/ (7)
Normal (1)	M	144.0	147.5	152.0	146.4	142.5	143.7	143.3
	SD	16.0	18.2	22.1	28.4	18.2	17.8	21.1
Hypokinetic(2)	M	174.2	189.3	175.9	170.7	200.2	178.9	186.9
	SD	53.7	62.2	52.5	50.9	85.4	70.3	46.8
Hyperkinetic	M	193.4	159.7	189.0	201.5	197.9	217.7	223.3
	SD	49.8	114.9	62.9	51.4	44.5	64.3	62.2
F. Ratio		3.8	0.5	1.5	3.9	4.1	5.3	7.9

F. Prob.		0.05	NS	NS	0.05	0.05	0.05	0.05
Post hoc-Groups		1&3			1&2 1&3	1&2 1&3	1&2 1&3	1&2 1&3
Subgroups of (3)								
Chorea (1)	M	176.0	185.0	185.0	165.0	183.0	179.0	203.0
	SD	28.3	29.5	33.5	28.0	32.9	23.9	22.3
EVT(2)	M	214.0	239.0	226.0	225.0	177.0	193.0	220.0
	SD	55.2	87.7	48.8	45.0	31.5	33.0	95.9
Dystonia(3)	M	201.0	213.0	205.0	234.0	228.0	296.0	239.0
	SD	65.4	100.0	101.5	69.3	52.7	77.5	69.7
Dyskinesia (4)	M	175.0	195.0	138.0	180.0	202.0	201.0	199.0
	SD	51.0	19.4	17.0	65.5	53.7	49.6	46.8
F. Ratio		0.6	10.1	1.2	1.5	1.1	4.8	0.6
F. Prob.		NS	0.05	NS	NS	NS	NS	NS
Post hoc - Groups			2&1, 4&2,3 2&3					

Table 3.40 : Means (M) and standard deviations (SD) of peak frequency levels of monosyllabic repetitions (Hz) and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

3.4.2.5 Peak Frequency of DDK Repetitions

Mean peak frequency of repetitions of syllables was analysed and the results are given in Table 3.40. The results can be summarized as follows :

a) Peak frequency levels were significantly different between the three main groups with respect to syllables /pa/, /ba/ /da/ /ga/ and /ja/. The mean frequency levels of hypokinctic and hypcrkinetic dysarthria groups were significantly higher than in the repetitions of normals, but there was no statistically significant difference between the hypokinetic and the hyperkinetic groups. However, there was high variability in the frequency values of the hypokinetic and the hyperkinetic groups as reflected in high standard deviations.

b) Mean frequency values were significantly different between the subgroups of hypokinetic dysarthrics only in respect of syllable /ta/. None of the other differences was statistically significant. In general, peak frequency values of DDK repetitions was higher in the EVT group followed by the dysarthria group. Again, there was high variability in the data as reflected in high standard deviations.

		/pa/ (1)	/ta/ (2)	/ka/ (3)	/ba/ (4)	/da/ (5)	/ga/ (6)
Normal (1)	M	4.72	4.94	4.36	4.10	4.45	4.46
	SD	1.14	1.17	0.99	0.60	0.95	0.87
Hypokinetic (2)	M	4.37	4.15	3.80	3.53	3.92	4.06
	SD	1.24	1.14	1.00	0.82	1.07	1.06
Hyperkinetic	M	3.49	3.70	3.72	3.36	3.35	3.41
	SD	1.22	1.33	1.14	0.95	1.07	1.20
F. Ratio		1.91	1.77	1.06	2.13	1.30	1.55

F. Prob. NS NS NS NS NS NS

Subgroups of (3)							
Chorea (1)	M	2.40	2.80	2.93	2.46	2.60	2.70
	SD	1.31	1.40	0.75	0.80	1.41	1.21
EVT(2)	M	4.00	3.93	3.46	3.66	3.73	3.75
	SD	1.41	1.10	1.33	1.17	1.28	1.31
Dystonia(3)	M	3.80	3.20	4.50	3.90	4.20	2.93
	SD	1.69	1.60	1.83	0.42	0.53	2.05
Dyskinesia (4)	M	3.90	4.86	4.26	3.70	3.20	3.22
	SD	0.73	0.61	0.70	0.70	0.69	0.61
F. Ratio		1.15	1.62	1.07	1.97	0.62	0.27
F. Prob.		NS	NS	NS	NS	NS	NS

Table 3.41 : Means (M) and standard deviations (SD) of rate of repetitions of monosyllables (syllables/second) with bite block and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for sub-group analysis = 3,12

3.4.2.6 DDK Rate of Repetitions with Bite Block

Until now, as described in sections 3.4.2.1 to 3.4.2.5, the analysis was in respect of DDK repetitions without bite block. The subjects were asked to repeat the syllables keeping their fore finger in between the two rows of teeth. This was done to eliminate the role of jaw movement in the repetitions. Only the rate of repetitions has been analysed with bite block and the results arc given in Table 3.41. The results showed that none of the differences, either between the main groups, or between the subgroups, was significantly different for any syllable. In general, mean values of the hyperkinetic group were depressed compared to those of the hypokinetic group which in turn was depressed in relation to the normals.

		DDK Rate Syl/Sec	DDK rate in the first 5 Seconds	Repetitions in the first 1 second	Repetitions in the last 1 second
Normal (1)	M	5.84	5.96	6.00	5.80
	SD	0.85	0.96	0.82	1.03
Hypo-	M	4.88	4.90	4.87	4.75
kinetic (2)	SD	1.21	1.28	1.46	1.03
Hyper-	M	4.44	4.58	4.81	4.50
kinetic (3)	SD	1.30	1.28	1.33	1.50
F. Ratio		4.41	4.01	2.15	3.27
F. Prob.		0.05	0.05	NS	0.05
Post hoc		3&1	3&1		3&1
Subgroups of (3)					
Chorea (1)	M	4.73	5.13	4.75	5.25
	SD	1.27	6.02	0.95	1.50
EVT(2)	M	4.16	4.46	4.50	4.00
	SD	0.93	0.50	0.57	1.41
Dystonia(3)	M	4.11	4.25	4.75	4.00
	SD	2.16	2.22	2.36	2.16
Dyskinesia(4)	M	4.75	4.60	5.25	4.75
	SD	0.89	0.76	1.25	0.95
F. Ratio		0.29	0.22	0.19	0.61
F. Prob.		NS	NS	NS	NS

Table 3.42 : Means (M) and standard deviations (SD) of rate of repetitions of different segments of monosyllabic repetitions of syllable /pa/ (syllables/second) without bite block and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

		DDK Rate Syl/Sec	DDK rate in the First 5 Seconds	Repetitions in the first 1 second	Repetitions in the last 1 second
Normal (1)	M	5.99	6.14	6.40	5.90
	SD	0.88	0.01	0.96	0.74
Hypokinetic(2)	M	4.51	4.45	4.62	4.50
	SD	1.12	1.13	1.19	1.19
Hyperkinetic(3)	M	4.11	4.46	3.18	4.25
	SD	1.12	1.51	3.05	1.34
F. Ratio		9.94	6.08	1.16	6.50
F. Prob.		0.05	0.05	NS	0.05
Post hoc		1&2,3	1&2,3	1&2,3	1&2,3
Subgroups of (3)					
Chorea (1)	M	4.61	4.80	4.50	4.75
	SD	0.78	0.75	1.91	1.25
EVT(2)	M	3.85	4.00	4.00	4.00
	SD	0.56	0.30	0.00	0.81
Dystonia(3)	M	3.32	2.93	3.50	3.25
	SD	1.78	2.00	2.78	1.50
Dyskinesia(4)	M	4.66	5.65	4.75	5.00
	SD	0.70	1.27	2.92	1.41

F. Ratio	1.42	2.85	1.25	1.53
F. Prob.	NS	NS	0.05	NS
Post hoc			3&4 2&4,1&4	

Table 3.43 : Means (M) and standard deviations (SD) of rate of repetitions of different segments of monosyllabic repetitions of syllable /ta/ (syllables/second) without bite block and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

		DDK Rate Syl/Scc	DDK rate in the first 5 Seconds	Repetitions in the first 1 second	Repetitions in the last 1 second
Normal (1)	M	5.53	0.56	5.70	5.70
	SD	0.84	0.87	0.94	1.05
Hypokinetic(2)	M	4.27	4.25	4.50	4.00
	SD	0.89	1.12	1.06	1.41
Hyperkinetic(3)	M	4.01	4.05	4.25	3.56
	SD	1.08	1.19	1.29	1.15
F. Ratio		7.73	5.84	5.09	10.21
F. Prob.		0.05	0.05	0.05	0.05
Post hoc		1&2.3	1&2.3	1&2.3	1&2.3
Subgroups of (3)					
Chorea (1)	M	3.40	3.50	4.00	3.25
	SD	0.69	0.98	1.41	1.25
EVT (2)	M	4.06	4.40	4.25	4.25
	SD	0.59	0.34	0.50	1.25

Dystonia(3)	M	4.03	3.73	4.00	3.25
	SD	1.83	2.13	2.16	1.50
Dyskinesia(4)	M	4.54	4.40	4.75	3.50
	SD	0.92	1.03	0.95	0.57
F. Ratio		0.69	0.31	0.32	0.25
F. Prob.		NS	NS	NS	NS

Table 3.44 : Means (M) and standard deviations (SD) of rate of repetitions of different segments of monosyllabic repetitions of syllable /ka/ (syllables/second) without bite block and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,3 1 and for subgroup analysis = 3,12.

		DDK Rate Syl/Sec	DDK rate in the first 5 Seconds	Repetitions in the first 1 second	Repetitions in the last 1 second
Normal (1)	M	5.68	5.64	5.80	6.00
	SD	0.72	0.88	1.35	1.24
Hypokinetic (2)	M	4.51	4.76	4.50	4.50
	SD	1.11	1.09	1.06	1.06
Hyperkinetic (3)	M	3.99	4.06	4.18	3.87
	SD	0.90	1.06	0.98	1.31
F. Ratio		10.68	6.86	7.55	9.09
F. Prob.		0.05	0.05	0.05	0.05
		1&2,3	3&1	1&2,3	1&2,3
Subgroups of (3)					
Chorea (1)	M	4.24	4.26	4.75	3.00
	SD	0.49	0.80	0.95	0.00

EVT(2)	M	4.10	4.05	4.00	4.75
	SD	0.79	0.66	0.00	0.95
Dystonia(3)	M	3.32	3.73	3.75	3.00
	SD	1.44	2.10	1.50	0.90
Dyskinesia(4)	M	4.29	4.20	4.25	4.75
	SD	0.68	0.91	0.95	0.95
F. Ratio		0.99	0.12	0.21	3.62
F. Prob.		NS	NS	NS	0.05
					3&2
					1&2

Table 3.45 : Means (M) and standard deviations (SD) of rate of repetitions of different segments of monosyllabic repetitions of syllable /ba/ (syllables/second) without bite block and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

		DDK Rate Syl/Sec	DDK rate in the first 5 Seconds	Repetitions in the first 1 second	Repetitions in the last 1 second
Normal (1)	M	5.70	5.68	5.70	6.40
	SD	1.03	1.02	1.06	1.43
Hypokinetic (2)	M	4.10	4.22	4.12	3.75
	SD	0.99	1.03	1.24	1.28
Hyperkinetic (3)	M	3.67	4.25	4.06	3.44
	SD	1.15	0.72	1.29	1.31
F. Ratio		11.03	7.94	6.23	16.15
F. Prob.		0.05	0.05	0.05	0.05
Post hoc		1&2,3	1&2,3	1&2,3	1&2,3

Subgroups of (3)

Chorea(l)	M	3.39	4.13	4.25	1.25
	SD	1.03	0.42	1.25	1.00
EVT(2)	M	3.95	3.95	4.00	4.00
	SD	0.71	0.75	0.08	0.81
Dystonia(3)	M	2.94	5.25	3.25	2.75
	SD	1.71	5.25	2.06	1.70
Dyskinesia(4)	M	4.41	4.46	4.75	4.50
	SD	0.71	0.90	0.50	0.57
F.Ratio		1.30	0.91	2.93	0.93
F. Prob.		NS	NS	NS	NS

Table 3.46 . Means (M) and standard deviations (SD) of rate of repetitions of different segments of monosyllabic repetitions of syllable /da/ (syllables/second) without bite block and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

		DDK Rate Syl/Sec	DDK rate in the first 5Seconds	Repetitions in the first 1 second	Repetitions in the last 1 second
Normal (1)	M	5.30	5.34	5.30	6.30
	SD	0.94	1.07	1.25	1.63
Hypokinetic (2)	M	3.94	4.17	3.87	4.00
	SD	0.97	0.82	1.12	0.92
Hyperkinetic (3)	M	3.86	3.90	4.06	3.31
	SD	1.05	1.24	1.52	1.30
F. Ratio		7.09	4.84	3.24	15.69
F. Prob.		0.05	0.05	0.05	0.05

F. Ratio		7.84	6.34	6.77	8.23
F.Prob.		0.05	0.05	0.05	0.05
		1&2,3	1&2,3	1&2,3	1&2.3
Subgroups of (3)					
Chorea (1)	M	3.66	3.80	4.25	3.75
	SD	0.76	1.41	0.95	1.70
EVT (2)	M	3.70	3.80	3.75	4.00
	SD	1.08	1.24	1.25	1.15
Dystonia(3)	M	3.34	4.80	3.75	3.75
	SD	1.12	0.00	0.95	1.50
Dyskinesia (4)	M	4.47	4.20	4.75	4.25
	SD	1.02	0.87	0.95	1.50
F. Ratio		0.91	0.24	0.32	0.41
F. Prob.		NS	NS	NS	NS

Table 3.48 : Means (M) and standard deviations (SD) of rate of repetitions of different segments of monosyllabic repetitions of syllable /ja/ (syllables/second) without bite block and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,31 and for subgroup analysis = 3,12.

3.4.2.7 Segmental Analysis

It is sometimes said that the DDK repetitions in a group of dysarthric patients in the beginning and end of the sequence are different from those in the middle. This is because the patients may have difficulty in initiating or terminating the repetitions. Also, the loss of neural control over the articulatory movements may make the initial and final few repetitions more susceptible to variations.

Therefore, separate analyses were carried out in respect of repetitions in the first 1 second, repetitions in the last 1 second, and repetitions in the first 5 seconds. The mean rates were compared between the three main groups and between the four subgroups of hyperkinetic dysarthrics. The results are given in Tables 3.42 to 3.48 for syllables /pa/, /ta/, /ka/, /ba/, /da/, /ga/ and /ja/, respectively. The results in these Tables can be summarized as follows .

a) Mean rate of repetitions in the first 5 seconds and the last 1 second was significantly different between the three main groups in respect of syllable /pa/. Similar were the results obtained with respect to DDK rate of the entire sample (Table 3.42). None of the differences in mean rates, for any segment, was significantly different between the subgroups, as it was the case with the mean DDK rate for the entire sample.

b) The mean rate of/ta/ repetitions with respect to first 1 second, first 5 seconds and the last 1 second were all significantly different between the three main groups. Similar were the results for the entire sample. Subgroup analysis showed that DDK rate in the first 1 second sample was significantly different between the subgroups. However, the DDK rate for the entire sample was not significantly different between the subgroups (Table 3.43).

c) The results for the different segments of/ka/ repetitions was the same as the DDK rate for the entire sample. This was true for both the main group and subgroup analysis (Table 3.44). The difference in mean rate of repetitions for the entire sample as well as the different segments was significant between the hyperkinetic and the normal group, and between the hypokinetic and normal group.

d) The mean rate of repetitions of /ba/, was significantly different between the three main groups. This was also the case in respect of DDK rate for the entire sample of /ba/ repetition. In the subgroup analysis the mean rate in the last 1 second was significantly different between the subgroups, which was not the case with the entire sample (Table 3.45).

e) The mean rate of repetition, in each segment of /da/ was significantly different between the main groups. None of the mean DDK rates, for any segment, was significantly different between the subgroups of hyperkinetic dysarthria. The DDK rate for the entire sample also yielded similar results, both in the main group and subgroup analysis (Table 3.46).

f) The mean DDK rate of different segments of /ga/ repetitions yielded the same results, both in the main group and subgroup analysis, as the DDK rate for the entire sample (Table 3.47). The difference in mean rates between the hyperkinetic and normal groups, and between hypokinetic and normals, were statistically significant.

g) Segmental analysis and the entire sample analysis of repetitions of /ja/ yielded similar results (Table 3.48). The difference in mean rates were statistically significant between the hyperkinetic and normal, and hypokinetic and normal groups. There was no significant difference between the subgroups of hyperkinetic dysarthria.

These results indicated that to the extent that mean DDK repetitions can differentiate between the hypokinetic and hyperkinetic dysarthrias, or between the subgroups of hyperkinetic dysarthria, the loci and the duration of DDK sampie does not make a difference. Whether it is the entire sample or part of it, the analysis leads to the same conclusions.

		V1T	VTT	SIT(VL)	SIT (VD)
			(in milliseconds)		
Normal (I)	M	310.04	338.80	330.52	385.32
	SD	99.52	178.28	63.76	53.21
Hypokinetic (2)	M	509.87	410.31	471.84	477.93
	SD	212.83	153.97	140.94	238.62
Hyperkinetic (3)	M	528.48	373.45	590.44	500.65
	SD	264.11	128.64	259.34	247.80
F. Ratio		3.47	0.50	5.46	0.97
F.Prob.		0.05	NS	0.05	NS
Post hoc - Groups		1&3		1&3	
Subgroups of (3)					
Chorea (1)	M	608.25	375.50	443.50	625.50
	SD	389.12	139.60	250.46	268.25
EVT(2)	M	430.12	243.93	507.28	436.71
	SD	304.97	71.60	288.14	310.45
Dystonia(3)	M	417.72	389.67	522.48	315.24
	SD	120.98	87.67	137.92	89.78
Dyskinesia (4)	M	657.90	484.81	888.49	625.16
	SD	147.46	105.76	94.38	194.64
F Ratio		0.85	3.61	3.74	1.73
F Prob.		NS	0.05	0.05	NS
Post hoc - Groups			2&4	1&4 2&4	

Table 3.49 . Means (M) and standard deviations (SD) of voice initiation time (VIT), voice termination time (VTT) speech initiation time for sentence beginning with a voiceless consonant (SIT - VL) and sentence initiation time for a sentence beginning with a voiced sound (SIT - VD) and the results of ANOVA for the significance of difference of means between the main groups and between the subgroups. Degrees of freedom - difference between the main groups = 2,3 1 and for subgroup analysis = 3,12.

3.4.3 Voice Initiation and Termination Time

It is believed that the dysarthric subjects have difficulty in initiating, and terminating voice as well as in initiating speech. An analysis was done wherein the time the patients took in initiating or terminating phonation in response to a click sound was measured. A similar experiment wherein the patients were asked to initiate 2 sentences, one starting with a voiceless consonant and another starting with a voiced sound, in response to a click sound was also carried out. The results of these experiments as well as the results of ANOVA for the significance of difference in mean between the groups are given in Table 3.49. The results can be summarized as follows :

a) Mean voice initiation time (VIT) was significantly different between the main groups, but not the voice termination time (VTT). The hyperkinetic group had longer voice initiation time than normals. Speech initiation time (SIT) for the sentence starting with voiceless consonant was significantly different between the main groups with the hyperkinetic group showing longer speech initiation time than normals. Speech initiation time for the sentence starting with voiced sound was not significantly different between the groups. In general, the hyperkinctic group had longer initiation and termination times than the hypokinetic dysarthrics who in turn had longer initiation times than the normals.

b) Mean VIT was not significantly different between the subgroups of hyperkinetic dysarthrics whereas the mean VTT was significantly different between the subgroups. The dyskinetic group had longer VTT, but the difference was significant only between the EVT and the dyskinetic groups. SIT for the sentence starting with voiceless consonant sound was significantly different between the subgroups, but not the SIT for the sentence starting with voiced sound. Again the dyskinetic group had the longest SIT for the sentence starting with voiceless consonant, but the difference was significant only between the chorea-dyskinctic, and dystonia-dyskinctic groups.

3.4.4 Voice Onset Time

Voice onset time (VOT) is the time elapsed from the release of burst for the stop consonant to the onset of voicing for the succeeding vowel. VOT was measured in this study for the six stop consonants of /p/, /t/, /k/, /b/, /d/ and /g, each one in the vowel environment of /a/, /i/and /u/, and in the environment of a voiced and voiceless stop. Mean VOT for the different consonant and the results of AN OVA for the significance of difference in means between the groups are given in Tables 3.50 to 3.55 for the six stop consonants. The results can be summarized as follows .

a) None of the mean VOT's, for any of the voiceless stop consonants was significantly different between the main groups in any vowel environment.

Mean V0T1 (/p/ in vowel 'a' and voiceless 'k' environment), VOT 4 (/p/ in vowel 'i' and voiced stop 'g' environment), and VOT 6 (*/p/* in vowel 'u' and voiced stop /g/ consonant) were significantly different between the subgroups.

b) Only mean VOT for voiceless 'th' in the environment of vowel /a/ and voiced stop 'g' environment was significantly different between the subgroups (Table 3.51). All other differences in VOTs for voiceless stop 'th' between the subgroups were not statistically significant.

c) Only the mean VOT for 'k[1] in the vowel 'a' and in the voiced stop /d/ context was significant between the subgroups. None of the other differences in mean VOT for 'k' in any context, was significant, either for the main groups or for the subgroups.

d) Mean VOT's for all the voiced stops /b/, /d/ and /g/ in the environment of all vowels, were significantly different between the main groups. For all the consonants, the difference in VOT was significant between the hyperkinetic and the hypokinetic group, and between the hypokinetic and the normal group. An exception was the VOT for 'g' in the vowel /i/ and consonant /th/ environment.

d) None of the differences in mean VOT for any voiced consonant in any of the environment studied was statistically significant between the subgroups.

However, it must be mentioned that there was large variability in the mean values as reflected in the large standard deviations.

		VOT 1 Pakka	VOT 2 Pagga	VOX 3 Pikka	VOT 4 Pigga	VOT 5 Pukka	VOT 6 Pugga
Normal (1)	M	11.10	11.60	11.20	10.90	14.20	18.80
	SD	1.44	3.02	2.09 '	3.54	3.91	8.01
Hypokinetic(2)	M	21.75	32.12	20.25	20.62	31.12	32.87
	SD	7.32	19.22	3.61	11.67	17.06	14.07
Hypcrkinctic(3)	M	46.30	7.72	67.87	74.18	114.43	79.87
	SD	72.75	65.02	125.71	112.34	258.89	14.07
F. Ratio		1.63	0.77	1.55	2.43	1.13	0.58
F. Prob.		NS	NS	NS	NS	NS	NS
Subgroups of 3							
Chorea (1)	M	12.50	13.00	11.75	16.50	17.75	14.50
	SD	4.12	5.71	2.06	14.54	7.63	6.55
EVT(2)	M	23.00	-47.50	35.50	49.25	69.00	-30.50
	SD	26.39	117.73	25.85	47.12	103.46	106.30
Dystonia(3)	M	135.00	52.75	212.00	214.75	349.75	314.00
	SD	107.84	19.65	202.30	156.77	472.97	337.72
Dyskinesia(4)	M	15.00	12.75	12.25	16.25	21.25	18.75
	SD	8.71	4.57	0.50	2.06	4.99	8.53
F. Ratio		4.52	1.91	0.59	5.34	1.71	3.18
F. Prob.		0.05	NS	NS	0.01	NS	0.05
Post hoc		3&1			3&1		4&3
		3&2,4			3&2,4		1&3

Table 3.50 : Means (M) and standard deviations of voice onset times (VOT) in respect of voiceless labial stop consonant /p/ and the results of the analysis of variance for the significance of difference

in means at the 0.05 confidence level. The sounds for which the VOT's are displayed and the words having the intended sound are shown in line 2 of the caption at the top of the table. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		VOT7 Thakku	VOT8 Thaggu	VOT9 Thikku	VOT10 Thiggu	VOT11 Thukku	VOT12 Thuggu
Normal (1)	M	16.40	18.00	19.40	18.90	20.60	18.90
	SD	27.37	5.05	6.85	3.69	6.36	5.15'
Hypokinetic (2)	M	27.37	25.63	45.37	44.87	28.62	23.75
	SD	29.01	24.65	71.20	73.16	15.28	9.72
Hyperkinetic (3)	M	-5.36	40.68	7.86	26.31	7.56	34.31
	SD	81.79	49.74	78.26	44.98	69.83	22.46
F. Ratio		0.82	1.27	0.91	0.71	0.54	0.06
F.Prob.		NS	NS	NS	NS	NS	NS
Subgroups of (3)							
Chorea (1)	M	16.25	18.50	25.25	27.50	20.75	21.00
	SD	5.43	6.60	13.59	13.50	6.89	5.29
EVT(2)	M	9.00	17.75	22.50	-16.75	20.75	19.75
	SD	10.09	10.27	15.26	70.10	16.19	9.81
Dystonia(3)	M	-57.75	105.50	-41.50	59.50	-32.75	68.25
	SD	167.20	68.84	160.31	28.11	145.43	12.28
Dyskinesia (4)	M	19.00	21.00	24.50	35.00	21.50	28.25
	SD	4.96	2.94	14.17	13.73	6.02	12.03
F.Ratio	0.76		6.10	0.65	2.66	0.54	20.03

F.Prob.	NS	0.05	NS	NS	NS	0.05
Post hoc - Groups		2&3				1&2
		1&3				3&1
						3&2
						4&3

Table 3.51 : Means (M) and standard deviations of voice onset times (VOT) in respect of voiceless linguodental stop consonant /th/ and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. The sounds for which the VOT's are displayed and the words having the intended sound are shown in line 2 of the caption at the top of the table. Degrees of freedom for the main analysis (between the three main groups) were 2,3 1 and 3,12 for the subcategory analysis.

		VOT13 Kattu	VOT14 Kaddu	VOT15 Kittu	VOT16 Kiddu	VOT17 Kuttu	VOT18 Kuddu
Normal (1)	M	33.20	30.50	33.50	43.70	32.60	35.10
	SD	12.23	14.08	11.53	13.94	9.52	13.32
Hypokinetic (2)	M	24.12	25.25	35.25	23.37	35.62	24.37
	SD	7.51	12.31	31.18	14.12	12.30	12.12
Hyperkinetic (3)	M	3.75	46.62	5.87	49.43	9.25	57.18
	SD	5.96	40.19	126.30	37.85	85.26	58.48
F. Ratio		0.64	1.72	0.42	2.31	0.72	1.90
F. Prob.		NS	NS	NS	NS	NS	NS

Subgroups of (3)

Chorea(l)	M	21.75	26.50	31.25	33.00	38.00	37.25
	SD	5.50	3.41	5.37	5.47	11.04	8.22
EVT(2)	M	44.25	37.00	54.75	48.00	28.00	47.50
	SD	27.01	26.40	23.37	26.98	12.75	11.81
Dystonia(3)	M	-78.50	99.50	-89.75	87.25	-66.75	117.00
	SD	181.35	47.50	249.14	59.28	158.29	99.87
Dyskinesia (4)	M	22.50	23.50	27.25	29.50	37.75	27.00
	SD	3.78	3.00	16.64	9.71	25.51	16.69
F.Ratio		1.47	6.86	1.07	2.56	1.59	2.53
F.Prob.		NS	0.05	NS	NS	NS	NS
Post hoc			3&1,2,4				

Table 3.52 : Means (M) and standard deviations of voice onset times (VOT) in respect of voiceless velar stop consonant /k/ and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. The sounds for which the VOT's are displayed and the words having the intended sound are shown in line 2 of the caption at the top of the table. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		VOT19	VOT20	VOT21	VOT22	VOT23	VOT24
		Battu	Baddu	Bittu	Biddu	Buttu	Buddu
Normal (1)	M	8.20	9.80	7.30	7.30	11.30	11.80
	SD	1.87	3.42	1.76	2.58	3.83	3.06
Hypokinetic (2)	M	-3.87	-6.25	2.12	4.00	14.25	17.12
	SD	46.85	27.50	26.13	21.56	5.81	7.20

Hyperkinetic (3)	M	-79.00	-92.50	20.43	-72.00	-107.43	-79.06
	SD	65.51	67.53	373.77	48.63	67.64	53.70
F. Ratio		11.14	17.06	0.02	21.30	27.40	26.06
F. Prob.		0.05	0.05	NS	0.05	0.05	0.05
Post hoc		3&2	3&2		3&2	3&1	3&1
		3&1	3&1		3&1	3&2	3&2
Subgroups of (3)							
Chorea(l)	M	-73.25	-88.50	-115.75	-109.50	-131.50	-117.50'
	SD	66.36	41.99	44.67	31.29	30.68	34.53
EVT(l)	M	-87.25	-93.25	-45.75	-74.75	-103.75	-68.50
	SD	70.77	107.21	106.27	71.34	107.13	53.43
Dystonia(3)	M	-48.50	-93.50	-54.50	-46.75	-103.00	-45.75
	SD	-107.00	-82.75	51.93	37.12	85.76	41.78
Dyskinesia (4)	M	-107.00	-94.75	297.75	-59.75	-91.50	-84.50
	SD	67.04	51.27	736.17	34.47	44.31	-10.63
F.Ratio		0.51	0.00	1.01	1.36	0.21	1.34
F.Prob.		NS	NS	NS	NS	NS	NS

Table 3.53 : Means (M) and standard deviations of voice onset times (VOT) in respect of voiced bilabial stop consonant /b/ and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. The sounds for which the VOT's are displayed and the words having the intended sound are shown in line 2 of the caption at the top of the table. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		VOT25 .Datta	VOT26 Daddfl	VOT27 Ditto	VOT28 Diddn	VOT29 Dutta	VOT30 Dudda
Normal (1)	M	15.30	10.30	11.00	10.30	9.20	11.30
	SD	15.95	4.11	5.51	4.69	2.61	2.05
Hypokinetic (2)	M	10.50	16.87	14.50	4.25	16.25	13.50
	SD	36.66	10.10	9.35	39.21	9.48	31.73
Hyperkinetic (3)	M	-109.25	-90.00	-117.18	-89.62	-105.06	-84.50
	SD	61.99	61.28	58.18	56.37	66.97	80.72
F. Ratio		6.56	24.50	42.79	21.21	26.66	11.73
F. Prob.		0.05	0.05	0.05	0.05	0.05	0.05
Post hoc		3&2	3&1	3&1	3&2	3&1	3&1
		3&1	3&2	3&2	3&1	3&2	3&2
Subgroups of (3)							
Chorea (1)	M	-138.75	-131.75	-128.25	-128.75	-106.50	-47.50
	SD	20.15	47.57	45.08	43.18	29.86	100.48
EVT(2)	M	-98.00	-48.00	-94.25	-70.00	-89.00	-91.25
	SD	79.21	72.95	86.59	68.84	101.19	116.30
Dystonia(3)	M	-99.75	-92.50	-129.75	-60.00	-119.25	-94.25
	SD	94.77	78.66	56.51	56.06	73.68	49.70
Dyskinesia (4)	M	-100.50	-87.75	-116.51	-99.75	-113.50	-105.00
	SD	44.76	17.67	55.91	47.75	68.76	62.58
F. Ratio		0.35	1.33	0.27	1.28	0.21	0.34
F. Prob.		NS	NS	NS	NS	NS	NS

Table 3.54 : Means (M) and standard deviations of voice onset times (VOT) in respect of voiceless linguodental stop consonant /dh/ and the results of the analysis of variance for the significance of

difference in means at the 0.05 confidence level. The sounds for which the VOT's are displayed and the words having the intended sound are shown in line 2 of the caption at the top of the table. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		VOT31 Gattu	VOT32 Gaddo	VOT33 Gittu	VOT34 Giddu	VOT35 Guttn	VOT36 Guddn
Normal (1)	M	21.50	13.60	19.30	15.00	20.60	22.90
	SD	26.97	3.43	11.10	4.26	14.81	10.10
Hypokinetic(2)	M	28.87	27.62	30.37	34.50	23.87	32.00
	SD	17.41	21.92	27.33	29.28	14.71	28.07
Hyperkinetic (3)	M	-119.43	-79.56	-97.87	-94.12	-124.56	-56.25
	SD	133.69	81.44	91.25	112.02	135.60	73.53
F.Ratio		9.87	12.72	14.98	9.50	10.10	10.44
F.Prob.		0.05	0.05	0.05	0.05	0.05	0.05
Posthoc		3&1	3&1	3&1	3&1	3&1	3&1
		3&2	3&2	3&2	3&2	3&2	3&2'
Subgroups of (3)							
Chorea (1)	M	-125.75	-145.75	-123.25	-125.75	-115.25	-109.75
	SD	51.95	43.19	64.27	84.78	30.62	41.68
EVT(2)	M	-40.00	-59.00	-87.75	-95.00	-85.50	-58.50
	SD	67.64	89.62	86.55	83.65	108.16	69.07
Dystonia(3)	M	-230.00	-57.75	-111.50	-111.50	-205.50	15.00
	SD	222.44	83.44	146.29	191.51	240.00	91.00
Dyskinesia(4)	M	-82.00	-55.75	-69.00	-44.25	-92.00	-71.75
	SD	77.37	92.23	78.87	82.66	96.00	36.43

F. Ratio	1.69	1.22	0.24	0.35	0.62	2.71
F. Prob.	NS	NS	NS	NS	NS	NS

Table 3.55 : Means (M) and standard deviations of voice onset times (VOT) in respect of voiced velar stop consonant /k/ and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. The sounds for which the VOT's are displayed and the words having the intended sound are shown in line 2 of the caption at the top of the table. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

3.5 Prosodic Variables

3.5.1 Two Rates of Sentence Production

A number of prosodic parameters were investigated on a speech production task which required the subjects to produce a sentence at normal and a fast rate. Speaking rate (syllable/second), speech rate (second/syllable) and articulation rate (syllable/second - but this time the pause time between words and clauses were subtracted from the total speaking time), word and gap duration, and frequency and intensity variations on the sentences were all analysed.

3.5.1.1 Speaking Rate, Speech Rate and Articulation Rate at Two Rates of Sentence Production

Means and standard deviations as well as the results of ANOVA for the significance of difference of means are given in Table 3.56. Results can be summarized as follows :

		Speaking		Speech		Articulation	
		Normal	Fast	Normal	Fast	Normal	Fast
		(Syl/sec)		(sec/syl)		(Syl/sec)	
Group (1)	M	6.01	6.51	0.17	0.15	6.21	6.71
	SD	1.08	1.36	0.34	0.03	1.08	1.36
Group (2)	M	4.31	4.55	0.24	0.24	4.37	4.65
	SD	1.24	1.51	0.06	0.09	1.12	1.51
Group (3)	M	3.97	4.82	0.26	0.26	4.07	4.90
	SD	0.97	1.99	0.08	0.08	0.97	1.99
F.Ratio		11.13	3.90	7.12	4.19	12.13	3.80
F.Prob.		0.05	0.05	0.05	0.05	0.05	0.05
Posthoc		3&1	3&1	1&2	1&3	3&1	3&1
		2&1	2&1	1&3	1&2	2&1	2&1
Subgroups of (3)							
Chorea (1)	M	4.07	4.37	0.25	0.23	4.07	4.31
	SD	0.13	0.42	0.12	0.00	0.13	0.42
EVT(2)	M	3.76	6.33	0.31	0.20	3.76	6.34
	SD	1.76	2.43	0.10	0.12	1.76	3.43
Dystonia(3)	M	3.97	4.27	0.26	0.25	3.98	4.28
	SD	0.77	1.25	0.10	0.10	0.78	1.25
Dyskinesia(4)	M	4.07	4.36	0.26	0.26	4.08	3.36
	SD	0.97	1.54	0.10	0.10	0.97	1.55
F. Ratio		0.07	1.02	0.47	0.27	0.07	1.03
F. Prob.		NS	NS	NS	NS	NS	NS

Table 3.56 : Means (M) and standard deviations (SD) of rate (syllables/second) and duration (second/syllable) in speaking, reading and whispering tasks at normal (N) and fast (F) rates of speech production and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Analysis has been made for the difference in means between the main groups as well as between the subgroups of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

a) Although statistically not tested, there did not seem to be a difference in the speaking rate at normal and fast rate of sentence production even in the case of normal speakers. However, only the EVT group seemed to show significant difference.

b) The mean speaking rate was significantly different between the main groups with both the hypokinetic and hyperkinetic dysarthrics having a lower rate than the normal. This was also true at the fast rate of sentence production.

c) Speech rate being a complementary measure of speaking rate, the mean speech rates at both normal and fast rate of production, were significantly different between the main groups.

d) The speaking rate and the articulatory rates were almost similar in all the groups indicating that the subject did not pause between words or clauses. This was true at both rates of production. This being the case, it was not surprising to note that the mean articulatory rates were significantly different between the groups, like the speaking rate.

e) None of the differences in mean values of either speaking, speech or articulatory rates was statistically significant between the subgroups of hyperkinetic dysarthria.

3.5.1.2 Word Duration at Two Rates of Speech Production

There were 5 words in the sentence produced. Duration of words at two rates of production was analysed. Mean durations and the results of ANOVA for the significance of difference in means are given in Table 3.57 The results can be summarized as follows :

a) The mean duration of each of the five words was significantly different between the main groups, at both normal and fast rate of production. The word durations were longer in the hypokinetic and the hyperkinetic groups than in the normal speakers. In all instances, the mean duration was significantly different between normals and the hyperkinetic groups. However, there was large variability in the data with high standard deviations

b) None of the differences in mean duration of words was significant between the four subgroups of hyperkinetic dysarthria. However, of the 4 groups, the EVT group seemed to demonstrate longer durations than other subgroups.

		1st Word		2nd Word		3rd Word		4th Word		5th Word	
		N	F	N	F	N	F	N	F	N	F
		(Duration in m. sees.)									
Gpl	M	394	278	139	109	480	366	261	198	406	362
	SD	84	47	26	23	79	81	45	36	96	60
Gp2	M	516	437	206	173	583	502	353	273	549	478
	SD	100	118	83	78	104	11	90	130	150	180
Gp3	M	502	431	209	171	731	595	453	354	553	500
	SD	143	138	69	51	253	200	207	110	152	150
F.Ratio		3.93	6.53	4.16	4.86	5.72	6.95	4.73	7.68	3.95	3.17
F. Prob		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Post hoc		1&3	1&3	1&2	1&3	1&3	1&3	1&3	1&3	1&2	1&3
		1&2	1&2	1&3	1&2					1&3	1&2
Subgroups of (3)											
(1)	M	468	427	179	139	547	486	444	346	439	398
	SD	86	159	26	27	45	134	52	50	66	59
(2)	M	614	460	250	182	857	664	491	392	607	592
	SD	163	145	87	64	173	203	126	134	158	140
(3)	M	483	436	253	218	717	573	415	318	616	468
	SD	109	110	50	39	100	150	176	142	122	138
(4)	M	446	401	455	142	802	657	461	360	548	537
	SD	53	44	53	28	200	201	161	124	58	66
F. Ratio		1.1	0.1	2.8	3.0	1.2	0.6	0.1	0.3	1.2	1.4
F. Prob.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3.57 : Means (M) and standard deviations (SD) of word duration (in milliseconds) at normal (N) and fast (F) rate of speech

production and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Analysis has been made for the difference in means between the main groups as well as between the subgroups of hypcrkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis

		1st Gap		2nd Gap		3rd Gap		4th Gap	
		N	F	N	F	N	F	N	F
		(Gap duration in m. sees)							
Normal (1)	M	130	63	67	47	109	51	50	37
	SD	88	10	12	15	83	28	17	17
Hypokinetic (2)	M	195	173	93	71	341	270	70	74
	SD	161	181	20	18	413	406	27	34
Hyperkinetic (3)	M	210	136	121	74	351	180	103	79
	SD	171	86	106	27	237	183	44	28
F.Ratio		0.93	2.64	1.59	4.90	2.97	2.05	7.4	7.98
F. Prob		NS	NS	NS	0.05	NS	NS	0.05	0.05
Post hoc					1&2			1&3	1&2
					1&3			2&3	1&3
Subgroups of(3)									
Chorea (1)	M	219	174	201	82	427	223	94	72
	SD	67	79	104	25	58	23	27	10
EVT(2)	M	333	169	102	86	429	191	125	100
	SD	59	67	32	38	84	90	42	41
Dystonia(3)	M	184	110	98	67	165	66	107	89
	SD	13	32	33	30	42	9	45	9
Dyskinesia (4)	M	105	90	80	61	381	237	87	53
	SD	41	24	22	9	113	125	62	13

F. Ratio	1.31	0.91	1.02	0.61	1.12	0.61	0.51	3.31
F. Prob.	NS	NS	NS	NS	NS	NS	NS	NS

Table 3.58 : Means (M) and standard deviations (SD) of gap duration (pause duration between the words - in milliseconds) at normal (N) and fast (F) rate of speech production and the results of the analysis of variance for the significance of difference in means. Separate analysis has been made for main groups and the subgroups. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

3.5.1.3 Gap Duration at Two Rate of Speech Production

The duration of gaps between the words at two rates of production was analysed and the results are given in Table 3.58. There were 5 words in the sentence produced and therefore, theoretically four gaps were possible. In fact, in this study, four gaps could be identified in all speakers and at both rates of production. The results in Table 3.58 can be summarized as follows :

a) The mean gap durations were significantly different between the main groups only with respect to second and fourth gap.

b) None of the differences in mean gap duration between the 4 subgroups was significant.

The significance of this result is that, in general, the temporal pattern of speech in dysarthrics is not significantly different from that of normal speech.

		Mean FO		Max. FO		Min. FO		Range FO	
		N	F	N	F	N	F	N	F
		(in Hz)							
Normal (1)	M	171	197	280	277	101	99	179	192
	SD	35	47	72	78	17	28	66	63
Hypokinetic (2)	M	170	179	301	273	98	113	207	145
	SD	45	51	24	67	23	36	22	72
Hyperkinetic(3)	M	119	210	296	281	107	109	190	172
	SD	39	41	55	62	32	31	59	62
F. Ratio		2.21	1.27	0.38	0.03	0.39	0.49	0.56	1.18
F.Prob		NS	NS	NS	NS	NS	NS	NS	NS
Subgroups of(3)									
Chorea (1)	M	196	208	303	262	101	103	202	158
	SD	33	38	59	65	12	7	30	37
EVT(2)	M	189	203	314	298	105	102	209	196
	SD	44	33	44	35	24	18	34	37
Dystonia(3)	M	241	253	310	322	136	141	173	182
	SD	25	30	47	52	20	21	32	34
Dyskinesia(4)	M	170	175	258	241	85	90	175	152
	SD	19	25	41	57	8	4	50	51
F. Ratio		3.50	3.91	0.81	1.42	2.11	2.51	0.34	0.36
F. Prob		0.05	0.05	NS	NS	NS	NS	NS	NS
F. Prob.		4&3	4&3						

Table 3.59 : Means (M) and standard deviations (SD) of the frequency variations (Hz) at normal (N) and fast (F) rate of speech production and the results of the analysis of variance for the significance

of difference in means at the 0.05 confidence level. Analysis lias been made for the difference in means between the main groups as well as between the subgroups of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		Mean Int		Max. Int.		Min.Int.		Range Int.	
		N	F	N	F	N	F	N	F
					(in dB)				
Normal (1)	M	38	43	52	54	17	23	34	31
	SD	4.0	3.6	3.1	2.7	5.0	4.5	6.1	5.0
Hypokinetic (2)	M	39	41	52	54	12	15	40	39
	SD	6.9	8.0	3.1	3.8	3.5	5.8	3.5	4.7
Hyperkinetic (3)	M	37	40	53	53	13	15	39	38
	SD	5.0	4.0	2.8	1.8	6.1	6.6	6.3	7.4
F. Ratio		0.73	1.10	0.30	0.11	2.58	5.80	3.26	4.80
F. Prob		NS	NS	NS	NS	0.05	0.05	0.05	0.05
Post hoc						2&1	2&1	1&3	1&3
							3&1		1&2
Subgroups of (3)									
Chorea (1)	M	35	40	52	53	11	14	40	38
	SD	2.9	3.9	2.1	1.7	6.8	6.2	7.7	8.3
EVT(2)	M	34	38	51	54	12	14	39	41
	SD	2.2	3.5	2.6	1.9	2.9	3.5	3.6	6.6
Dystonia(3)	M	38	42	53	54	16	19	36	35
	SD	8.3	5.5	4.1	1.7	3.9	4.4	3.7	3.3
Dyskinesia(4)	M	39	41	54	52	12	13	41	39
	SD	4.7	2.9	2.9	1.8	3.8	2.9	4.6	3.5

F. Ratio	0.81	0.81	0.42	1.03	0.52	0.61	0.36	0.36
F. Prob.	NS	NS	NS	NS	NS	NS	NS	NS

Table 3.60 : Means (M) and standard deviations (SD) of the intensity variations (dB) at normal (N) and fast (F) rate of speech production and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Analysis has been made for the difference in means between the main groups as well as between the subgroups of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

3.5.1.4 Frequency Variations at Two Rates of Speech Production

The spectral characteristics of speech (frequency and intensity variations) at two rates of speech production were analysed. Speaking fundamental frequency, minimum and maximum speaking F0 and speaking F0 range were analysed on the sentence as a whole. The results, given in Table 3.59, can be summarized as follows :

a) There was no significant difference between the main groups with respect to any frequency parameter measured. However a visual inspection suggested that the speaking F0 was less in the hyperkinetic group compared to normals and hypokinetic groups.

b) None of the differences in the mean values between the subgroups of hyperkinetic dysarthria with respect to any of the frequency parameters analysed was statistically significant.

The significance of these results is that the dysarthric speakers show similar frequency variations in their speech as the normal speakers.

3.5.1.5 Intensity Variations at Two Rates of Speech Production

Mean intensity, intensity range and maximum and minimum intensity of the productions of a sentence at two rates were analysed and the results are tabulated in Table 3.60. The intensity measures are made for the whole sentence. Results can be summarized as follows.

a) Only the mean minimum intensity and intensity range were significantly different between the main groups, at both rates of production. Mean minimum intensity in the hypokinetic and hyperkinetic groups was less than that of normals. Mean maximum intensity being the same in all the three groups, it meant that the mean intensity range was more in the case of both the dysarthric groups. The significance of this finding is that the dysarthric groups tend to be more variable in their intensity of speech, compared to the normals, and thus cannot be said to have monotonous loudness in their speech.

b) None of the differences in means, with respect to any of the intensity variations, between the subgroups of hyperkinetic dysarthrias was significant. The implication of this finding is that the subgroups of hyperkinetic dysarthrias cannot be differentiated from one another based on the intensity fluctuations in their speech.

		Speaking		Reading		Whispering	
		Rate	Durn.	Rate	Durn.	Rate	Durn.
Normal (1)	M	5.25	0.19	4.87	0.20	4.72	0.21
	SD	0.58	0.02	0.78	0.03	0.64	0.02
Hypokinetic (2)	M	4.69	0.21	3.63	0.28	4.60	0.34
	SD	0.68	0.03	0.85	0.05	0.29	0.34
Hyperkinetic (3)	M	3.07	0.37	2.62	0.42	2.82	0.35
	SD	1.06	0.78	0.84	0.14	1.09	0.10
F. Ratio		21.95	2.01	23.26	13.19	20.21	2.02
F.Prob.		0.05	NS	0.05	0.05	0.05	NS
Post hoc		3&2		3&2	1&3	3&2	
		3&1		1&2,3	2&3	3&1	
Subgroups of (3)							
Chorea (1)	M	3.61	0.28	2.86	0.36	2.71	0.28
	SD	0.74	0.05	0.68	0.09	1.87	0.06
EVT (2)	M	3.16	0.33	2.88	0.38	3.15	0.34
	SD	1.41	0.17	0.93	0.56	1.05	0.09
Dystonia(3)	M	2.41	0.61	2.25	0.50	2.66	0.40
	SD	1.34	0.63	0.90	0.20	0.76	0.15
Dyskinesia(3)	M	3.11	0.39	2.50	0.45	2.76	0.37
	SD	0.55	1.45	0.99	0.17	0.71	0.82
F. Ratio		0.84	0.82	0.44	0.69	0.13	1.08
F. Prob.		NS	NS	NS	NS	NS	NS

Table 3.61 : Means (M) and standard deviations (SD) of rate (syllables/second) and duration (second/syllable) in speaking, reading and whispered speaking tasks and the results of the analysis of variance

for the significance of difference in means at the 0.05 confidence level. Analysis has been made for the difference in means between the main groups as well as between the subgroups of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		Reading		Speech	
		Freq. (Hz)	Int. (dB)	Freq. (Hz)	Int. (dB)
Normal (1)	M	196	41	197	39
	SD	44	3.18	34	4
Hypokinetic (2)	M	201	40	194	41
	SD	34	3.25	26	4
Hyperkinetic (3)	M	197	40	203	39
	SD	44	2.99	52	3
F. Ratio		0.03	0.33	0.14	1.07
F. Prob.		NS	NS	NS	NS
Subgroups of (3)					
Chorea(l)	M	173	38	171	38
	SD	30.4	2.3	32.8	2.8
EVT(2)	M	203	41	217	39
	SD	49.1	3.4	54.3	3.9
Dystonia(3)	M	240	40	257	39
	SD	30.8	3.2	45.4	4.2
Dyskinesia(4)	M	171	39	166	39
	SD	33.2	2.6	13.1	2.9
F. Ratio		3.11	0.92	4.37	0.14
F. Prob.		NS	NS	0.05	NS
Post hoc				4&2	
				4&3	
				1&3	

Table 3.62 : Means (M) and standard deviations (SD) of fundamental frequency and intensity in reading and spontaneous speech tasks and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Analysis has been made for the difference in means between the main groups as well as between the subgroups of hyperkinetic dysarthria. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

3.5.2 Spontaneous Speech and Reading

3.5.2.1. Rate of Production

Speaking rate, reading rate and whispered speaking rate, as also the duration of syllables under these three speech production modes, were measured. Speaking rate and whispered speaking rate were computed from the sample of spontaneous speech on the story telling task while the reading rate was computed from the reading of an all-phoneme passage. The duration of syllables is a complementary measure of rate of production. Speaking rate is the number of syllables spoken in each second while the speech rate is the duration of each syllable. The results, given in Table 3.61, can be summarized as follows:

a) Mean speaking rate was significantly different between the main groups. Mean speaking rate was less in the hyperkinetic group compared to the hypokinetic group which in turn had significantly lower speaking rate than the normal group.

b) Mean reading rates were all significantly different between the main groups with the normals having the highest reading rate followed by the hypokinetic and the hyperkinetic dysarthric group in that order. The difference between the normal and the hypokinetic group was also statistically significant. Correspondingly, the duration of syllables in reading also showed similar relationships.

c) Mean whispering rate was significantly different between normals and the hyperkinetic dysarthrics and between the hypo- and hyperkinetic dysarthrics. Mean syllable duration in whispering was not significantly different between the groups.

d) None of the differences in mean values, either with respect to the rate of production, or duration of syllables, in any mode of speech production (speaking, reading or whispered reading), between the subgroups of hyperkinetic dysarthrias was statistically significant. However, the dystonia group appeared to be slowest followed by the dyskinetic group, but the differences were not statistically significant.

3.5.2.2 Frequency and Intensity Variations: Spontaneous Speech and Reading

The results on the frequency and intensity variations in speaking and reading tasks, given in Table 3.62, can be summarized as follows:

a) There was no significant difference in the mean values of frequency or intensity, either in reading or speaking, between the three main groups. The significance of this result is that the dysarthric speakers cannot be said to be monotonous in their speech.

b) Only the mean frequency in the speaking task was significantly different between the four subgroups of hyperkinetic dysarthrias with the EVT and the dystonia groups recording significantly higher speaking frequency than the dyskinetic group.

3.6 Nasal Resonance

Two aspects of nasality were analysed. They were nasalance and TONAR (The Oral Nasal Acoustic Ratio). The mean nasalance values on vowels /a/, /i/, /u/, /e/, and /o/, consonants */ml* and /z/ and on two sentences as well as the results of ANOVA for the significance of difference in means are given in Table 3.63. One sentence had both nasal and non-nasal sounds (nasal sentence - NS) while the other one had no nasal sounds (non-nasal sentence - NNS). The results can be summarized as follows:

a) Mean percentage of nasalance on */ml* and nasal sentence (NS) were significantly different between the three main groups. Both the hypo- and hyperkinetic groups had significantly higher nasalance on /m/ than normals while only the hypokinetic dysarthrias had higher nasalance than normals on nasal sentence.

b) None of the differences in mean nasalance values, except on /z/, was statistically significant between the subgroups of hyperkinetic dysarthrias. Dystonia group recorded the highest nasalance percentage and it was significantly different from the chorea group.

In general, the results indicated that the hypokinetic group showed higher nasality (higher nasalance values) followed by the hyperkinetic group, but the difference was not statistically significant except on consonant /m/ and the nasal sentence. Among the subgroups, there was no visible definite trend except that chorea could be classified under the low nasality group while EVT, dystonia and dyskinesia could be classified under the high nasality group, though the difference in mean values were not statistically significant.

The mean TONAR values and the results of ANOVA for the significance of difference in means, given in Table 3.64, can be summarized as follows:

a) Only the mean TONAR values on the sentence without any nasal sounds were significantly different between the three main groups with the hypokinetic group recording the lowest TONAR. It was significantly lower than that recorded by both the normal and the hyperkinetic groups. A general trend observed was that the mean TONAR values were less in the hypokinetic dysarthria compared to the normals, while it was higher in the hyperkinetic group compared to the normals.

b) None of the differences in mean TONAR values was significantly different between the subgroups of hyperkinetic dysarthria. A general trend was that the dyskinetic group had higher mean TONARs on all the phonetic- linguistic units analysed than the other three subgroups.

The general trend in the TONAR results confirmed the findings on nasalance. The hypokinetic group can be considered a high nasality group (lower TONAR values) compared to the hyperkinetic group, though the mean difference between them was not statistically significant except on the non-nasal sentence.

		/a/	/i/	/u/	/E/	/o/	/m/	/z/	NS	NNS
Normal (1)	M	8.1	18.3	12.1	12.6	14.4	71.2	16.3	46.9	12.4
	SD	4.8	12.0	8.8	7.7	8.8	19.0	8.6	23.3	6.5
Hypokinetic(2)	M	18.0	12.5	22.8	16.0	14.0	84.6	25.7	76.5	22.4
	SD	11.1	5.2	20.4	4.5	15.2	9.9	16.0	11.1	13.2
Hyper-(3)	M	14.4	17.0	12.5	19.3	8 . 5 8	5.2	17.8	51.4	16.6
kinetic	SD	13.4	22.5	17.8	18.0	6.5	11.7	19.2	23.5	15.9
F. Ratio		1.9	0.2	1.2	0.7	1.4	3.4	0.8	4.4	3.2
F.Prob.		NS	NS	NS	NS	NS	0.05	NS	0.05	0.05
							3&1.2		1&2	1&2
Subgroup of (3)										
Chorea(l)	M	8.2	2.2	2.1	6.4	7.5	78.5	4.8	43.0	16.0
	SD	8.2	2.8	2.8	4.7	5.8	18.6	2.1	23.4	8.33
EVT(2)	M	12.4	23.5	7.8	30.5	6.6	86.9	21.2	57.0	19.1
	SD	6.7	21.7	1.6	26.5	7.3	7.1	11.3	11.2	17.8
Dystonia(3)	M	18.1	19.4	16.3	20.7	11.2	91.8	39.1	66.1	25.4
	SD	13.4	17.4	6.2	15.3	8.7	9.1	25.2	10.5	24.3
Dyskinesia(4)	M	18.9	22.9	23.7	19.6	8.7	83.4	6.2	59.4	6.0
	SD	22.6	36.9	28.5	16.2	5.6	9.2	7.6	39.9	5.2
F. Ratio		0.5	0.7	1.1	1.2	0.3	0.8	4.9	0.6	1.0
F.Prob.		NS	NS	NS	NS	NS	NS	1&3	NS	NS

Table 3.63 : Means (M) and standard deviations (SD) of nasalance on vowels /a,i, u, e, o/, consonants /m, z/ and two sentences (sentence with nasal sounds - NS - and a second sentence with no nasal sounds - NNS) and the results of the analysis of variance for the

significance of difference in means at the 0.05 confidence level, Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

		/a/	/i/	/u/	/e/	/o/	/m/	/z/	NS	NNS
Normal (1)	M	15.3	6.7	12.1	8.4	7.0	2.1	6.3	2.6	8.5
	SD	11.8	5.6	12.0	4.5	3.5	3.3	4.2	2.6	4.9
Hypokinetic(2)	M	7.0	2.26	3.4	7.9	1.5	3.6	2.9	2.6	1.6
	SD	7.6	2.6	21.8	8.2	1.2	5.6	2.9	2.2	1.7
Hyper-(3)	M	12.3	38.7	31.1	9.2	11.0	13.5	16.3	5.8	9.7
kinetic	SD	19.4	80.2	52.8	12.5	12.8	25.7	25.2	13.9	8.0
F. Ratio		0.6	1.5	1.7	0.0	2.9	1.4	1.8	0.4	4.6
F. Prob.		NS	NS	NS	NS	NS	NS	NS	NS	0.05
										2&1
										2&3

Subgroups(3)

		/a/	/i/	/u/	/e/	/o/	/m/	/z/	NS	NNS
Chorea(l)	M	31	18.0	15.0	22.8	23.2	3.2	19.3	1.9	6.9
	SD	31.7	16.8	9.8	18.9	19.4	3.8	16.1	1.6	3.3
EVT(2)	M	2.3	3.4	4.5	1.1	2.1	20.3	2.3	1.3	10.6
	SD	2.7	3.3	7.0	1.1	2.0	36.5	1.7	0.6	10.8
Dystonia(3)	M	3.5	3.6	6.0	5.4	6.5	10.3	4.0	2.8	4.6
	SD	3.8	4.2	6.2	5.5	7.2	9.5	6.2	3.4	5.4
Dyskinesia(4)	M	12.2	17.4	8.9	7.6	12.1	20.2	39.7	17.2	16.6
	SD	12.6	17.3	9.1	6.8	7.2	40.0	41.1	26.8	7.2
F. Ratio		2.3	3.2	9.1	3.2	2.7	0.3	2.4	1.2	2.06

F.Prob	NS	NS	0.05	NS	NS	NS	NS	NS	NS
				1&2,3,4					

Table 3.64 : Means (M) and standard deviations (SD) of TONAR on vowels /a,i, u, e, o/, consonants /m, z/ and two sentences (sentence with nasal sounds - NS - and a second sentence with no nasal sounds - NNS) and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Degrees of freedom for the main analysis (between the three main groups) were 2,31 and 3,12 for the subcategory analysis.

3.7 Speech Intelligibility

Intelligibility of spontaneous speech was rated by a panel of three judges on a 7-point rating scale. Normals had mean intelligibility rating of ' 1' on the scale. The mean intelligibility ratings and the results of ANOVA for the significance of difference in mean ratings arc given in Table 3.65. The results can be summarized as follows:

a) Both the hypokinetic and the hyperkinetic dysarthrics had lower intelligibility ratings than normals which was statistically significant at 0.05 level.

b) Among the subgroups of hyperkinetic dysarthrias, the dystonia group had the lowest speech intelligibility ratings followed by the EVT groups and the chorea and dyskinetic groups together. However, only the difference in mean rating between the dystonia group on the one hand and the other subgroups on the other hand, was statistically significant.

Figure 3.4 is a graphic illustration of the mean speech intelligibility ratings of the different groups. Normals had mean intelligibility ratings of 1.00 (completely intelligible), but this has not been depicted in the figure. The dystonics had the poorest rating for speech intelligibility. A comparison with the mean percentage of articulatory errors (Figure 3.3) shows that the intelligibility ratings are closely related to the former.

		Intelligi-bility			Intelligi-bility
			Subgroups of (3)		
Normal (1)	M	1.00	Chorea	M	2.00
	SD	0.00		SD	0.00
Hypokinetic (2)	M	3.00	EVT (2)	M	3.25
	SD	0.93		SD	1.50
Hyperkinetic (3)	M	2.94	Dystonia (3)	M	4.50
	SD	1.29		SD	0.58
F Ratio		13.57	Dyskinesia (4)	M	2.00
F. Prob.		0.05		SD	0.00
Post hoc - Groups		1&3	F. Ratio		8.87
		1&2	F. Prob.		0.05
			Post hoc - Groups		3& 1,4,2

Table 3.65 : Means (M) and standard deviations (SD) of speech intelligibility ratings and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Degrees of freedom for the main analysis (between the three main groups -left half of the table) were 2,31 and 3,12 for the subcategory analysis (right half of the table).

3.8 Severity of Dysarthria

Severity of the speech of dysarthrics was also judged by a panel of judges on a 7-point scale with 1 standing for normal and 7 standing for profound degree of severity. The results, given in Table 3.66, can be summarized as follows :

a) There was a significant difference in the mean ratings of the hypokinetic and hyperkinetic dysarthrias on the one hand and of the normals on the other hand. In other words, both the hypokinetic and the hyperkinetic dysarthrias had higher ratings of severity than the normals, but the two groups could not be differentiated from each other based on severity ratings on severity of speech.

b) Among the subgroups, the dystonia group had significantly higher severity ratings than the other three groups of chorea, EVT and dyskinesia. The last three groups could not be differentiated between each other.

Figure 3.5 is a visual representation of the mean severity ratings of the speech in different dysarthric groups. Normals had a mean rating of 1.00, but, this has not been shown in the figure. It may be noted that the pattern of severity rating roughly follow the pattern of speech intelligibility ratings shown in Figure 3.4. The implication of this observation is that, when we asked the judges to rate the dysarthric speech for severity, they perhaps, have considered mainly the speech intelligibility, or it may be that speech intelligibility and severity of the speech are closely linked to each other, as perceived by a set of listeners. It should also be mentioned that speech intelligibility ratings roughly corresponded to the severity of articulation disorder in these patients.

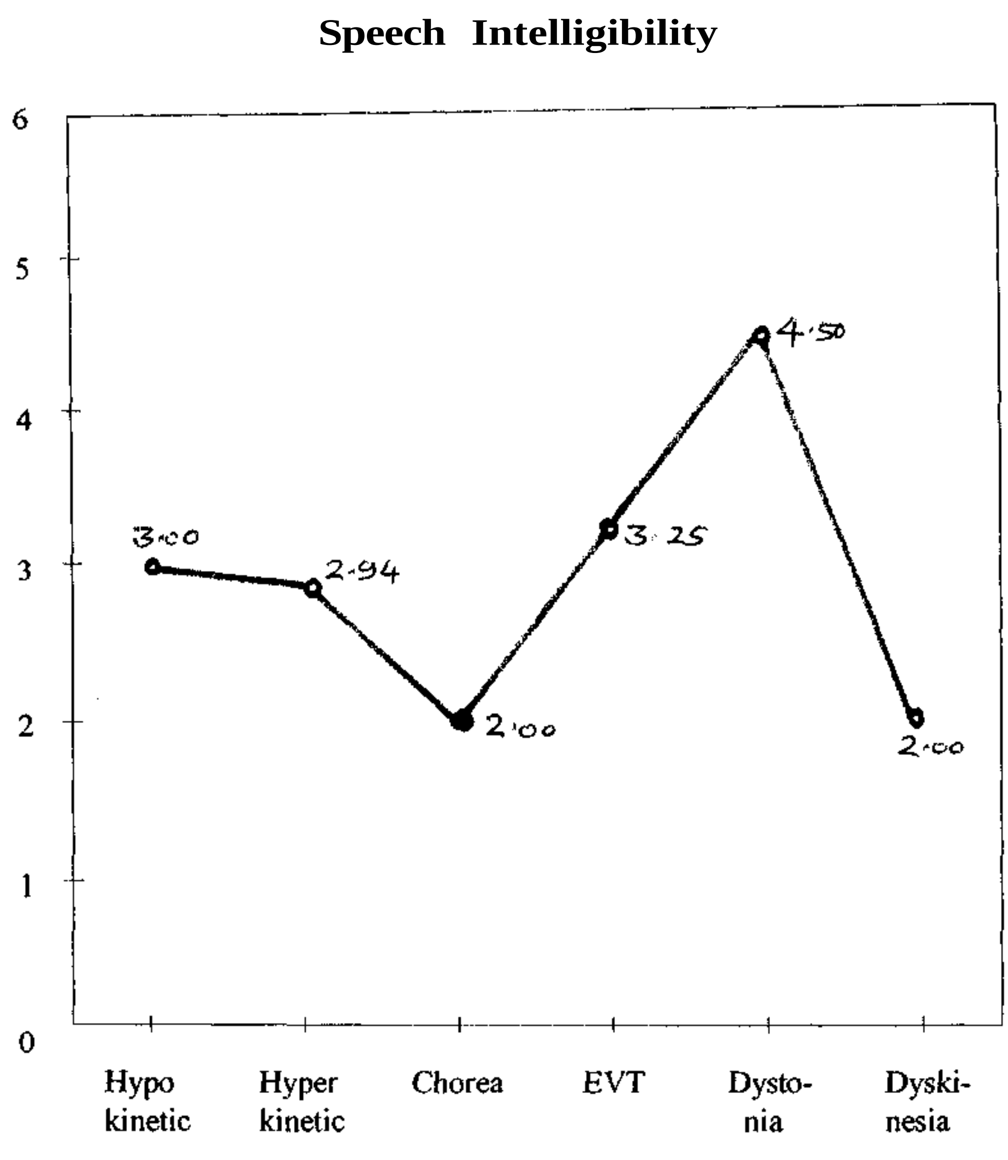

Figure 3.4 : Graphic illustration of the mean speech intelligibility ratings, on a 7-point scale, of dysarthtic speech. '1' stands for intelligible speech while '7' represents completely unintelligible speech.

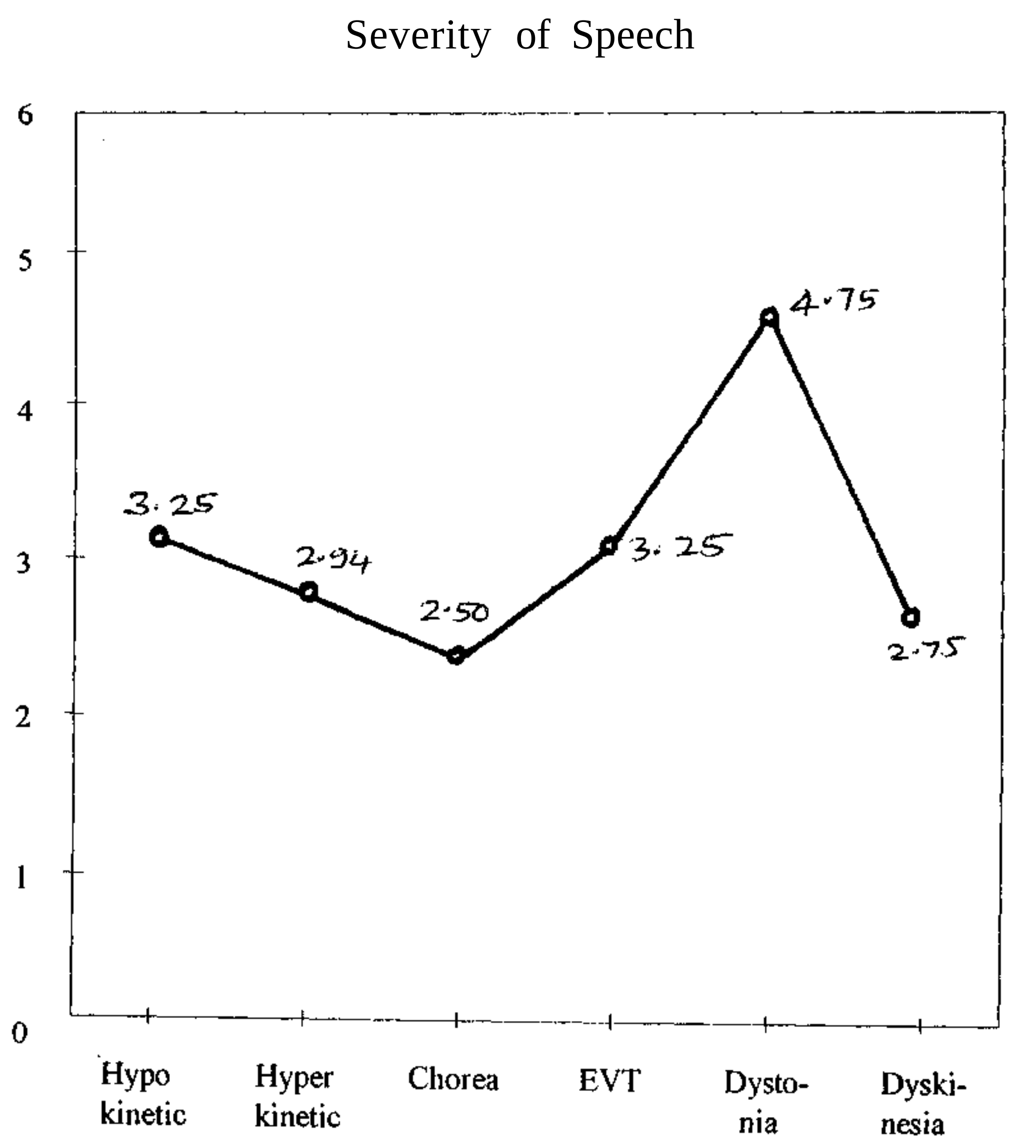

Figure 3.5 : Graphic illustration of the mean severity ratings of dysarthric speech, on a 7-point scale. '1' stands for normal speech while ' 7' reflects

		Severity			Severity
			Subgroups of (3)		
Normal (1)	M	1.00	Chorea(l)	M	2.50
	SD	0.00		SD	0.58
Hypokinetic (2)	M	3.25	EVT (2)	M	3.25
	SD	0.71		SD	0.96
Hyperkinetic (3)	M	2.94	Dystonia	M	4.75
	SD	1.29		SD	0.96
F. Ratio		25.0	Dyskinesia (4)	M	2.75
F. Prob.		0.05		SD	0.50
Post hoc - Groups		1&3	F. Ratio		6.72
		1&2	F. Prob.		0.05
			Post hoc - groups		3&1,2,4

Table 3.66 : Means (M) and standard deviations (SD) of dysarthria severity ratings and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Degrees of freedom for the main analysis (between the three main groups - left half of the table) were 2,3 1 and 3,12 for the subcategory analysis (right half of the table).

3.9 CT Scan Findings

Using the standard measurements, various indices were calculated indicating subcortical and cortical atrophy (Erkinjutti et al, 1987). The results on the means of different measurements on the CT scan and results of ANOVA are given in Table 3.67. These results can be summarized as follows:

Of the various indices, bifrontal index (BFI), bicaudate index (BCI), maximum width of 3rd ventricle (V3), cella media index (CMI) and the ratio of V3 to transverse diameter of skull (width = V3/TDS) all indicated subcortical atrophy. BCI is with special reference to caudate atrophy; V3 and the ratio width/TDS refer more to thalamic atrophy.

On the contrary, a parameter such as number of sulci in 2 upper CT cuts (Sulci) indicate more on cortical atrophy while the ratios of APD of pons to APD of 4th ventricle (APD = APDP/APDV4) and TD of pons to CP angle cistern (TD = TDP/CPAC) indicate on the degree of brainstem involvement (pontine atrophy).

The results of ANOVA shown in Table 3.67 clearly indicated that both hypo- and hyperkinetic groups were significantly different from normals with regard to BFI, V3, Sulci and TD.

		BFI	BCI	V3	CMI	Width	Sulci	APD	TD
Gp 1	M	0.239	0.124	2.00	0.208	0.032	3.00	3.69	9.15
	SD	0.002	0.027	0.05	0.034	0.008	0.05	1.65	1.55
Gp2	M	0.311	0.154	1.87	0.222	0.039	6.00	2.68	5.67
	SD	0.031	0.034	0.52	0.018	0.010	1.41	1.01	1.08
Gp3	M	0.325	0.129	1.50	0.232	0.036	7.25	4.01	4.38
	SD	0.050	0.035	0.60	0.050	0.013	1.69	1.57	1.90
F.Ratio		16.38	2.08	3.65	1.05	0.99	30.4	2.12	22.5
F.Prob		0.05	NS	0.05	NS	NS	0.05	NS	0.05

Post hoc		1&2		3&1			1&2		3&1
		1&3					3&1.2		2&1
Subgroups of (3)									
S.Gp(l)	M	0.328	0.181	2.0	0.298	0.047	8.75	2.8	5.00
	SD	0.005	0.012	0.0	0.021	0.004	2.36	1.23	0.91
S.Gp(2)	M	0.299	0.128	1.88	0.238	0.045	7.50	5.37	4.73
	SD	0.036	0.028	0.85	0.052	0.017	1.29	2.42	2.20
S.Gp(3)	M	0.363	0.107	1.0	0.202	0.024	0.75	3.75	-
	SD	0.091	0.008	0.0	0.002	0.002	0.96	0.29	-
S.Gp(4)	M	0.312	0.102	1.13	0.191	0.026	6.0	4.13	4.71
	SD	0.004	0.005	0.25	0.015	0.004	0.82	0.63	2.2
F.Ratio		1.24	19.18	5.26	10.63	6.61	2.49	0.3	0.94
F.Prob.		NS	0.05	0.05	0.05	0.05	NS	NS	NS
Post hoc			4&1	3&2	4&1	3&2			
			2&1	4&2	2&1	4&2			
			3&1	3&1	3&1	3&1			
				4&1		4&1			

Table 3.67 : Means (M) and standard deviations (SD) of a number of quantitative measures on the CT scan (BFI = Bifrontal index; BCI = Bicaudate index; V3 = Maximum width of 3rd ventricle; CMI = Cella media index; Width = Maximum width of 3rd ventricle/TD skull; Sulci = Number of sulci seen in 2 upper CT scans; APD = APD of pons/APD of 4th ventricle; and TD = TD of pons/CP angle cistern) and the results of the analysis of variance for the significance of difference in means at the 0.05 confidence level. Degrees of freedom for the main analysis (between the three main groups - left half of the table) were 2,31 and 3,12 for the subcategory analysis (right half of the table)

In relation to BFI, both the hypo- and hyperkinetic group differed from the normals though there was no statistically significant difference between the two groups.

The hyperkinetic group had relatively low mean values compared to the normals in the area of V3 indicating no significant atrophy.

Both the hypo- and hyperkinetic groups differed from the normal group in terms of increased sulci which indicated a cortical atrophy. Here again, the atrophy was much more in the hyperkinetic group in comparison to the hypokinetic group. Similarly, pontine atrophy was more evident in both the groups in comparison with the normals.

In the subgroup analysis, amongst the 4 groups of hyperkinetic dysarthria, there was no significant difference between them in terms of cortical or brainstem atrophy. The differences were more significant on BCI, V3, CMI and width.

The chorea group differed from the other three in terms of BCI while there was no significant difference amongst the other three. It is well known that the caudate nuclei are involved in chorea and that caudate atrophy is regularly seen.

Dystonia group had lower width of the 3rd ventricle followed by dyskinesia in relation to the other two groups. This was also true regarding CMI and width. There was no evidence of localized lesion in cortical or brainstem regions in any of these two groups.

3.10 Correlations

3.10.1 Relationship Between Severity of Dysarthria and Speech Intelligibility

Product-Moment correlations were computed for the relationship among speech intelligibility, severity of dysarthria, speaking rate, etc. Statistical significance was not tested. The results tabulated in Table 3.68, separately for the hypokinetic and hyperkinetic dysarthrias, can be summarized as follows :

A : Hypokinetic Group

a) In the hypokinetic dysarthria group, there was a high positive correlation between speech intelligibility and the percentage of misarticulations, between speech intelligibility and severity of dysarthria and a negative correlation between speech intelligibility and reading rate. These results suggested that high intelligibility is strongly associated with low reading rate, low severity of dysarthria and low percentage of misarticulations. The correlation between speech intelligibility and speaking rate, though negative was very low.

b) There was a negative correlation between reading rate and misarticulations indicating that lower reading rates were associated with higher misarticulation errors. There was a high negative relationship between reading rate and severity of dysarthria.

c) There was a high +ve correlation between severity of dysarthria and misarticulations and a high -ve correlation between severity and reading rate.

d) Speaking rate was not particularly well correlated with any of the factors under discussion here.

	Intclli-bility	Reading Rate	Severity	Speaking Rate
Hypokinetic Group				
Misartn.	0.77	-0.53	0.91	-0.11
Reading rate	-0.68	--	-0.70	-0.30
Severity	0.87	-	-	-0.24
Speaking rate	-0.06			
Hyperkinetic Group				
Misarticulation	0.86	-0.46	0.83	-0.64
Reading rate	-0.46	--	-0.38	0.82
Severity	0.83	--	-	-0.53
Speaking rate	-0.64			

Table 3.68 : Product-moment correlations for the relationship between speaking rate, reading rate, percentage of misarticulations, speech intelligibility, and severity of dysarthria ratings. Separate analyses have been made for the hypokinetic and the hyperkinetic dysarthrias.

B: Hyperkinetic Dysarthria

Hyperkinetic dysarthria was analysed as a single group. The results were:

a) There was a high positive correlation between speech intelligibility and misarticulation, speech intelligibility and severity of dysarthria, and a negative correlation between speech intelligibility and speaking rate. There was a negative, but a somewhat lower correlation speech intelligibility and reading rate.

b) Reading rate and articulatory errors were negatively correlated.

c) There was a high positive correlation between severity of dysarthria and misarticulations.

d) Unlike in hypokinetic dysarthrias, speaking rate was highly correlated with severity of dysarthria (negative correlation) and with the percentage of misarticulations (again a negative correlation).

3.10.2 Correlation Between Speech Features and Neuro Findings

In this study, the six deviant speech dimensions of oral diadochokinetic (DDK) rate, speaking rate, reading rate, percentage of misarticulations, severity of dysarthria and speech intelligibility were correlated with neurological and CT scan Findings to understand the neurological bases of the speech deviations. CT scan findings were correlated to establish the possible neuroanatomic site of lesion producing deviant speech.

Table 3.69 and 3.70 show the correlation matrices for the hypokinetic and hyperkinetic dysarthria groups, respectively, in respect of neurological features. The mean value of each dimension was correlated with average number of instances of the presence or absence of a given neurological feature. The latter are qualitative in nature. In groups of patients of this size (hypokinetic dysarthrics = 8 and hyperkinetic dysarthrics = 16) and with this kind of data, a reasonably conservative level of 0.05 was considered for significance testing. Accordingly, a correlation of the magnitude of 0.707 (for hypokinetic group) and 0.497 (for hyperkinetic group) was considered to be significant at 0.05 level.

	DDK rate	Speech Intelli-gibility	Misarti-culation	Readg rate	Dysarthria Severity	Speakg rate
1. DTRs :						
Brisk	-.33	.00	.01	.50	-.21	.23
Depressed	-.24	.43	.14	-.48	.42	-.16
Normal	.68	-.43	-.16	-.17	-.14	-.14
2. Motor Weakness	-.27	.33	-.04	-.58	.21	-.57
3. CN involvement	.42	-.43	-.04	.55	-.14	-.17
4. Dystonia	.23	-.33	-.18	.20	-.21	-.58
5. Hypokinesia	.01	.00	-.52	-.27	-.21	.05
6. Maskface	.24	-.43	-.14	.48	-.42	.16
7. Incoodination	-.24	.43	.14	-.48	.42	-.16

Abbreviations : CN = Cranial Nerve, DTR = Deep Tendon Reflex

Note: Attempts were also made to compute correlations between speech findings and other neurological findings like higher mental functions, plantars, rigidity, tremor, chorcatic movements, wasting, fasciculation, titubation, oral movements, tandem gait and family history, in the hypokinetic group. But, no correlations could be computed because of the zero variability in the data on these factors.

Table 3.69 : Correlations between speech and neurological findings in hypokinetic dysarthria.

	DDK rate	Speech Intclli-gibility	Misarti-dilation	Readg rate	Dysarthria Seventy	Speakg rate
1 Family history	.05	-.29	-.36	.08	-.31	.07
2 H.M.F	.18	-.75*	-.66*	.08	-.62*	.25
3. DTRs :						
brisk	-.01	-.46	-.47	.16	-.47	.10
depressed	.14	-.19	-.12	-.19	-.07	-.03
normal	-.05	.55*	.53*	-.07	.51*	-.08
4. Plantars :						
flexor	11	19	.10	-.17	.07	-.19
extensor	-.11	-.19	-.10	.17	-.07	.19
equivocal	^	^	^	^	^	^
5. Motor weakness	-.53*	.47	.36	-.22	.23	-.21
6. CN invol-vement	-.11	-.06	-.16	-.27	-.21	-.11
7. Tremors	.30	.24	.11	-.07	.13	-.06
8. R'gidity	.03	-.19	-.29	-.01	-.30	.28
9. Dystonia	^	^	^	^	^	^

10. Hypokinesia	26	-.19	-.20	-32	-.30	-18
11. Maskface	^	^	^	^	^	^
12. Chorea	04	-.20	-.31	-06	-29	-.11
13. Wasting/ fasciculation	.16	-28	-.32	.37	-27	.22
14. Titubation	.27	-.08	-.24	.40	-.16	.44
15. Oral movements	-.55*	.18	.14	-21	.19	-.23
16. Incoordination	.52*	-.19	-.24	.45	-.30	.47
17. Tandem	.30	-.28	-.25	.45	-.27	.49

* = Significant at the 0.05 level.

^ = correlation coefficients could not be computed because zero variability in data

Abbreviations : CN = Cranial Nerve DTR = Deep Tendon Reflex
HMF = Higher Mental Functions

Table 3.70 : Correlations between speech and neurological findings in hyperkinetic dysarthria

Table 3.69 showed that there were no significant correlations observed for the hypokinetic group. However, for the hyperkinetic group, 9 correlations were significant (Table - 3.70). These were inspected to sec whether any neurological basis emerged. On such inspection, it was noted that motor weakness and incoordination of limbs were correlated with diadochokinetic rate.

Further inspection revealed that speech intelligibility and higher mental function (HMF) were correlated with normal deep tendon reflex (DTR). Speech intelligibility, misarticulations and dysarthria severity were correlated with HMF.

The meaning of this correlation is that when higher mental functions were affected, it led to poor performance in the speech parameters. Speech intelligibility, misarticulations and dysarthria severity were correlated with normal DTR's. Considering the particular way the data were arranged in computing this correlation, this specific result has to be interpreted to mean that presence or absence of DTR's has no relationship with either misarticulation or speech intelligibility or dysarthria severity. Abnormal oral movements and incoordination were correlated with DDK. This should be interpreted to mean that higher oral movements were associated with decreased DDK rate while incoordination led to increase in DDK rate.

3.10.3 Correlation Between Speech Features and CT Scan Findings

Correlations were also computed between the speech parameters (DDK rate, speech intelligibility etc.) and CT scan findings. CT scan findings consisted of both qualitative and quantitative assessments. Therefore, separate correlations were computed for qualitative and quantitative CT findings.

Table 3.71 and 3.72 shows the correlation matrices for hypokinetic and hyperkinetic groups, respectively. Table 3.71 reveals 4 correlations which were statistically significant. It was noted that the DDK rate correlated with the number of sulci (seen in 2 upper CT cuts). Normally, the number of sulci observed arc 2-4, and more than this is considered to be an indication of cortical atrophy. It is reasonable to infer that more the number of sulci, more the cortical atrophy and less is the DDK rate.

	DDK rate	Speech Intelli-gibility	Misarti-culation	Readg rate	Dysarthria Seventy	Speakg rate
Qualitative						
1. Verm atrophy	.21	.00	.31	-.40	.29	-.65
2. C.H. atrophy	-.24	.28	.41	-.27	.37	-.54
3. CPL cistern	.52	.00	.53	.08	.37	-.22
4. Cis magn	.52	.00	.53	.08	.37	-.22
5. S.C.cistern	-.09	-.59	-.61	.64	-.68	-.30
6. L.C.cistern	-.25	-.29	-.58	.29	-.48	.11
7. Q.G.cistern	.27	-.33	.04	.58	-.21	.57
8. Amb.cistern	^	^	^	^	^	^
Quantitative						
9. Mx.W.V3	.24	-.29	-.28	-.12	-.09	-.62
10. No.Sulci	-.89*	.43	.01	-.25	.00	.30
11. V3/TD.SK	.43	-.76*	-.54	.34	-.57	-.52
12. BF Index	-.13	-.19	-.30	.39	-.40	.17
13. BC Index	-.37	.37	.03	-.40	.30	-.53
14. CM Index	-.17	.32	.17	-.49	.18	-.54
15. Sul scor	-.36	.64	.71*	-.09	.57	-.04
16. Pons/V4	-.46	.60	.21	-.46	.55	-.07
17. Pons/CPL	-.57	.70*	.42	-.57	.54	-.57

* = Significant at the 0.05 level.

^ = correlation coefficients could not be computed because zero variability in data

Table 3.71 : Correlations between speech and CT scan findings in hypokinetic dysarthria

	DDK rate	Speech Intelli-gibility	Misarti-culation	Readg rate	Dysarthria Severity	Speakg rate
Qualitative						
1. Verm atrophy	.10	.03	-.22	.14	-.19	.16
2. C.H atrophy	.17	.28	-.01	.07	.01	-.10
3. CPL cistern	.34	.25	.11	.22	.17	.07
4. Cis magn	.34	.25	.11	.22	.17	.07
5.S.Cistern	-	-	-	-	-	-
6. L.C. cistern	.31	-.10	-.17	-.01	-.28	-.07
7. Q.Gcistern	.51*	-.24	-.32	.04	-.29	.06
8.Ambcistern	-	-	-	-	-	-
Quantitative :						
9. Mx.W.V3	.10	-.04	-.29	-.04	-.24	-.14
10. No.Sulci	.23	-.14	-.25	.21	-.21	.19
11.V3/TD.SK	.16	.02	-.19	.10	-.11	-.10
12. BF Index	-.30	.32	.34	.10	.41	.01
13. BC Index	.16	-.20	-.31	.08	-.24	.02
14. CM Index	.28	-.22	-.37	.25	-.37	.02
15.Sulscor	.20	.14	-.20	.27	-.21	-.05
16. Pons/V4	-.13	-.05	-.02	-.02	-.04	.00
17.Pons/CPL	.44	-.67	-.61	.16	-.62	.27

* = Significant at the 0.05 level.

^ = correlation coefficients could not be computed because zero variability in data

Abbreviations : 1) Verm atr = Vermian atrophy; 2) C.H. atr = Cerebellar hemispheric atrophy; 3) CPL cist = Cerebellopontine angle cistern; 4) Cis magn = Cisterna magna; 5) S.C.cist = Superior cerebellar cistern; 6) L.C. cist = Lateral cerebellar cistern; 7) Q.G.cist = Quadrigeminal cistern; 8) Amb.cist = Ambiens cistern; 9) Mx.W.V3 = Maximum width of 3rd ventricle; 10) No.Sulci = Number of sulci seen in 2 upper CT cuts; 11) V3/TD.SK = max. width of 3rd ventricle/ TD of skull; 12) BF Index = Bifrontal; 13) BC Index = Bicaudate; 14) CM Index = Cella media; 15) Sul scor = Sulcus score; 16) Pons/V4 = APD of pons/APD of 4th ventricle and 17) Pons/CPL = TD of pons/ CP angle cistern.

Table 3.72 : Hyperkinetic dysarthria : Correlations between speech and CT scan findings.

Speech intelligibility was correlated with two variables :

a) with the ratio of the maximum width of 3rd ventricle to transverse diameter of the skull at that level. This ratio reflects on the degree of thalamic atrophy in the subcortical region in the vicinity of the 3rd ventricle, and

b) with the ratio of the transverse diameter of pons to cerebellopontine angle cistern. This parameter gives the degree of pontine atrophy in the brainstem and cerebellum. The relationship was negative meaning that greater atrophy of the region was associated with poorer speech intelligibility.

Further inspection revealed that the percentage of misarticulations was significantly correlated with the sulcus score, that is, the average width of the 4 widest sulci in the two upper CT cuts which is an indication of cortical atrophy. Higher sulcus score (greater than lmm) indicates greater cortical atrophy and this was associated with higher percentage of misarticulations.

Table 3.72 shows the correlation matrices of speech and CT scan findings in the hyperkinetic dysarthria group. Inspection of this matrix, revealed 4 significant correlations. The DDK rate and the presence of quadrigcminal cistern were significantly correlated. Further, inspection revealed that speech intelligibility, percentage of misarticulations and severity of dysarthria were significantly correlated with the ratio of transverse diameter of the pons and cercbello-pontine angle cistern (which is in the brain stem & cerebellum region indicating some degree of pontine atrophy).

3.11 Multivariate Analysis of the Speech-Voice Parameters

Canonical Discriminant Function (CDF), a multivariate technique, was employed to analyse the data pertaining to phonatory, resonatory, articulatory and prosodic aspects of speech of three groups of subjects, namely, (i) hypokinetic dysarthria, (ii) hyperkinetic dysarthria, and (iii) normal (control group). The purpose was to :

a) classify a given patient into one of the diagnostic categories

b) identify the structural configuration of a set of voice and speech parameters in multidimensional discriminant space, and thus to identify the underlying hypothetical speech-voice dimensions associated with diagnosis as in factor analysis, and

c) identify the prominence of a given voice or speech parameter among several parameters of voice-speech.

Since the total number of speech-voice parameters were many, and the sample size was less, only some important parameters for CDF analysis were selected. Thirtysix variables from phonatory, 10 variables from resonatory, 96 variables from articulatory, and 12 variables from prosodic aspects of speech were selected. The various variables (measures) which were selected for CDF analysis are listed below :

Phonatory Measures

I. Maximum Phonation Duration (sees)	2. Raise Time (RT) in msecs
3. Fall Time (FT) in msecs	4. Intensity Decay (ID) in dB
5. Frequency Decay (FD) in Hz	6. Mean F0 in Hz
7. Frequency range	8. Fluctuations/sec
9. Extent of fluctuations	10. P sigma
II. Mean intensity in dB	12. Intensity Range
13. Fluctuations/sec	14. Extent of Fluctuations
15. Jitter (TO - period) in percentage	16. PVI
17. DPQ (%)	18. RAP [3 Point]
19. RAP [5 Point]	20. DLT

21. Jitter in F0 (%) 22. Shimmer(dB)

23. AVI

24. DPQ(%)

25. APQ

26. HNR lin dB]

27. LTAS - Intensity 0 to 1 kHz |in dB|

28. S/Z Ratio

Phonation - Frequency and Intensity Glide

29. Frequency Range (Hz)

30. Intensity Range (dB)

Reading

31-33 Mean Frequency (Hz), Frequency Range (Hz) and Intensity Range (dB)

Spontaneous Speech

34. Mean Frequency (Hz)

35. Mean Intensity (dB)

36. Frequency Range (Hz)

37. Intensity Range (dB)

Resonatory Parameters

38-47 TONAR ans Nasalance for /a/, /o/, /z/, /i/ & nasal sentence.

Articulatory Parameters

48. Voice initiation time - VIT (msec.)
49. Voice termination time - VTT (msec.)
50. Sentence initiation time - Voiceless. SIT-VL (msec.)
51. Sentence initiation time - Voiced. SIT-VD (msec.)

52-87 : All the 36 VOT's (values in msec.s) .

DDK - Repetition Tasks for /p/, /t/, /k/, /b/, /d/, /g/ and /j/ monosyllables and the related parameters consisting of

88. Total no. of repetitions
89. No. of syllables in the First one second
90. Mean syllable duration (in m.secs)
91. Mean intersyllabic duration (in msec)
92. Mean peak intensity of each utterance in dB
93. Mean peak frequency of each utterance in Hz
94. DDK rate
95. Difference between the number of repetitions in the first one second and the last one second.

Prosodic Parameters

Each of the following four factors in spontaneous speech, reading and whispered reading were selected.

Time taken	Speaking rate
No. of syllables	Speech Rate

CDF analysis was carried out in two parts : In the first part, using 154 variables detailed above, CDF analysis was carried out in seven stages, under 4 aspects of speech as shown in Table 3.73.

		Aspects of speech	No. of variables used for CDF by CDF analysis	No. of variables selected by CDF analysis
Phonation	1.	Voice parameters related to frequency, intensity jitter, shimmer, HNR & LTAS measures.	36	10
	2.	Frequency and intensity glide, S/Z ratio measures		
Resonance	3.	TONAR & Nasalance	10	4
	4.	VIT, VTT etc.		
Articulation			96	23
	5.	Voice onset time		
	6.	Oral diadochokinetic measures for monosyllables		
Prosody	7.	Rates of speech, reading and whispered speech; speaking and reading fundamental frequency	12	6
Total			154	43

Table 3.73 . Summary of parameters selected for CDF analysis

In step-wise CDF analysis, 43 variables were selected, that is, 10 of the 36 from phonatory, 4 of the 10 from resonatory, 23 of the 97 from articulatory, and 6 of the 12 from prosodic parameters were selected.

In the second part of CDF analysis, altogether 43 variables (selected from the first part of CDF analysis) were included for analysis. Finally, in the combined analysis, 12 variables out of 43 variables were selected.

The results with respect to the first part (in 7 stages) and the second part (combined) CDF analysis are given one by one in the succeeding paragraphs with relevant table of results, figures and explanations.

It is important to note that, in all the CDF analysis, the "discriminant space " consisted of two dimensions because the number of groups was three and the number of variables selected was only a few. Secondly, the variables were selected in such a way that the absolute value of their intercorrelation coefficients did not exceed 0.5.

3.11.1 First Part of CDF Analysis

3.11.1.1 **Phonatory** Aspects

Under the phonatory aspect, 36 variables were used in the CDF analysis, of which 27 variables pertained to voice parameters while the remaining 9 were related to phonational range (frequency and intensity glide) and the S/Z ratio. The result of these analyses are presented in this subsection.

i) Voice Parameters

In step-wise analysis, 7 out of 27 variables were selected. As said earlier, as the number of groups was three and the number of variables was seven, the discriminant space consisted of two dimensions. The first canonical variate accounted for 78.8% of the total variation in the data structure while the second canonical variate accounted for the rest.

In univariate analysis (one way ANOVA), 13 out of 27 variables were significant in distinguishing the three groups under study, with or without assuming equality of variance. Among the seven variables selected by step-wise discriminant functions analysis, 2 variables, namely, fall time and deviation from linear trend (DLT - Jitter) were not significant in the univariate analysis.

The mean values of 2 canonical variables are shown in Table 3.74 for each group. These mean values were used as coordinates to plot the location of the three groups in a 2-dimcnsional space. It may be noted that the canonical variates were statistically uncorrelated within groups. Therefore, representation as orthogonal reference axes was appropriate (Overall and Klett, 1972). The plot is shown in Figure 3.6.

When we look into the first canonical variate alone in Figure 3.6, it could be seen that the normal and hyperkinetic groups were more nearer to each other while the hyperkinetic group stood alone and at considerable distance from the other two. On the other hand, when both the canonical variables were used, the distance among all the groups was increased and they were distinct.

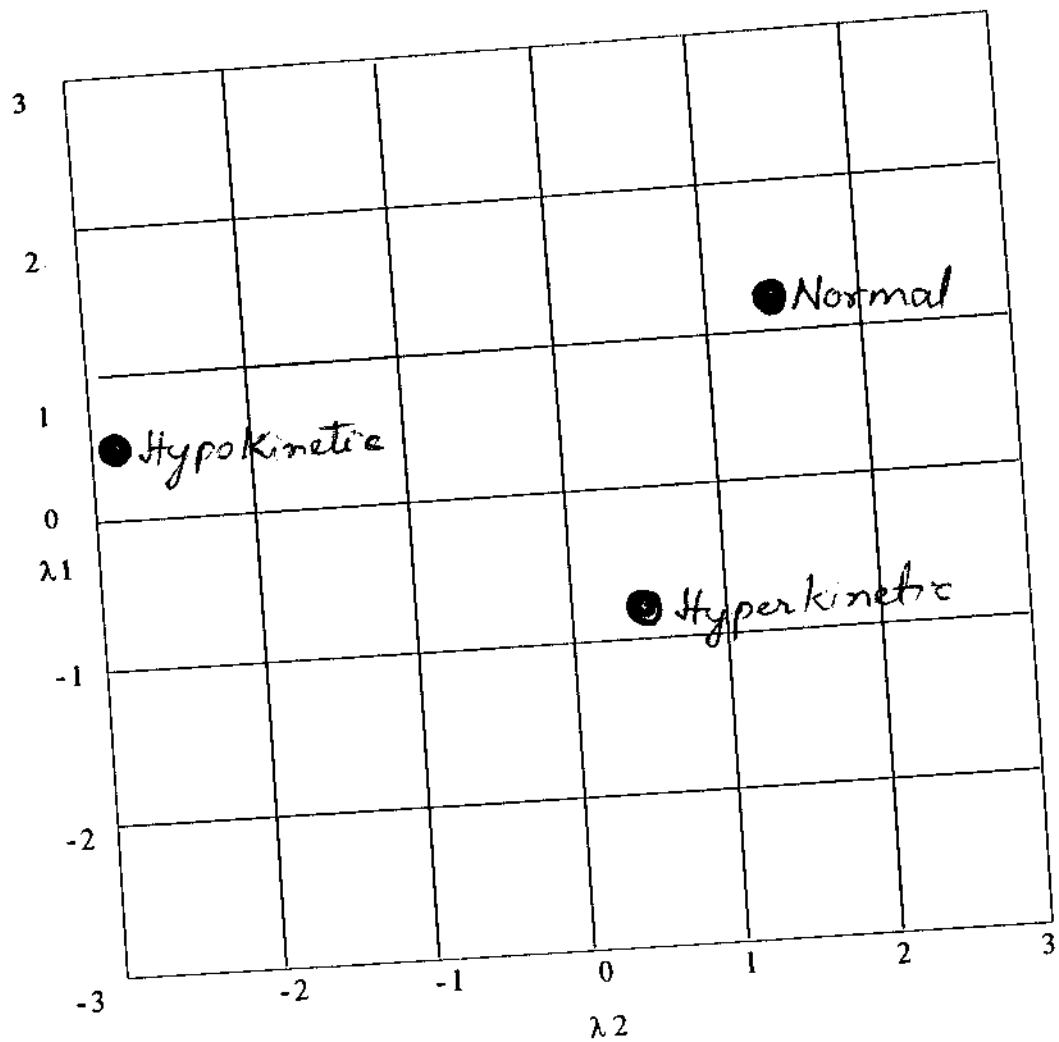

Figure 3.6 : Configuration of the three main groups in the two-dimensional canonical space with reference to phonatory parameters.

	Group	λ1	λ2
1.	Normal	1.36	1.06
2.	Hypokinetic	-2.79	0.33
3.	Hyperkinetic	0.54	-0.83

Table 3.74 : Canonical means

The standardized canonical coefficients are presented in Table 3.75. The standardized coefficients show relative importance of the variables in distinguishing different groups. Accordingly, RAP at 5-point, **DLT** and jitter (in frequency) were having more loads than the remaining variables, thus showing their prominence in separating groups.

Variable	Coefficients	
Fall time	0.26989	0.85112
Frequency F0	-0.78146	0.16348
Fluctuations/sec (frequency)	0.58588	-0.95326
Fluctuations/sec (intensity)	0.43529	-0.56553
RAP5 point	2.14666	0.84962
DLT	-2.10912	-0.59335
Jitter in frequency	-1.96744	-0.33715

Table 3.75 : Standardized coefficients for the canonical variables

The multiple group discriminant functions (Anderson, 1958) were computed and the coefficients for the three groups are given in Table 3.76. Based on this, the classification was computed for the trail analysis. Jackknifed classification was also computed and the results are shown in Table 3.77.

Variables	Normals	Hypo-kinetic	Hyper-kinetic
Fall time	0.01	-0.00	-0.00
Frequency F0	-0.00	0.15	0.01
Fluctuations/sec (frequency)	-0.01	-0.11	0.06
Fluctuations/sec (intensity)	-0.09	-0.41	0.06
RAP5-point	21.40	-184.08	-51.01
DLT	-0.99	9.07	2.12
Jitter in frequency	-0.02	2.17	0.55

Table 3.76 : Classification functions

Group	Percent	Number of cases classified into correct group		
		Normal	Hypo-kinetic	Hyper-kinetic
Trail analysis :				
Normal	80.0	8	0	2
Hypokinetic	87.5	0	7	1
Hyperkinetic	81.3	2	1	13

Total	82.4	10	8	16

Jackknifed classification :

Normal	80.0	8	0	2
Hypokinetic	87.5	0	7	1
Hyperkinetic	68.8	4	1	11
Total	76.3	12	8	14

Table 3.77 : Classification matrix

Generally, the correct classification is more for trail analysis and less for Jackknifed analysis (validation) and the problem is well known as a shinkage problem. Accordingly, the correct classification was 82% for trail analysis and 76.5% for the validation analysis. However, the difference was not much. Thus, the seven variables selected were good enough to discriminate the groups under study and the correct classification was at least 76.5 %

ii) Phonational Range (Frequency and Intensity glide) and S/Z ratio

In this analysis, three out of 9 variables were selected. The discriminant space consisted of 2-dimensions. The first canonical variate accounted for only 63.53% of the total variation in the data structure, while the second canonical variate accounted for the rest.

In one-way ANOVA, 5 out of 19 variables were significant in distinguishing the three groups under question, with or without assuming equality of variance. All the three variables selected by the CDF analysis were different from univariate analysis. The canonical means (for the canonical variables) for the 3 groups are given in Table 3.78.

Group	λ. 1	λ2
Normal	1.01038	0.14167
Hypokinetic	-0.62414	0.77277
Hyperkinetic	-0.31942	-0.47493

Table 3.78 : Canonical variables evaluated at group means

The mean value of 2 canonical variates were used as Cartesian coordinates to plot the location of the three groups. The canonical variates are statistically uncorrelated within groups. Therefore, their representation as orthogonal reference axes is appropriate. The results are illustrated in Figure 3.7.

When looked into the first canonical variate alone, it can be seen that the two patient groups were more nearer and the normal group stands alone and at a considerable distance. On the other hand, when both the canonical variates were taken into account the distance among all the three groups was increased and they were distinct.

The standardized canonical coefficients are presented in Table 3.79. The standardized coefficients show the relative importance of the variables in distinguishing between different groups. Accordingly, the variable intensity range in spontaneous speech is having more load than the remaining two variables.

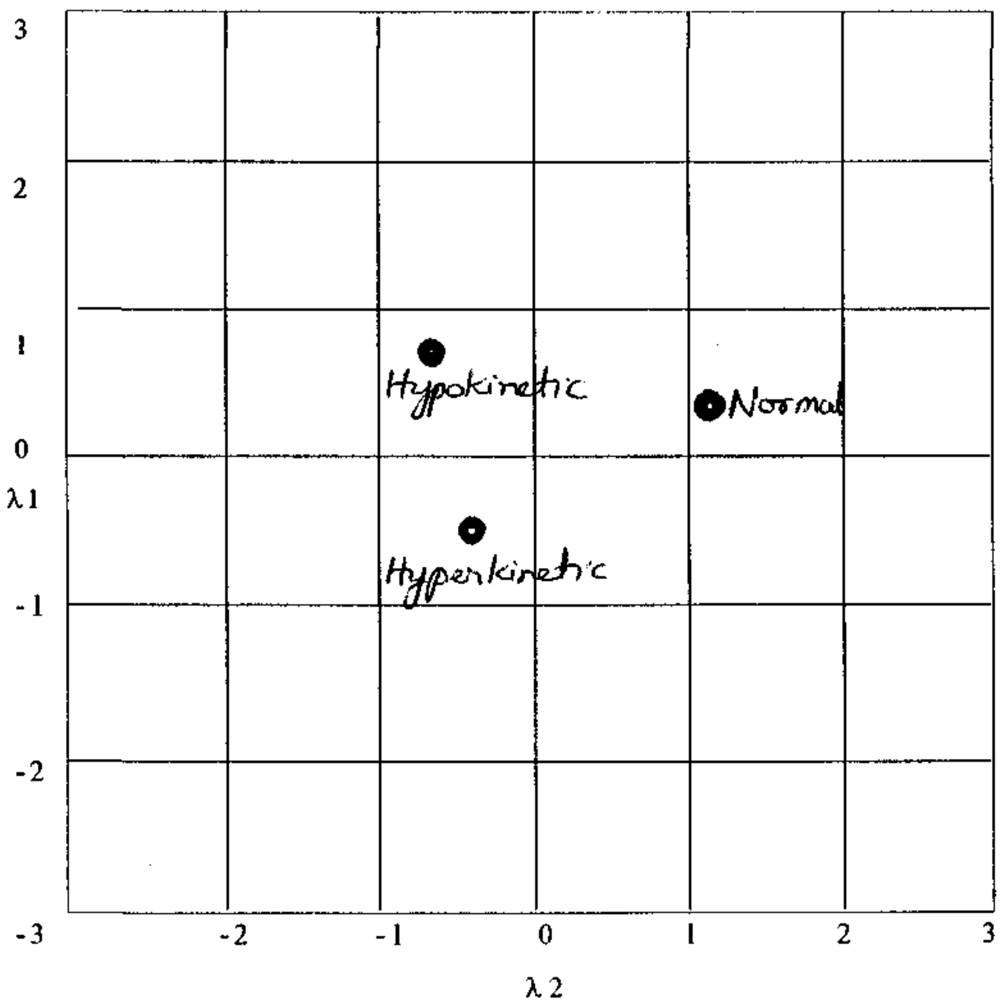

Figure 3.7: Configuration of the three main groups in the two-dimensional canonical space with reference to parameters like speaking and reading frequency, s/z ratio etc.

Variables	$\lambda 1$	$\lambda 2$
Frequency range (reading)	0.40950	0.72443
Intensity range (reading)	0.29254	-0.75637
Intensity range (speech)	-0.97402	0.07608

Table 3.79 : Coefficients for canonical variables

Based on the multiple group discriminant function, the classification was computed for the trail analysis as well as jackknifed classification. The results are shown in Table 3.80.

Group	Percent	Number of cases classified into correct group		
		Normal	Hypo-kinetic	Hyper-kinetic
Trail analysis :				
Normal	70.0	7	1	2
Hypokinetic	50.0	1	4	3
Hyperkinetic	50.0	5	3	8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Jackknifed classification : 268

Normal	70.0	7	1	2
Hypokinetic	25.0	1	2	5
Hyperkinetic	50.0	5	3	8
Total	50.0	13	6	15

Table 3.80 : Classification matrix

Generally, the results of the two classifications were the same. The implication is that the three variables selected are good enough to distinguish between the groups under investigation.

3.11.1.2 **Resonatory** Aspects

Four variables out of 10 resonatory parameters were selected by CDF analysis. The first canonical variate accounted for 78.7% of the total variation in the . data structure, and the second variate accounted for the rest. The coefficients of canonical variables for resonatory aspects are shown in Table 3.81.

Group	$\lambda 1$	$\lambda 2$
Normal	1.23920	0.13371
Hypokinetic	-0.79580	0.64422
Hyperkinetic	-0.37660	-0.40568

Table **3.81** . Canonical variables evaluated at group means

In one-way ANOVA, 3 of the 10 variables were found to distinguish the three groups. Among the 4 variables selected by the discriminant analysis, the nasalance values on vowels /a/ and *lol* and TONAR values on *I'll* were not significant in ANOVA.

Figure 3.8 represents the location of the 2 canonical variates in the 2-dimensional space. As seen in Figure 3.8, both the patient groups were nearer to each other while the normal group stood alone when only the first canonical variate was considered. When, both variates were considered, all the three groups stand apart, distinctly.

Table 3.82 shows the standardized canonical coefficients and their relative importance of the variables in defining the groups. Accordingly, nasalance values on vowel /a/ and on the nasal sentence were more prominent than the other two variables in distinguishing between the three groups. The results of classification are given in Table 3.83.

Group	λ.1 λ	,2
Nasalance on/a/	-0.96803	-0.18535
TONAR on *I'll*	-0.51267	-0.54446
Nasalance on *lol*	0.65291	0.55653
Nasalance on nasal sentence	0.85070	0.47101

Table 3.82 : Standardized coefficients for canonical variables

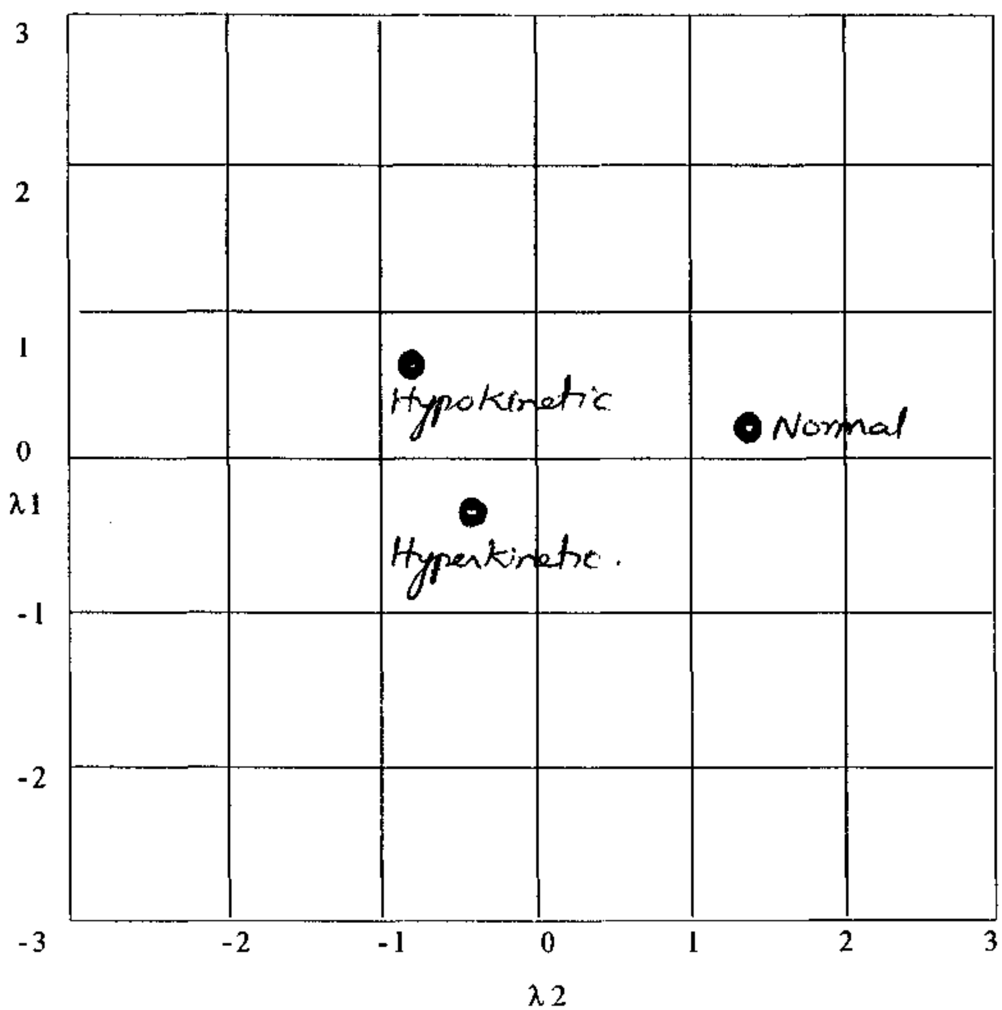

Figure 3.8: Configuration of the three main groups in the two-dimensional canonical space with reference to rcsonatory parameters.

Group	Percent	Number of cases classified into correct group		
		Normal	Hypo-kinetic	Hyper-kinetic
Trail analysis .				
Normal	80.0	8	2	0
Hypokinctic	75.0	0	6	2
Hyperkinetic	43.8	3	6	7
Total	68.8	11	14	9
Jackknifed classification :				
Normal	80.0	8	2	0
Hypokinetic	50.0	1	4	3
Hyperkinetic	25.0	4	8	4
Total	47.1	13	14	7

Table 3.83 : Classification matrix

It shows that correct classification is more for trail which was 69 % and less for Jackknifed classification which was 47%. However, the difference was not much. Thus, it can be seen that the four variables selected are sufficient enough to distinguish between the three groups.

3.11.1.3 Articulatory Aspects

i) Voice Reaction Time and Speech Initiation Time

In CDF analysis, among the four parameters related to voice initiation and termination time, and speech initiation time (for 2 sentences), two variables were selected. The first canonical variate accounted for 95.41% of the total variation in the data structure.

In one-way ANOVA also, 2 out 4 variables were significant in distinguishing between the three groups. Same variables were selected by the step-wise discriminant function. They were: voice initiation time (VIT) and speech initiation time (SIT). The canonical means for the canonical variates for the 3 groups are given in Table 3.84.

Group	$\lambda 1$	$\lambda 2$
Normal	0.95897	0.06766
Hypokinetic	-0.06456	-0.25682
Hyperkinetic	-0.56707	0.08613

Table 3.84 : Canonical variables evaluated at group means

Figure 3.9 shows the location of the three groups in the 2-dimensional space. When the first canonical variate was considered, the two patient groups were located very near to each other with very little space between them while the normal group stood alone distinctly. When both the canonical variates were

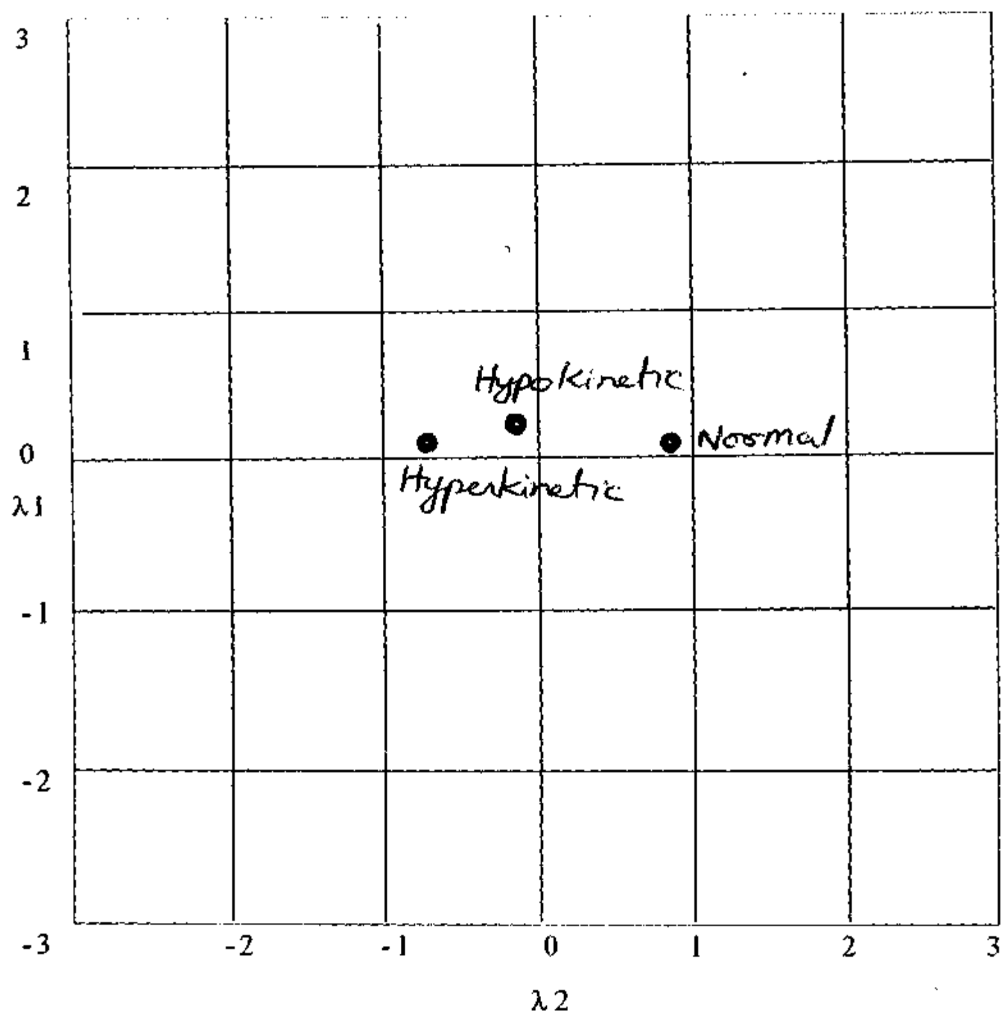

Figure 3.9 : Configuration of the three main groups in the two-dimensional canonical space with reference to voice initiation and speech initiation times.

considered, the group distinction between the hypokinetic and the hyperkinetic dysarthria was minimal. However, the three groups were differentially located with only a small distance between the patient groups. The standardized canonical coefficients are presented in Table 3.85.

Group	λ1	λ2
Normal	1.23920	0.13371
Voice initiation time	-0.51337	-0.88596
Speech initiation time (for sentence beginning with voiceless consonant)	-0.75486	0.69185

Table 3.85 : Standardized coefficients for canonical variables

The variable, 'speech initiation time' for the sentence beginning with voiceless sound is more prominent than the other variable of 'voice initiation time'. Table 3.86 shows the classification matrix for the three groups.

Group	Percent	Number of cases classified into correct group		
		Normal	Hypo-kinetic	Hyper-kinetic
Trail analysis :				
Normal	90.0	9	1	0
Hypokinetic	25.0	3	2	3
Hyperkinetic	56.3	4	3	9

Total	58.8	16	6	12

Jackknifed classification :

Normal	80.0	8	2	0
Hypokinetic	12.5	3	1	4
Hyperkinetic	56.3	4	3	9
Total	52.9	15	6	13

Table 3.86 : Classification matrix

The classification is, more or less, similar both in trail and in jackknifed validation. The correct classification was 59% for the trail and 53% for the validation. Thus, the two variables selected are good enough to distinguish the groups.

ii) Voice Onset Time (VOT) Measures

In CDF, the multivariate analysis selected only 11 variables out of 36 **VOT** measures. The first canonical variate of the 2-dimensional discriminant space accounted for 83.65% of the total variation in the data structure, while the second canonical variate accounted for the rest.

The univariate analysis selected 17 variables from among 36 variables which were significant in distinguishing between the three groups. The canonical means for the canonical variates for 3 groups are given in the Table 3.87.

Group	$\lambda 1$	$\lambda 2$
Normal	3.65782	2.26732
Hypokinetic	4.04754	-2.70198
Hyperkinetic	4.30991	-0.06608

Table 3.87 : Canonical variables evaluated at group means

The orthogonal representation of the 2 canonical means is shown in Figure 3.10. When we looked into the first canonical variate alone, we found that the normal and hypokinetic groups were more nearer to each other while the third group (hyperkinetic dysarthria) stood alone and at considerable distance. On the other hand, when both the canonical variables were taken into account, the distance between all the three groups increased making the three groups distinct. The standardized canonical coefficients which show their relative prominence in distinguishing the different groups are presented in Table 3.88.

Group	$\lambda 1$	$\lambda 2$
VOT in pakka	-4.07283	-4.78867
VOT in pigga	-4.68687	3.43755
VOT in pukka	7.07621	-5.63394
VOT in thaggu	2.29223	1.92790
VOT in thikku	1.53013	-2.70130
VOT in kaddhu	0.80640	-2.11444
VOT in kiddhu	-1.09004	4.17359
VOT in dbatta	2.15966	1.17701
VOT in dhudda	0.74344	0.08303

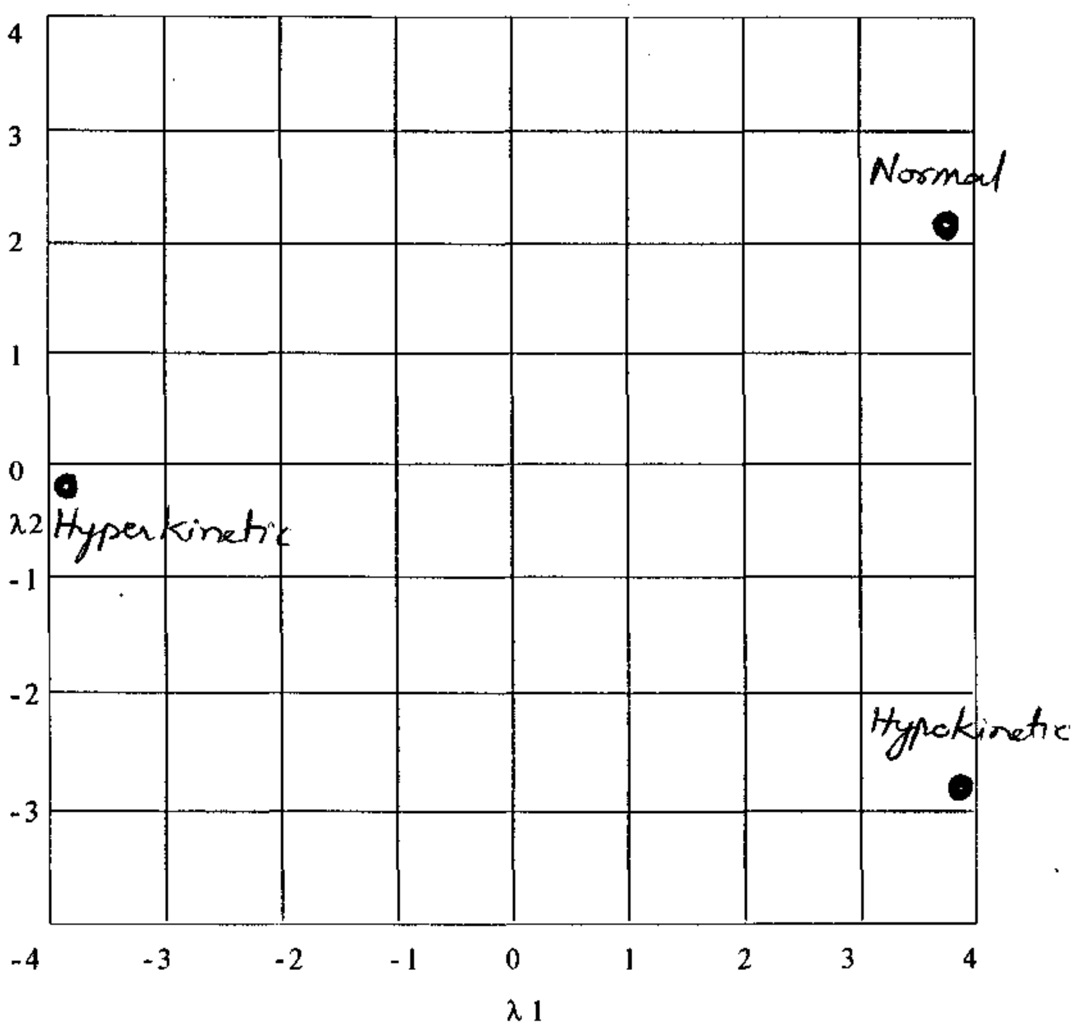

Figure 3.10 : Configuration of the three main groups in the two dimensional canonical space with reference to VOTs.

VOTindhutta	1.13851	-0.47098
VOTingatta	-0.38484	-1.41734

Table 3.88 : Standardized coefficients for canonical variables

Accordingly, the VOT values of the initial sound of the words 'pukka', 'pigga' 'pakka', 'thaggu, 'dhatta' are in the order of prominence, bearing more loads than the remaining variables. Table 3.89 gives classification functions for the three groups, based on which, the classification was computed for trail as well as Jackknifed validation.

Group	Percent	Number of cases classified into correct group		
		Normal	Hypo-kinetic	Hyper-kinetic
> Trail analysis :				
Normal	90.0	9	1	0
Hypokinetic	100.0	0	8	0
Hyperkinetic	100.0	0	0	16
Total	97.1	9	9	16
Jackknifed classification :				
Normal	90.0	9	10	

Hypcrkinctic	87.5	1	1	14
Total	88.2	10	9	15

Table 3.89 : Classification matrix

As seen from Table 3.89, the correct classification is more for trail and slightly less for Jackknifed validation. The correct classification was 97% for trail analysis and 88% for the validation analysis. The difference is not much. Therefore, it was inferred that 11 variables among 36 VOT's were good enough to distinguish the three groups under study.

iii) Diadochokinetic Repetitions of Monosyllables

The CDF analysis selected 10 out of 56 variables of oral diadochokinesis The first canonical variate of the two dimensional discriminant space accounted for 96.95% of the total variation in the data structure, while the second canonical variate accounted for the rest.

In the univariate analysis, 42 out of 57 variables were found to significantly distinguish between the three groups under study. Out of the 10 variables selected by the discriminant function analysis, 6 were found to be sufficient for group differentiation. The canonical means for the canonical variates for the 3 groups are given in Table 3.90.

Group	$\lambda 1$	$\lambda 2$
Normal	3.50938	0.18515
Hypokinetic	-0.32878	-0.75390
Hyperkinetic	-2.02897	0.26123

Table 3.90 : Canonical variables evaluated at group means

Using the mean values of canonical variates, orthogonal representation of the location of the three groups is shown in Figure 3.11. It was clear from the figure that the diadochokinetic measures clearly distinguished between the three groups. When looked into the first canonical variate alone, it van be seen that both the patient groups were nearer to each other while the normal group was distinctly placed at a considerable distance from the two patient groups. On the other hand, when both the variates were taken into account, the distance among all the groups increased, particularly between the patient groups.

Group	$\lambda 1$	$\lambda 2$
Total repetition of/pa/	1.00	0.82
Mean intersyllabic duration	-0.73	0.92
Repetition of/ka/in 1st second	-0.43	0.14
Mean inter syllabic duration of/ba/	0.52	-0.14
Peak intensity of/da/	-0.98	0.68
Difference in repetition of/ga/in first and last one second	1.30	-0.38

Table 3.91 : Standardized coefficients for canonical variables

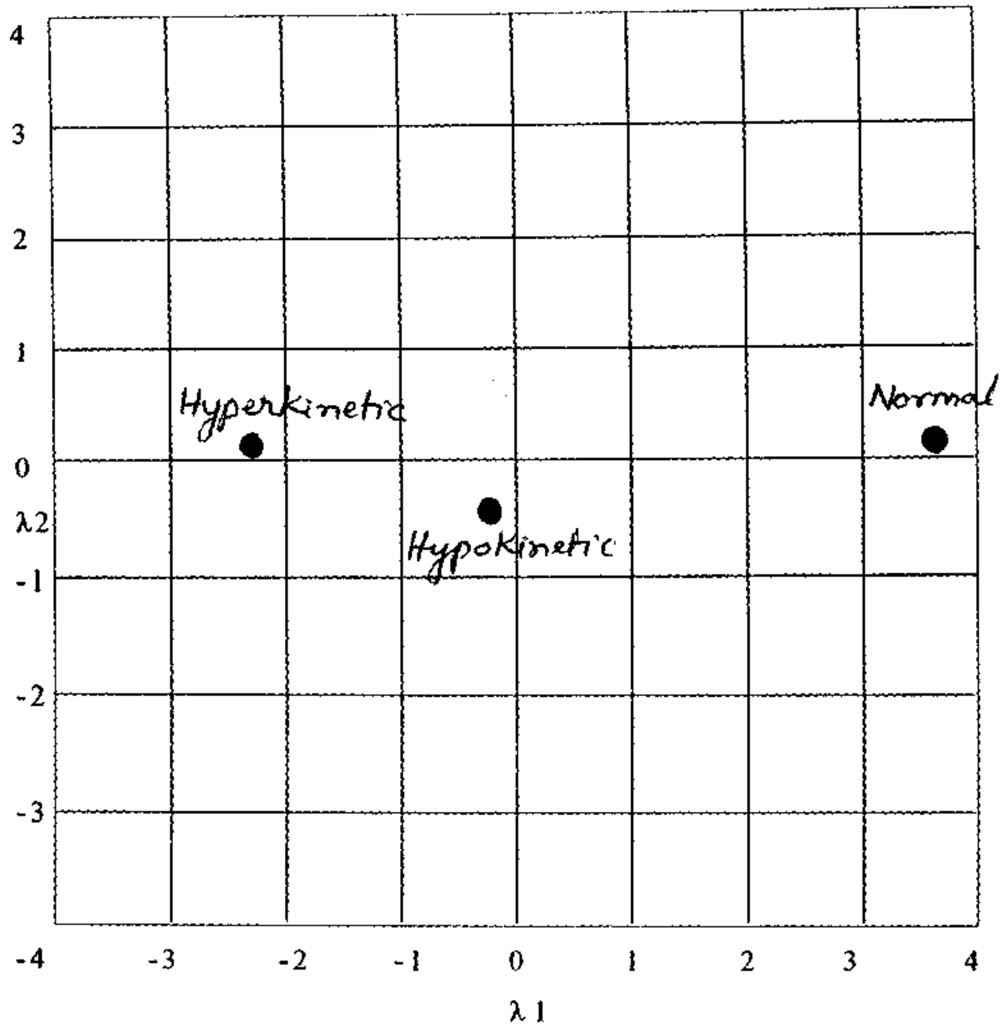

Figure 3.11 Configuration of the three main groups in the two dimensional canonical space with reference to DDK measures.

Table 3.91 shows the standardized coefficients for canonical variables employed to distinguish between in distinguishing the 3 groups. The variables such as 'total repetitions of /pa/' and 'the difference between repetitions of /ga/ in the first 1 and last 1 second' are having more loads than the remaining 8 variables. Based on multiple group discriminant functions, the classification was computed for trail analysis and Jackknifed validation analysis. Table 3.92 reveals the classifications.

Group	Percent	Number of cases classified into correct group		
		Normal	Hypo-kinetic	Hyper-kinetic
Trail analysis :				
Normal	90.0	9	1	0
Hypokinetic	87.5	0	7	1
Hyperkinetic	87.5	0	2	14
Total	88.2	9	10	15
Jackknifed classification:				
Normal	90.0	9	1	0
Hypokinetic	87.5	0	7	1
Hyperkinetic	75.0	0	4	12
Total	82.4	9	12	13

Table 3.92 : Classification matrix

The correct classification was more for trail analysis, which was 88% and slightly less for the Jackknifed analysis, which was 82%. Thus, 6 of the 10 variables, selected were found to be sufficient to distinguish between the 3 groups.

3.11.1.4 Prosodic Aspects

Under the prosodic aspects, measures such as rate of speaking, reading and whispered speech were included. In the discriminant function analysis, six of the 12 variables relating to prosody were selected. The first canonical variate accounted for 78.78% of the total variation in the data structure while the second variate accounted for the rest, in the two dimensions of discriminant space.

ANOVA of the prosodic factors selected 7 of the 12 variables. The 6 variables selected from the discriminant function were the same variables, as selected in ANOVA. Canonical means are given in Table 3.93.

Group	$\lambda 1$	$\lambda 2$
Normal	2.42002	0.43970
Hypokinetic	-0.08787	-1.54797
Hyperkinetic	-1.46858	0.49917

Table 3.93 : Canonical variables evaluated for group means

The orthogonal representation of these means of canonical variates is plotted in Figure 3.12. It is clear from the figure that all the three groups are distinctly spaced at considerable distance from each other with the two patient groups being somewhat nearer to each other.

The standardized coefficients for the canonical variables are given in Table 3.94. The results illustrated that variables of reading rate and duration (duration of syllable) bore more loads in classifying the groups.

Variable	$\lambda 1$	$\lambda 2$
No. of syllable in spontaneous speech	0.46205	0.33794
Speaking rate in spontaneous speech	0.69471	-0.20633
Speaking rate in reading	1.52560	0.74868
Syllable duration in reading	1.60386	-0.18969
Time taken for whispered reading	-0.10282	1.43031
Speech rate in whispered reading	-0.48687	-0.67778
Constant	-14.95390	-7.82812

Table 3.94 : Standardized coefficients for the canonical variables

Table 3.95 shows the classification of groups for the trail analysis as well as Jackknifed validation. On this aspect of speech production, both classifications lead to correct grouping to the extent of 91 %.

Group	Percent	Number of cases classified into correct group		
		Normal	Hypo-kinetic	Hyper-kinetic
Trail analysis				
Normal	100.0	10	0	0
Hypokinetic	87.5	1	7	0
Hyperkinetic	87.5	0	2	14
Total	91.2	11	9	14
Jackknifed classification				
Normal	100.0	10	0	0
Hypokinetic	87.5	1	7	0
Hyperkinetic	87.5	0	2	14
Total	91.2	11	9	14

Table 3.95 : Classification matrix

3.11.2 Second Part of the CDF analysis

As indicated earlier, the second part of the canonical discriminant function analysis was made by pooling all the selected variables from the first part of the CDF analysis. Altogether, 43 variables were picked up pertaining to the 4 aspects of speech. In this step-wise analysis, 31 variables were eliminated and only 12 variables were selected. Since the number of groups was three and the number of variables was 12, the discriminant space consisted of two dimensions. The first canonical variate accounted for nearly 99% of the total variation in the data structure, while the second canonical variate accounted for only 1%. The canonical means for the canonical variables for the 3 groups are given in Table 3.96.

The mean values of 2 canonical variatcs were used as coordinates to plot the location of the three groups in two-dimensional space. It may be noted that the canonical variates were statistically uncorrelated within the groups, so that the representation as orthogonal reference axes was appropriate (Overall and Klett, 1972). A visual representation of the results are in Figure 3.13. If one looks into the first canonical variate only, it could be seen that the normal and the hypokinetic dysarthric groups were more nearer to each other while the hyperkinetic group stood alone at a considerable distance. On the other hand, when both the canonical variables were taken into account, the distance among all the groups increased and the three groups were distinct from each other. The standardized canonical coefficients are presented in Table 3.97. The standardized coefficients show their relative prominence in distinguishing between groups.

Variable	$\lambda 1$	$\lambda 2$
Extent of freq fluctuations	-5.90930	-0.55773
Intensity glide range	-0.38392	1.02038
TONAR on /z/ sound	-4.23370	0.03756
TONAR on nasal sentence	2.83612	0.35837

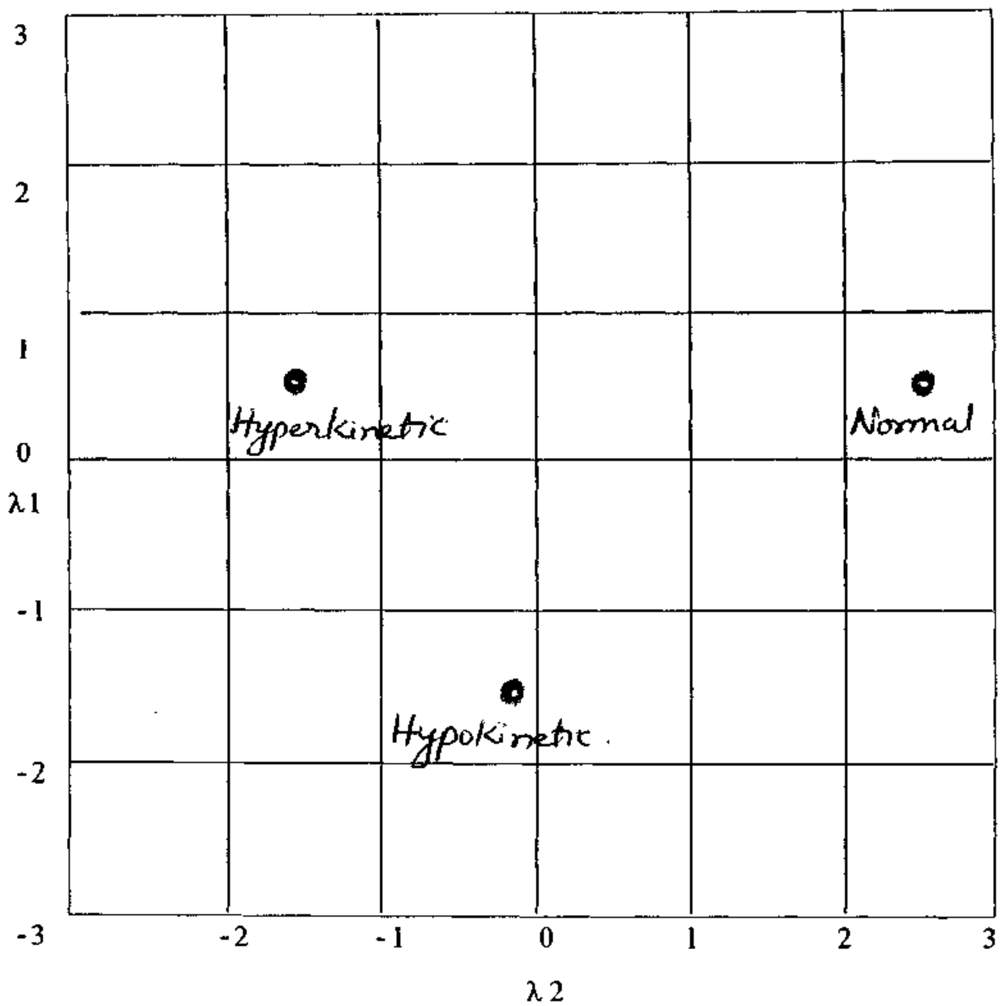

Figure 3.12 : Configuration of the three main groups in the two-dimensional canonical space with reference to speaking and reading rates.

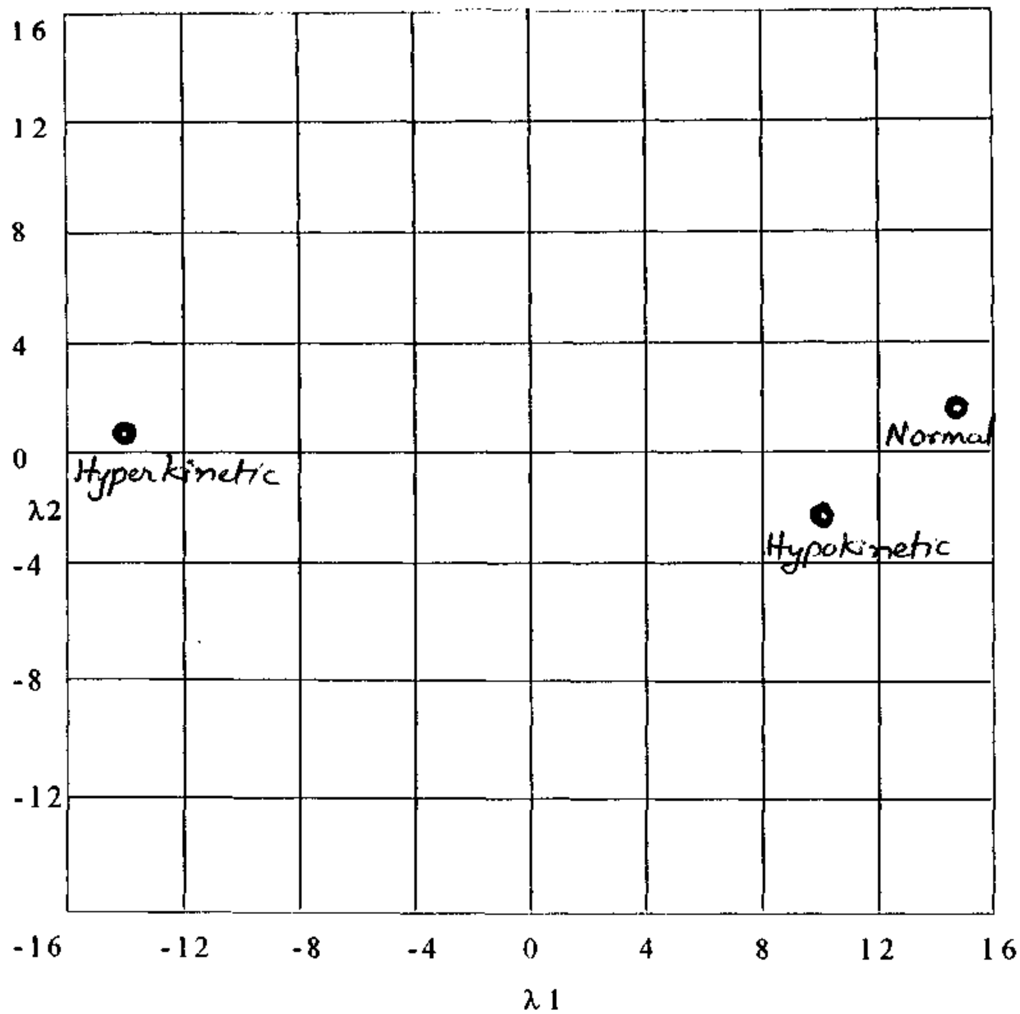

Figure 3.13 : Configuration of the three main groups in the two dimensional canonical space with reference to all the speech-voice measures (combined).

Speech rate in reading	-2.40348	-1.77278
Time taken for whispered reading	1.65829	2.16818
SIT for sentence 1	1.25489	-0.95392
SIT for sentence 2	-1.58758	-0.28187
VOT in 'thaggu'	4.56845	0.36032
VOT in'dhatta'	-2.32189	0.48634
VOT in'dhutta'	-3.98306	-0.45220
Mean peak intensity of/da/in DDK	-2.54381	-0.47174

Table 3.97 : Coefficients for canonical variables

Accordingly, the variables, are listed below :

i) Extent of frequency fluctuation/second.

ii) VOT value for the initial sound of the word /thaggu/,

iii) TONAR value in the neutral /Zh/ sound,

iv) VOT value for the initial sound of the word :/dhadda/.

v) TONAR value in nasal sentence and having more loads than the remaining variables.

The multiple group discriminant function (Anderson, 1958) was done and the coefficients for the three groups are given in Table 3.98.

Based on this, the classification was computed for the trail analysis as well as Jackknifcd classification. The results are shown in Table 3.99. It should be noted that the classification made by trail analysis and Jackknifed validation is the same with 100% agreement between the two systems.

Variables	Normals	Hypo-kinetic	Hyper-kinetic
Extentof frequency fluctuations	12.23	18.37	50.46
Intensity glide range	0.98	0.73	2.00
TONAR on /z/ sound	1.20	1.76	4.97
TONAR on nasal sentence	0.47	-2.19	-5.83
Speech rate in reading	120.92	275.19	762.16
Time taken for whispered reading	-0.63	-4.50	-13.23
SIT for sentence 1 (voiceless sound)	-0.07	-0.07	-0.24
SIT for sentence 2 (voiced sound)	0.06	0.10	0.28
VOTin'thaggu'	-0.77	-1.13	-3.03
VOT in 'dhatta'	0.79	1.04	2.80
VOT in'dhutta[1]	0.90	1.37	3.77
Mean peak intensity of /da/ repetition	0.54	0.79	1.98
Constant	-70.23	-112.83	-727.70

Table 3.98 : Classification functions

Group	Percent	Number of cases classified into correct group		
		Normal	Hypo-kinetic	Hyper-kinetic
Trail analysis :				
Normal	100.0	10	0	0
Hypokinetic	100.0	0	8	0

Hyperkinetic	100.0	0	0	16
Total	100.0	10	8	16

Jackknifed classification:

Normal	100.0	10	0	0
Hypokinetic	100.0	0	8	0
Hyperkinetic	100.0	0	0	16
Total	100.0	10	8	16

Table 3.99 : Classification matrix

Thus, from the second part of the CDF analysis, the 12 variables so selected were good enough to discriminate the three groups under study. List of variables or measures selected and the classification matrix are given in the Tables 3.98 and 3.99, respectively.

Chapter 4

DISCUSSION

The present study was an investigation of the deviant speech-voice dimensions in hypokinetic and hyperkinetic dysarthrias. The study also investigated the deviant dimensions of speech-voice in the subgroups of hyperkinetic dysarthrias. In addition, the analysis addressed the question of which deviant speech-voice dimensions are sufficient to diagnose a given dysarthric condition. The design of the study was like this : speech samples from a group of hypokinetic and . hyperkinetic dysarthrics were recorded once. The speech protocol consisted of items to evaluate phonatory, articulatory, resonatory and prosodic aspects of speech-voice The recorded speech-voice samples were subjected to acoustic analysis wherever required. Two types of analyses were done: one, identification of speech-voice deviant dimensions in each dysarthric category, and two, discriminant function analysis which gives information on the minimum number and type of speech deviations which identify hypokinetic or hyperkinetic dysarthria. Correlation analyses were also run to understand the relationship between neurological findings and speech-voice dimensions.)

4.1 Subjects

The study was designed to analyse the deviant speech-voice dimensions in hypokinetic and hyperkinetic dysarthrias. Therefore, depending upon the inclusion and exclusion criteria for the selection of patients, 8 subjects with Parkinson's disease (hypokinetic dysarthria) and 16 subjects with hyperkinetic dysarthrias were selected. As the patterns of deviations in speech and voice may be different in different types of hyperkinetic dysarthria, the latter group was further divided into 4 groups of chorea, essential voice tumor, dystonia and tardive dyskinesia with 4 subjects in each of these 4 categories.

4.1.1 Hypokinetic Dysarthria Group

The subjects in this group were Parkinsonics. There were 6 males and 2 females in this group in the age range of 20 to 60 years. Average duration of the dysarthric problem in these patients was 2.75 years, while the average duration of speech problem itself was 1.13 years (range 4 months to 4 years). All these subjects were clinically diagnosed to have Parkinson's disease by a neurologist. The CT examinations demonstrated an essentially normal study in six of these patients. All these patients had extrapyramidal symptoms with resting tremors and rigidity. Masked facies was observed in 6 of them while gait was disturbed in 5 patients. DTR's were brisk in 6 patients, plantars were flexor in all the subjects while only 3 subjects manifested cerebellar symptoms. However, there were wide variations among the subjects in terms of clinical features like tremors, extent of speech difficulty, weakness of limbs and difficulty in walking, among others.

4.1.2 Hyperkinetic Dysarthria Group

The hyperkinetic dysarthria group consisted of 11 males and 5 female speakers in the age range of 22-50 years. The average duration of dysarthric problem in these patients was 6.44 years while the average duration of the speech problem itself was 3.44 years. Again all these patients were clinically diagnosed to have some kind of hyperkinetic dysarthria. CT scans showed diffused cortical atrophy in only 6 of them while in the remaining subjects they revealed an essentially normal study.

DTR's were brisk in 7 patients and normal in 8 subjects. Plantars were flexor in 15 of them. 10 of these patients also showed some kind of cerebellar involvement (incoordination or disturbance of gait). Almost all of them demonstrated some type of extrapyramidal involvements (tremors, dystonia or chorea).

There were 4 groups of hyperkinetic dysarthria: chorea (4 patients - average age = 44.25 years), essential voice tremor (4 patients - average age = 52.5 years), dystonia (4 patients - average age = 46 years) and tardive dyskinesia (4 patients - average age = 43 years). The chorea group consisted of one female speaker, the essential voice tremor and dystonic groups - 2 each while the dyskinetic group did not have any female speakers.

4.1.3 Characteristics of the Two Groups

The two groups were matched for age, sex of the speakers, socioeconomic status, linguistic background and in general, for family history of the problem. Except patients with chorea, no other patients had positive family history of the problem.

However, as evident in Tables 3.1 through 3.7, patients in each group varied in terms of clinical characteristics. One major aspect on which the hypokinetic and hyperkinetic dysarthria could not be matched was the duration of dysarthria as well as the duration of the speech problem itself. While the hypokinetic dysarthric had dysarthria for an average duration of 2.75 years (1.12 years of speech problem), the hyperkinetic dysarthrics had dysarthria for an average duration of 6.44 years (3.44 years-speech problem). This difference was evident even among the subgroups of hyperkinetic dysarthric patients. While patients with chorea had dysarthria for an average duration of 4.75 years (1.25 years of speech problem), it was 6.5 years in the EVT group, 6.75 years (3.5 years of speech problem) in the dystonic group and 10.75 years (only 2.5 years of speech problem) in the tardive dyskinetic group. The significance of the longer or shorter duration of dysarthria on the severity of the dysarthric or speech problem in these patients is not clear, but in the absence of this information, conclusions based on the study of 2 dissimilar groups might be suspect.

Both the hypokinetic and the hyperkinetic dysarthria groups (except the dyskinetic group) had both male and female speakers. Though separate analysis have been made for male and female speakers, particularly for the phonatory factors, the effect of combining data from male and female speakers in the analysis of deviant speech-voice dimensions is not known. Therefore, the results of this study should be interpreted with caution.

A control group of 10 normal subjects (8 males and 2 females), matched for age, educational level, socioeconomic status and linguistic background, among others, was also included in the study. Normal speakers were subjected to screening neurological examination.

4.2 Speech Protocol

A comprehensive speech protocol was employed to test aspects of phonatory, articulatory, resonatory and prosodic aspects of speech. A number of objectives had to be fulfilled in employing a reliable and clinically useful speech protocol. The most important objective was to obtain an adequate sample of the speech of the patients ensuring at the same time that the recording time would not be too much prolonged. This is important, considering the poor tolerance level of the dysarthric patients. But at the same time, the speech sample collected must be reliable enough to characterize the patients speech difficulties. Speech responses ought to reflect the phonetic and phonatory difficulties that the patients may have was another criterion. Speech stimuli used should be simple, easy to carry out and that they should not tax the intelligence of the patients.

One another consideration was that the speech stimuli employed should have largely equivalent versions in different languages of this country. This is particularly relevant in a multilingual country like ours. Except for the all-phoneme passage, this objective has been achieved. Other considerations in the development of the speech protocol were:

(a) unambiguous evaluation criteria, (b) analysis time should be brief, and (c) evaluation should provide statistically reliable results.

The speech protocol employed in this study consisted of

a) Phonation of vowels / a, i, u/ in isolation (samples obtained two times with different sets of instructions) to analyse the voice characteristics and measure maximum phonation duration. The objective here was vjo verify the maintenance of stable articulation as well as sustained control of respiration and its coordination with laryngeal and supralaryngeal activity./Some dysarthrics show particular problems with stability in FO, sound intensity and formant frequency.

b) Phonation of /a/ for frequency glide and intensity glide. This task was for determining whether the patient has the capacity to alter FO and intensity on a nonspeech task in a range adequate for speech intonation.

c) Sustained production of vowels /a, i, u, e, o/, and consonants /m/ and /z/ and the production of two simple sentences for analysis of nasal resonance.

d) A picture-word articulation test for analysing articulation of speech sounds.

e) Diadochokinetic repetitions of monosyllabic, bisyllabic and trisyllabic sequences for analysis of DDK related parameters including rate. The repeated syllable task verifies the patients' capacity to alternate between conditions of an entirely closed and an entirely opened vocal tract. Many patients with neurogenic speech disturbances show excessive difficulties in performing a clearly articulated alternation between the two conditions. This task also allows a comparison of occlusions in the anterior and the posterior superior vocal tract. Patients frequently produce well articulated anterior plosives, but inadequately formed posterior plosives.

f) Production of two sentences at two rates for the analysis of prosodic factors. This task assesses the patients's ability to control speaking rate in sentences.

g) A sample of spontaneous speech of one to two minutes duration.

h) A list of 36 CVCCV words for measurement of voice onset time.

i) A reaction time task. This task assesses whether a patient has difficulty with the rapid initiation of speech and whether this difficulty occurs only when phonation is involved or when supralaryngeal articulation is required as in a sentence.

j) Reading of an all-phoneme passage.

K) Sustained production of /s/ and /z/ sounds for the computation of s/z ratio. The comparison between performances on tasks like production of /s/ and /z/ is expected to provide information on the capacity to coordinate superior and inferior vocal tract activity. Voiceless fricatives involve a coordination of respiratory and supralaryngeal activities, while voiced fricatives involve an additional coordination with laryngeal musculature (Keller, Vigneux and Laframboise, 1991).

Besides this, a group of independent judges (not speech pathologists), but including the tester, rated the speech intelligibility and dysarthria speech severity on a 7-point rating scale. Testing for prosodic factors in this study, was limited to an analysis of rate of production, duration and gaps in the production of 2 sentences at two rate of productions besides speaking and reading rates. We recognize that, this is inadequate in characterizing prosody. Speech stimuli to test intonation, stress and rhythm should have been included in the protocol for a more comprehensive study of prosody in the speech of dysarthrics .

Similarly, analysis of resonance was limited to the analysis of nasal resonance (TONAR and nasalance). Vocal tract resonance characteristic (formants) were not considered at all. We recognize that this is a very poor characterisation of resonance characteristics.

Recording of speech samples as in this protocol takes less than 40 minutes and this should be acceptable in a clinical situation. The. limitation, however, is in terms of the time it takes to analyse the speech

samples obtained. In this study, it took nearly 24 to 30 hours of annalysis time for each patient on a PC Pentium (150 MHz). If we were to include other aspects of prosody and resonance as described above, the analysis time would be still longer. However, a careful selection of speech stimuli and the responses to be analysed and their length will reduce the analysis time to a reasonable limit. Further work is warranted in this direction.

4.3 Analyses

The study addressed three issues - first, identification of the deviant speech-voice dimensions in hypokinetic and hyperkinetic dysarthrias including the subgroups of hyperkinetic dysarthrias; second, identification of factors sufficient for classification of a dysarthric condition, and third, the neurological basis of speech deviations in dysarthria) Therefore, speech samples obtained were recorded from previously identified dysarthric patients and the speech samples were subjected to acoustic and other analyses. A canonical discriminant function analysis (CDF) was done to identify speech deviations that are sufficient to identify a given dysarthric condition. As the number of subjects was too small and the number of parameters evaluated was too large, some pruning had to be done in the selection of parameters for CDF analysis. Neurological bases of speech deviation was evaluated by analysis and correlating CT scan and neurological findings with speech findings. We, again, recognize that the neurological bases of deviant speech in dysarthrias as dealt in this study has a very nar-

between speech factors in the two major dysarthric categories,

4.4 Phonatory Factors

4.4.1 Fundamental Frequency and Related Measures

In a comprehensive study of motor speech in a group of 17 male Parkinsonian subjects, Canter (1963, 1965a) reported several phonatory abnormalities as well as some surprising failures to differ from normal performance. Measurement of fundamental frequency and related measures, in this study, showed that both the hypokinetic and the hyperkinetic dysarthrics had a higher FO than normals, though the difference was not always significant. But, on phonation of vowels /i/ and /u/, the hyperkinetic group could be differentiated from the normals, but the two dysarthric groups could not be differentiated from each other.

One of the FO related parameters which was significantly different between the normal and the dysarthric groups in the present study was the number of fluctuations in frequency. Number of fluctuations here refers to the number of fluctuations of the magnitude of 8 Hz in the phonation. Both the hypokinetic and the hyperkinetic dysarthrics showed a greater number fluctuations than the normals but, the difference was statistically significant only between the normals and the hyperkinetic groups (vowel /a/ and /u/) while on phonation of vowel /i/, the difference between the 2 dysarthric groups was also significant. The number of fluctuations reflect on the stability of the vibrating mechanism. Though the difference between the 3 groups was not always significant, the pattern of difference was consistent: the hyperkinetic dysarthrics showed greater number of fluctuations than the hypokinetic dysarthrics who in turn showed greater number of fluctuations than the normals.

The greater instability of the vibratory mechanism in the hypokinetic group can be explained on the basis that the rigidity of the oro-facial structures and slowness of movements perhaps had also extended to the laryngeal musculature. We can hypothesize that the choreiform movements in the chorea group (involuntary sudden burst of motor units), tremors in the EVT group and abnormal lingual movements in the dystonic and the dyskinetic groups had also involved the laryngeal musculature and thus the high fluctuations in frequency in these subgroups .

Among the subgroups of hyperkinetic dysarthrics, the EVT group showed greater number of fluctuations than the other three groups while chorea, dystonia and dyskinesia group had, on an average, the same number of fluctuations as the hypokinetic dysarthrics. The higher mean number of fluctuations in frequency in the hyperkinetic groups was largely contributed to by the higher mean value of the EVT group. Therefore, differentiating hypokinetic from hyperkinetic dysarthrias on the basis of the number of frequency fluctuations may be somewhat erroneous. But, with a proper and more rigorously controlled population of dysarthrics, the number of fluctuations in frequency has the potential to distinguish between the normal and the hypokinetic dysarthria and between the hypokinetic and the EVT groups.

An unexpected result, in the subgroups of hyperkinetic dysarthrias, was that the dystonic and the dyskinetic group had the highest mean extent of fluctuations. Three of the 4 dystonics in the study were lingual dystonics (the other one had laryngeal dystonia) and no clinical indications were evident in them of laryngeal involvement. All the four with tardive dyskinesia were said to be lingual dyskinetics. This perhaps explains the high standard deviation observed in this group. Also, the data on the extent of frequency fluctuations in these groups can be taken to mean that the laryngeal system was involved in these patients, and thus, acoustic analysis of voice may identify the subclinical syndrome in those disorders.

4.4.1.1 Perturbation - Jitter

Various indices of frequency perturbation (jitter) like jitter (FO), jitter (T%), perturbation velocity index etc. were evaluated for their distribution in different groups of dysarthrics. PVI, DPQ, RAP3, RAP5,, and DLT are all indices of the same jitter, the difference being in the way they are computed. Jitter measurements reflect on the short term instability of the laryngeal vibrators. Jitter (T%), PVI, DPQ, and jitter (FO) were significantly different between the main groups.

Mean jitter (T%) values of the hypokinetic and the hyperkinetic groups were significantly different from that of normals as also between the 2 dysarthric groups. In other words, all the jitter factors, for which the mean differences between the groups wore significant, could differentiate dysarthric groups from normals. Jitter (T%) values could also differentiate between hypokinetic and hyperkinetic groups. Significant differences in perturbation factors were also observed to some extent in the phonation of vowel /u/ (jitter T%, PVI and jitter FO) but, these findings were not repeated on the phonation of vowel /i/. It is not clear as to what difference the phonetic unit can make in influencing perturbation factors except that it is also a part of the large variability in the speech features of the neurologically impaired patients. However, as jitter (T%) and jitter (FO) are the standard forms of jitter, it is evident that this measure can be used to discriminate between the dysarthric groups.

We have defined FO perturbation, or jitter as the degree to which the FO of successive periods differ. Neurologically, a substantial portion of the short-term FO variability may be due to inherent 'sloppiness' in sustained contraction of the intrinsic laryngeal muscles (Baer, 1980, 198 1). One would expect jitter to increase as control over laryngeal muscle tone becomes more coarse, or as the number of active motor units decreases (Scherer et. al., 1987; Orlikoff, 1989).

However, the same thing cannot be said to be true in differentiating the subgroups of hyperkinetic dysarthrics based on jitter factors. Jitter measurements on the phonation of vowel /a/ could differentiate EVT group from other subgroups. One explanation is that the fine tremors in these patients had also involved the laryngeal measurements. If so, it becomes difficult to explain the results on jitter in the phonation of vowel /i/ which showed that the dyekinatic group would be differentiated from other subgroups. The EVT group did show high jitter related measurements on vowel /i/ too, but the dyskinetic groups had even higher values. Since all the dyskinetic patients in this study had lingual dyskinesia, a conjecture is that the tongue elevation as required in the production of vowel /i/ somehow influenced jitter values in this group or that the dyskinesia had also extended to laryngeal muscles. None of the jitter values was significantly different between any group on the phonation of vowel /u/.

The usefulness of acoustic perturbation measures as a screening tool for neuropathological groups has not been clearly documented. Ramig et.al (1988) indicated, in their study of patients with myotonic dystrophy, Huntington's and Parkinson's disease, that acoustic analysis (FO, jitter, shimmer, HNR) of the voice in these dysarthric groups may not only contribute to the differential diagnosis, but also, document disease progression. Zwirner, Murry and Woodson (1991) in a study of patients with ataxia, Parkinson's and Huntington's disease indicated that perturbation measures (jitter, shimmer, signal-to-noise ratio, FO, and standard deviation of FO) of the neuropathological groups showed a higher degree of variability. Of the five parameters studied, only the standard deviation of FO differentiated among neuropathological subgroups.

The results of the present study, though cannot be directly compared with other studies already reported, supports the results of Zwirner et. al (1991) in their essence. There were many phonatory variables in the present study, like fluctuations in frequency, fluctuation in intensity, extent of fluctuations, jitter (T%), jitter (FO), shimmer in dB etc., which differentiated between normal and dysarthrics, but the results were not consistent. Differentiation between hypokinetic and hyperkinetic dysarthrias, or between the subgroups of hyperkinetic dysarthrics, was not always possible in this study based on the phonatory measures. A visual inspection of the pattern of significance of difference in means between different groups in different phonatory measures in this study broadly suggests one thing - that the phonatory measures show a high degree of variability in the neuropathological groups compared to normals.

It has been shown that phonatory abnormalities in Parkinson's disease were related to the rigidity of the phonatory posture of the larynx (Hanson et.al, 1984). On this basis, high jitter and shimmer have been predicted to occur in the Parkinson's as well as Huntington's disease patients (Zwirner, Murry and Woodson, 1991). In the present study, the patients in both Parkinson's disease and Huntington's chorea categories did demonstrate substantially higher jitter and shimmer than the normals, but probably because of the high standard deviations exceeding the means in some instances, this effect was statistically nonsignificant.

4.4.2 Voice Intensity and Related Measures

Intensity related measures seem to have greater potential in discriminating between different dysarthrics judging from the number of mean differences which were statistically significant between the dysarthric groups. Mean intensity was significantly different between the normal and the hypokinetic groups while maximum and minimum intensities were significantly different not only between the normal and the dysarthric groups, but also between the hypokinetic and the hyperkinetic dysarthrias (vowel /a/). The lower intensity in the hypokinetic group can be explained on the basis of weakness of laryngeal muscles (weakness of limbs and oro-facial structures including soft palate had been evident in clinical examination and therefore, weakness of laryngeal muscles is also inferred). Mean maximum intensity, fluctuations in intensity per second, and extent of fluctuations in intensity (vowel /\/) could differentiate between the hypo- and hyperkinetic groups while some of the intensity related measures on vowel /u/ yielded significant difference between the groups.

Reduced vocal intensity is a factor contributing to the impaired intelligibility of many patients with Parkinson's disease (Ramig, 1992). Reduced loudness in Parkinson's disease has been attributed to glottal incompetence (Hanson, Gerrat and Ward, 1984; Perez et. al., 1994), and reduced respiratory support (Critchley, 1981) associated with respiratory and laryngeal muscle rigidity and hyperkinesia (Hirose and Joshita, 1987).

Among the subgroups of hyperkinetic dysarthrias, mean number of fluctuations in intensity seemed to differentiate between EVT and the other subgroups, and to some extent between chorea and other subgroups. Fluctuations in intensity refers to 3 dB variations in intensity (positive or negative). As expected, the EVT group showed the highest mean number of fluctuations in intensity. Choreiform movements of the laryngeal structure, inferred in this case, may have been partially responsible for the high mean values of intensity fluctuations in the chorea group. On the same basis, it was expected that the large choreiform movements should have also brought about greater fluctuations in intensity (extent of fluctuations) in the chorea group in contrast to the fine tremors of the EVT group. But this was not the case. Perhaps the wasting of muscles and the slow movements offset the influence of choreiform movements to some extent in their influence on the intensity of phonation.

Mean shimmer values like shimmer in dB and amplitude perturbation quotient (vowel /a/), and amplitude variability index (vowel /i) were significantly different between groups. However, these factors could differentiate hypo- and hyperkinetic groups from normal, but not between the two dysarthric groups themselves. Thus, their importance in the identification of specific dysarthric groups is doubtful.

Among the subgroups of hyperkinetic dysarthrias, the shimmer factors seemed to differentiate the EVT group from the other subgroups. Evidently the EVT group had the highest mean values related to shimmer. The tremors, involving the laryngeal muscles, were perhaps responsible for the higher shimmer values observed in the EVT group.

Figure 4.1 is an illustration of the fundamental frequency and intensity profile of the voice of a normal male speaker. A cyclic pa-

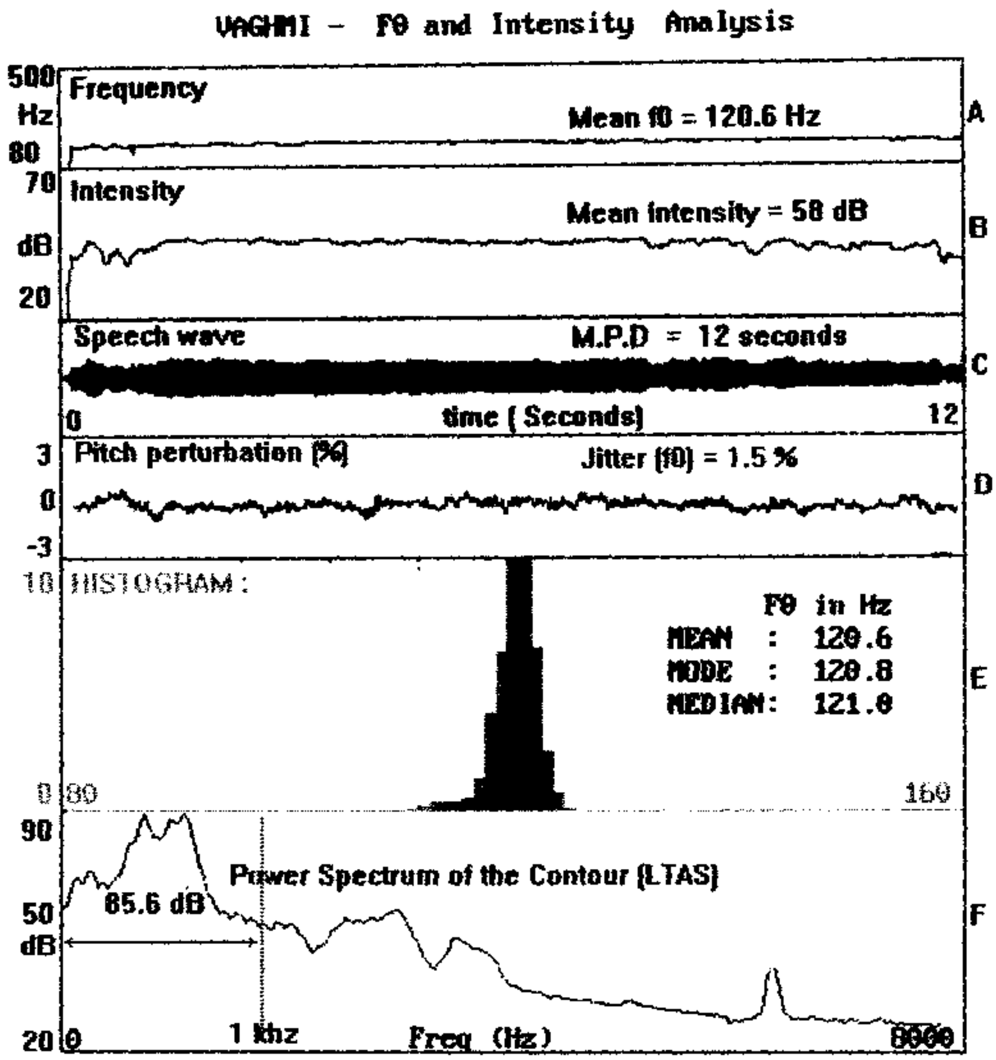

Figure 4.1: Fundamental frequency and intensity profile of the voice of a normal male speaker. The subject phonated a steady vowel /a/ at a mean fundamental frequency of 120 Hz and intensity of 58 dB for a duration of 12 seconds. Above figure has six sections A to F where, A stands for frequency curve, B for intensity curve, C stands for speech wave of the entire voice sample, D for the Jitter variations - frequency perturbations (1.5%), E shows the histogram of frequency distribution in the entire voice sample, and F depicts the long term average spectrum of the voice from 0 to 8 KHz.Tn this curve, the first peak stands for mean F0, and title subsequent peaks represent the multiples (harmonics and subharmonics) of F0. The average intensity from 0 to 1KHz (85.6dB) is highlighted in the Figure.

rameter profile of this type is a useful tool in voice analysis to quantify visually what is perceived aurally. Similar voice profiles of the dysarthric subjects have been displayed in Figures 4.2 (Parkinson's disease - female speaker), 4.3 (Huntington's chorea - female speaker), 4.4 (Huntington's chorea - male speaker), 4.5 (essential voice tremor), 4.6 (oromandibular dystonia), 4.7 (laryngeal dystonia) and 4.8 (tardive dyskinesia - male speaker). In all these figures, there are 6 sections which are denoted as A, B, C, D, E and F where A denotes (frequency curve), B (intensity curve), C (speech wave), D (jitter - frequency in percentage), E (histogram) and F (long term average spectrum).

The subject phonated a steady /a/ vowel at mean FO of 120 Hz (A) and mean intensity of 58 dB (B) for a maximum phonation duration of 12 seconds. C is a display of the steady speech wave of the voice sample. Jitter variations - FO which was 1.5% are shown in D. Histogram (E) shows a distribution of the cyclic parameter values for the whole voice sample of 12 seconds. Note that the greatest number of occurrences of FO are near the midrange value (120 Hz), whereas large deviations from the midrange occurred infrequently. In section F arc displayed the long term average spectrum of the voice from 0 to 8 kHz which is a useful display of the dominant frequencies that modulate the contour. Note that the first peak stands for mean FO of the voice, and the subsequent peaks represent the multiples (harmonics and subharmonics) of FO. In this subject, the average intensity, in the frequency range of 0 to 1 kHz, was 85.6 dB.

Figure 4.2 illustrates of the fundamental frequency (FO) and intensity profile of the voice of a Parkinsonic female subject, on vowel /a/. This subject had a mean frequency of 187 Hz (A). Note the fluctuations in frequency at the beginning and end of the curve which is not present in the normal voice profile (Figure 4.1 - A). The mean intensity of the voice was 50 dB (B), which is lesser than normal profile and the phonation duration was 6.97 seconds (C). Note the wild fluctuations in jitter (D), which was 5.5%, in this subject. A comparison of histogram (E) in Figure 4.1 and 4.2 shows a wide frequency distribution for the Parkinsonian subject. The last section (F) displays the long term average spectrum where the intensity was 70 dB in the frequency range of 0 to 1 kHz, which is significantly lesser than that in normals. In summary, the parkinsonic subject's voice profile was characterised by reduced intensity, reduced FO, reduced maximum phonation duration, wide distribution of frequency, with high percentage of jitter variation and reduced LTAS in the frequency range of 0 - 1 kHz.

Figure 4.3 shows the frequency (FO) and intensity profile of the phonation of vowel /a/ by a female subject with Huntington's chorea. This subject had FO of 242 Hz (A) and a mean intensity of 60 dB (B). Note the variation in intensity and also the intensity decay of 10 dB (55 dB - 45 dB), within a span of 3.97 seconds phonation (C). Also, note the large and wild variations in jitter (7%) when compared to the normal profile and this was more than parkinsonic voice sample. Histogram showed wide frequency distribution with more number of oc-

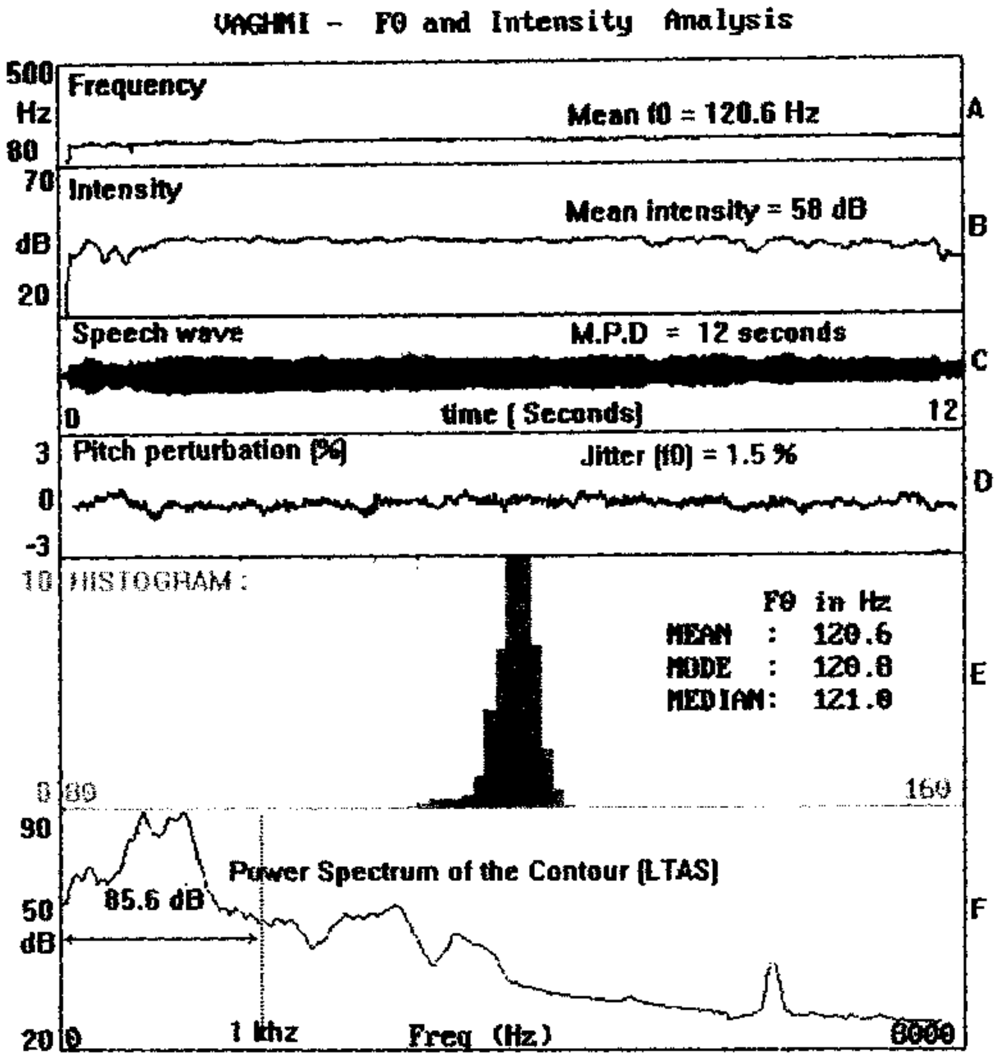

Figure 4.1: Fundamental frequency and intensity profile of the voice of a normal male speaker. The subject phonated a steady vowel/a/at a mean fundamental frequency of 120 Hz and intensity of 58 dB for a duration of 12 seconds. Above figure has six sections A to F where, A stands for frequency curve, B for intensity curve, C stands for speech wave of the entire voice sample, D for the jitter variations - frequency perturbations (1.5%), E shows the histogram, of frequency distribution in the entire voice sample, and F depicts the long term average spectrum of liie voice from 0 to 8 KHz. In this curve, the first peak stands for mean F0, and the subsequent peaks represent the multiples (harmonics and subharmomcs) of FO. The average intensity from 0 to 1 KHz (85.6) is highlightned in the figure

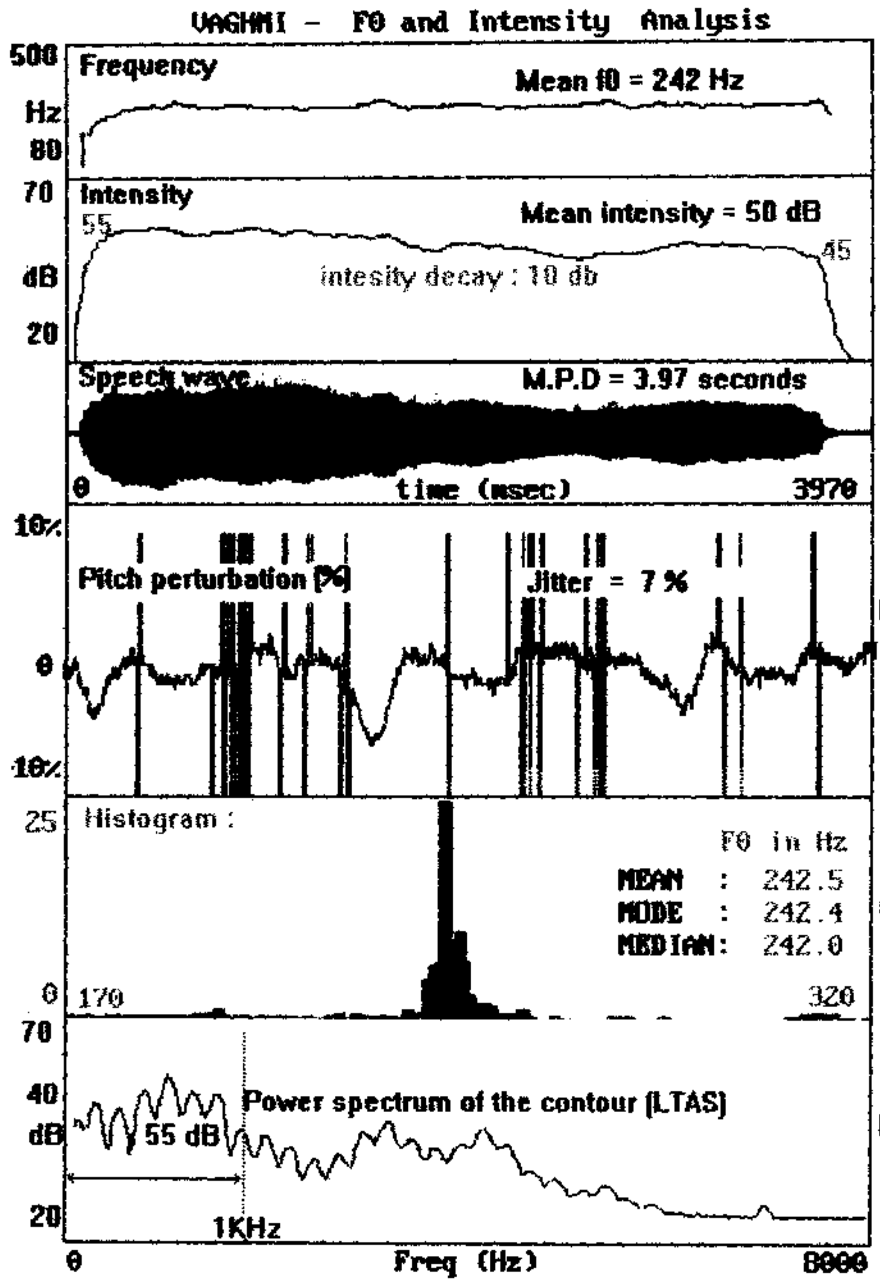

Figure 4.3: Fundamental frequency and intensity profile of the voice of a female subject with Huntmgton's chorea.

A : Frequency curve (mean FO : 242 Hz)
B : Intensity curve (mean Intensity: 60 dB)
C : Display of speech wave (MPD : 3.97 seconds)
D: Jitter-frequency pertubations (7%)

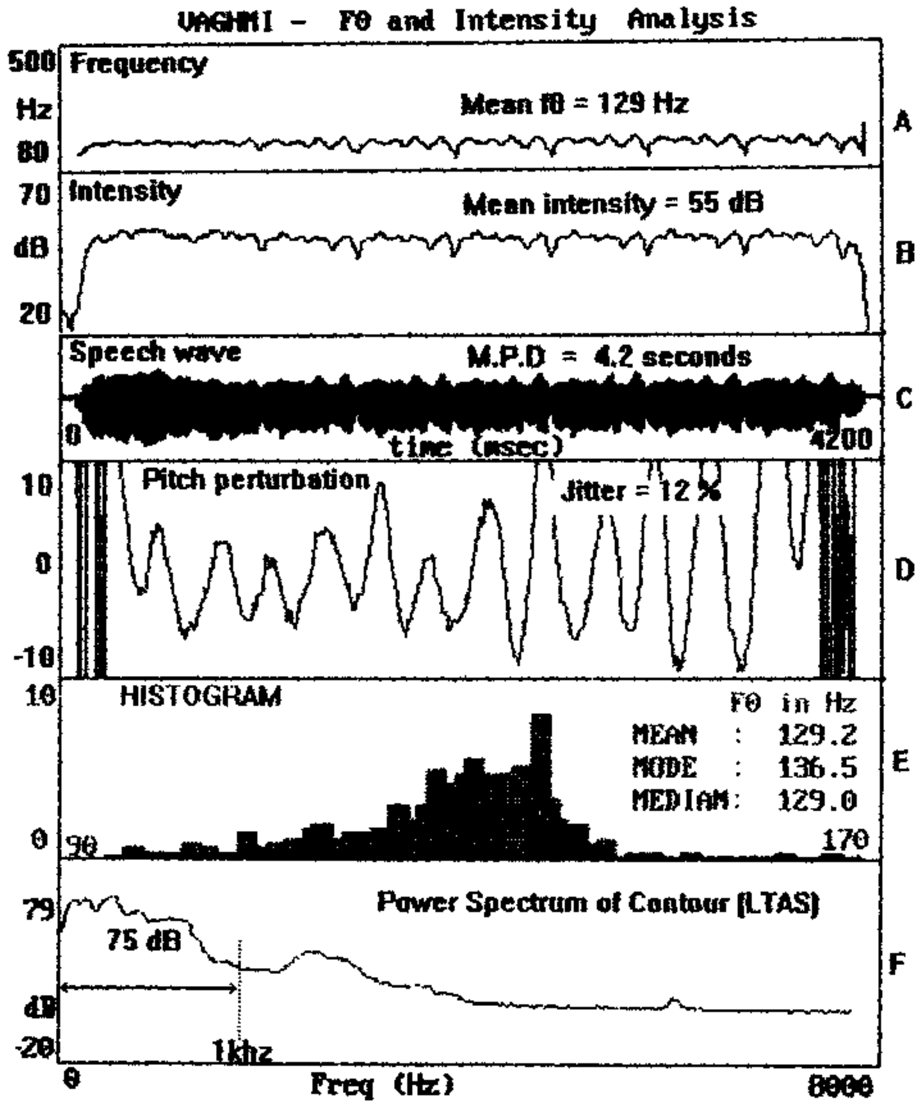

Figure 4.5: Fundamental frequency and intensity profile of the voice of a male subject with essential voice tremor.

A: Frequency curve (mean FO : 129 HZ)
B . Intensity curve (mean Intensity: 55 dB)
C : Display of speech wave (MPD : 4.2 seconds)
D : Jitter - frequency perturbations (15%)
E : Histogram of frequency distribution (90 to 170 Hz)
F : LTAS curve (average intensity :75 dB)

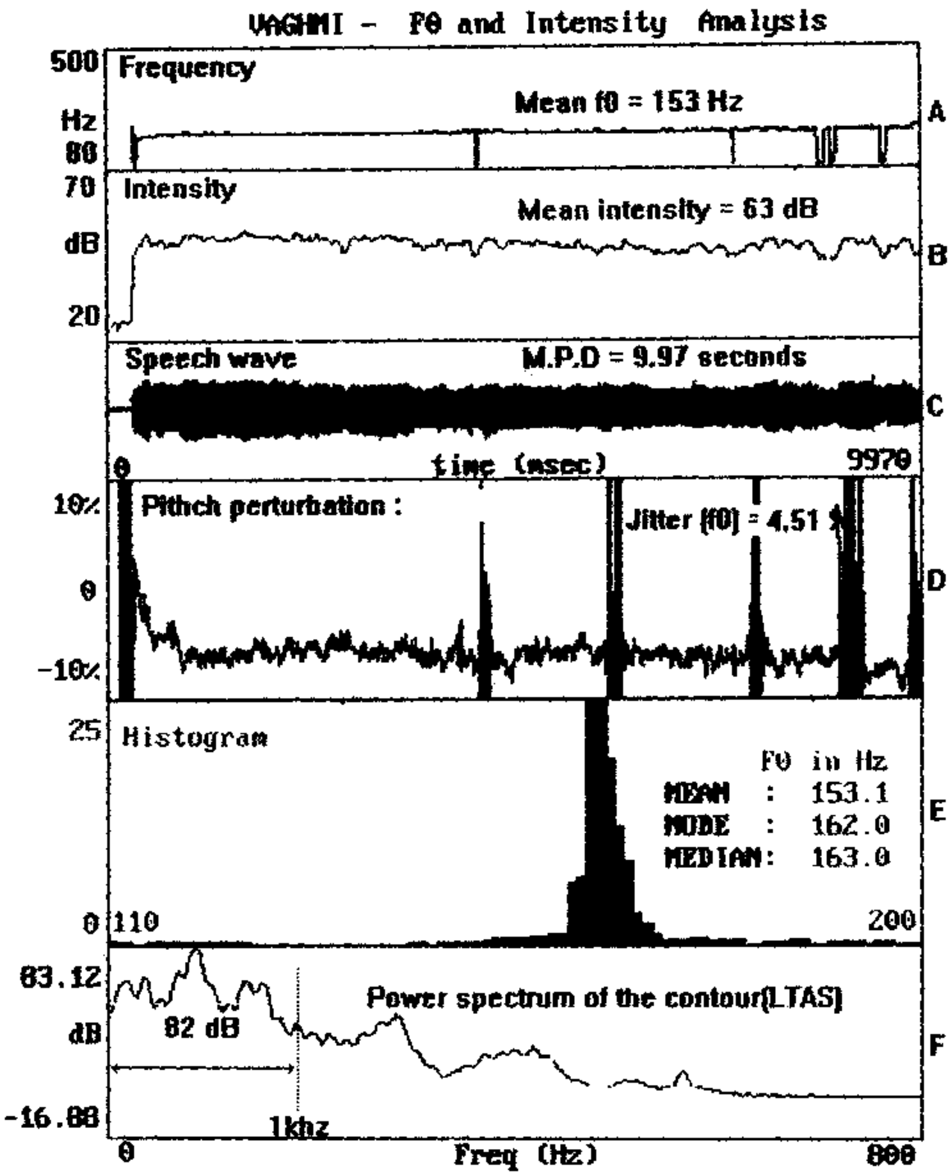

Figure 4.6: Fundamental frequency and intensity profile of the voice of a male subject with oromahdibular dystonia.

A: Frequency curve (mean FO : 153 Hz)
B : Intensity curve (mean Intensity: 63 dB)
C : Display of speech wave (MPD : 9.97 seconds)
D : Jitter - frequency perturbations (4.51%)
E : Histogram of frequency distribution (110 to 200 Hz)
F : LTAS curve (average intensity: 82 dB)

currences of FO near the midrange value. The long term average spectrum of the voice, between 0 to 1kHz, was 55 dB only (F).

Figure 4.4 illustrates the frequency and intensity profile of voice (vowel /a/) of a male subject with chorea. Note the wide variations in frequency (A) and intensity (B). These variations can be seen in the speech wave (C) also. High jitter variations (7%) were observed (D). Histogram (E) shows wide distribution in frequency. The LTAS curve (F) shows an average intensity of 85dB in the frequency range from 0 to 1 kHz which is similar to a normal profile.

Figure 4.5 is an illustration of frequency (FO) and intensity profile of the voice of a subject with essential voice tremor. Characteristic, regular and rhythmic variations in frequency (A) and intensity (B) are observable even in speech wave (C). Such rhythmic variations were not observed either in normal or in chorea subjects or in other dysarthric categories. The wide frequency distribution is displayed in histogram (E). The average intensity from 0-1 kHz was 75dB (F).

Figure 4.6 is a pictorial representation of the frequency (FO) and intensity profile of the voice of a dystonic subject (oromandibular dystonia). Note the variations in frequency (A) in terms of frequency halving and also irregular variations in intensity (B). Pitch perturbation (jitter variations) was higher (D). Frequency distribution is not conspicuous, but they are centred around 153 Hz, like in normal voice (E). The LTAS curve is similar to normal voice pattern with average intensity of 82 dB in the 0 to 1 kHz frequency range (F).

Figure 4.7 illustrate the voice profile of a male subject with laryngeal dystonia. This subject initiated sustained phonation of high frequency voice at 300 Hz which sharply decreased to 170 Hz in about 4 seconds time. Also note the frequency halving towards the termination of phonation (A). Similarly, there was high intensity variation in intensity where the intensity dropped from 67 dB to 30 dB in about 2 seconds time (B). Wild fluctuations in jitter (F0) in the beginning and termination of voice were remarkable (D). Frequency concentration was beyond the midrange and it distributed widely in the 200 Hz to 380 Hz range (E). The LTAS curve shows less number of multiples and also the average intensity was somewhat less at 73 dB (F).

Figure 4.8 shows the voice profile of a male subject with tardive dyskinesia (oro-facial). This subject had a steady voice in terms of frequency (A), but intensity variations were quite conspicuous (B). Intensity variations can be seen in the speech wave (C). The jitter variations were very high (D). The histogram shows a concentration of frequency at midrange (E). The LTAS curve show lower energy of 77 dB in the frequency range of 0 to 1 kHz, with only a few multiples (F).

4.4.3 Other Phonatory Measures

4.4.3.1 Maximum Phonation Duration (MPD)

Factors like maximum phonation duration (MPD), rise and fall time of intensity and intensity decay in the phonation were investigated. MPD is measured as the greatest length of time over which pho-

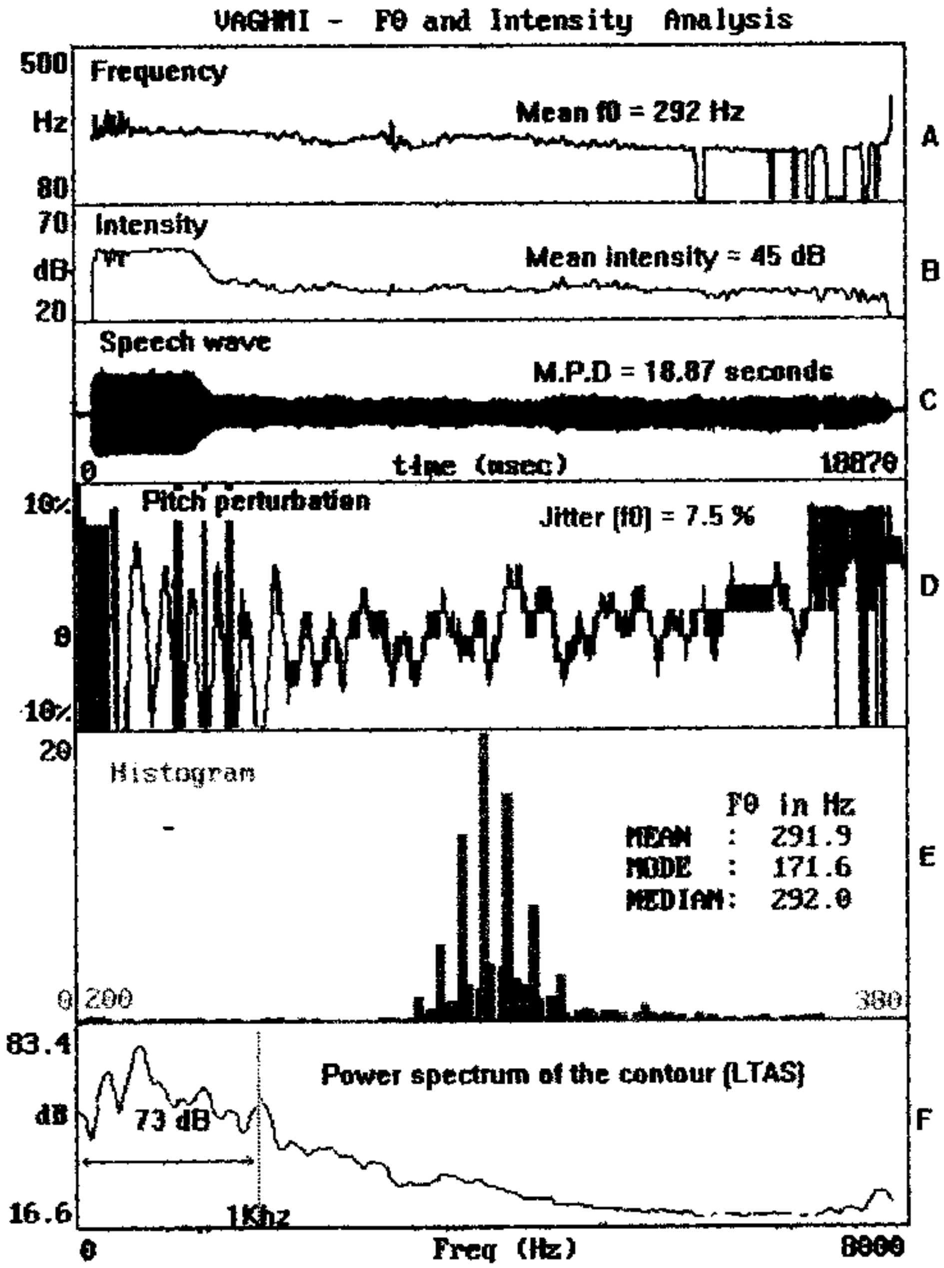

Figure 4.7 : Fundamental frequency and intensity profile of the voice of a male subject with laryngeal dystonia.

A: Frequency curve (mean FO : 292 Hz)
B . Intensity curve (mean Intensity : 45 dB)
C : Display of speech wave (MPD : 18.87 seconds)
D : Jitter - frequency perturbations (7.5%)
E : Histogram of frequency distribution (200 to 380Hz)
F : LTAS curve (average intensity 73 dB)

nation can be sustained for a vowel sound. In terms of the underlying respiratory and phonatory mechanics, the MPD task requires that the subject expend the maximum volume of air available for phonation during an effort of sustained phonation (Kent and Rosenbek, 1987). Additionally, MPD depends on the airflow through the larynx.

It was found that the hypo- and hyperkinetic dysarthrias were not significantly different from normals on these parameters. The implication is that none of these factors help in differentiating the dysarthric groups from normals. The dysarthric groups had depressed MPD, had higher rise and fall time on intensity and higher intensity decay (in hyperkinetic dysarthrias, but lower in hypokinetic dysarthrias) compared to the normals, but the differences were not statistically significant between the three groups. The rise time was defined as the time subjects take to attain a steady level of phonation after the initiation and it was measured primarily with respect to intensity. The Parkinsonian speakers were found to be slower on both rise time and fall time than normals, but the difference in mean was statistically not significant and the variability was very high. However, the slowness in Parkinsonism with regard to these two parameters is consistent with the slowness and paucity of movement generally seen in Parkinsonic patients.

The four subgroups of hyperkinetic dysarthria could not be differentiated based on these parameters. The surprising result was that the group of dystonics also could not be differentiated from the three other subgroups. It was expected that the performance of dystonics will be different from other subgroups, because, they were all lingual dystonics, and there was no clinical evidence of the involvement of the phonatory or the respiratory system in these patients. This indicated two things: (a) that either these phonatory related factors are not sensitive enough to differentiate between dysarthrics, or (b) that the involvement of the phonatory system in dysarthric conditions is more subtle than is believed hitherto. However, it must be noted that these were group means and that there was large variability in the individual data.

It was said earlier that MPD depends on the airflow through larynx. A speaker who wastes air (that is, has a large airflow) will have a shorter MPD than a speaker who has the same phonation volume, but a lower volume of airflow. MPD, by itself, cannot be said to distinguish a deficit in respiratory support (reduced phonation volume) from an inefficiency in vocal fold vibration (high airflow). In this study, dysarthrics showed a lower MPD than normals. The average difference in MPD between normals and dysarthric speakers was 2.5 seconds, but the difference between the groups was not statistically significant. However, no respiratory related measurement was done in this study. Therefore, we tentatively conclude that the respiratory and laryngeal dynamics, as reflected in the MPD task, lie outside the edge of normality in a group of dysarthrics.

Faheen et.al (1982) and Gerrat et.al (1984) have reported severe respiratory irregularities in dysarthrics. However, no respiratory related variable has been directly measured in this study. The MPD is an indirect measure of the respiratory support. In this study, the tardive dyskinetics had MPD's as large as the normals. In this limited context we report that dyskinetics may not have any respiratory irregularity. Weiner et.al (1978) have reported irregularities in truncal control, including diaphragmatic movements in patients with various forms of chorea. In the present study, patients with chorea and EVT did demonstrate a lower MPD in comparison with dystonics, dyskinetics and normals, but the difference in means were not significant. It can be said that in the EVT and chorea, the truncal and laryngeal musculature may be involved.

It is said that there will be vocal fold bowing in patients with Parkinson's disease (Hanson, Gerrat and Ward, 1984) which may result in incomplete membranous vocal fold closure (Verdolin and Palmer, 1994). The incomplete vocal fold closure might be expected to influence MPD. In the present study, the mean MPD's of the Parkinson's patients was less than that of both normals and hyperkinetic dysarthrias (on vowel /a/), but the differences were not significantly different. Therefore, it can be said that incomplete vocal fold closure because of bowing of vocal cords is a feature present during speech and that patients with Parkinson's disease perhaps override bowing for isolated vowel tasks such as those used in the present study.

Metter and Hanson (1986) reported large variation in MPD in their Parkinsonian patients, but their patients had mean MPD's with in the normal range. No definite relationship was observed between mean MPD and the degree of disability or severity of dysarthria.

4.4.3.2 S/Z Ratio

As has been repeatedly mentioned earlier, the MPD, by itself, cannot be used to distinguish a deficit in respiratory support from inefficiency in the vocal fold vibration. The ratio of the duration of a voiceless sound like /s/, and a voiced sound like *Izl,* expressed in the form of s/z ratio (Boone, 1977), has the potential to distinguish between deficiency of respiratory support and inadequacy of laryngeal valving. Boone (1977) noted that subjects with vocal fold pathology (example, thickening, polyps, or nodules) generally perform normally on the voiceless sound but abnormally on the voiced sound. That is, the s/z ratio will be around unity for speakers with normal phonatory mechanism, but larger than unity for individuals with laryngeal pathology.

In this study, the s/z ratio failed to differentiate between the normals and the dysarthric groups or between the subgroups of hyperkinetic dysarthria. The normal and the hyperkinetic groups showed values around unity, but the hyperkinetic group showed a value of 0.20 (the duration of *Izl* was longer than that of /s/ *).* This indicates that there was lack of respiratory support in the case of hyperkinetic dysarthrics, particularly in the subgroups of chorea and dystonia. Among the subgroups of hyperkinetic dysarthrias, S/Z ratio ranged from 0.60 (dyskinetic group) to 2.29 (chorea group). There was wide variation in the data as reflected in the high standard deviation.

4.4.3.3 Harmonic-to-Noise Ratio

Harmonic to noise ratio, as said earlier, is the ratio of the periodic energy at different harmonic frequencies to noise energy present at the same frequencies. It is supposed to reflect on the 'pureness' of the voice (Baken and Orlikoff, 1992). In this study, the HNR values of the dysarthric group were consistently lower than in the normal group, but the difference was not that high to be statistically significant. Among the subgroups of hyperkinetic dysarthrias, the chorea and the EVT groups had lower values than that of the dystonia and the dyskinesia groups. The HNR values in the dystonia and the dyskinesia groups were on par with those of normals, in general (an exception being vowel *I'll* in dyskinetic group). This was not surprising because the focus of dysarthria was the lingual system in the dystonic and the dyskinetic groups and perhaps the laryngeal system was only minimally involved. On the other hand, the tremor of the Parkinsonics and the EVT group and the chorciform movements of the chorea patients also involved the laryngeal system and hence, the lower HNR values in these groups. In general, these results failed to differentiate normal and the dysarthric groups.

Yanagihara (1967) developed a method to classify the degree of hoarseness into four grades, based on the noise relative to the harmonic component as seen on a spectrogram. Yuomoto, Gold and Baer (1982) have developed a new method of obtaining the ratio of the acoustic energy of the stable harmonic component to that of the noise (harmonic to noise ratio - HNR). Yuomoto, Sasaki and Okamura (1984) have shown that the HNR and the psychophysical measurement of the degree of hoarseness were positively correlated and that HNR can be reliably used as a quantitative index of the degree of hoarseness. Based on this premise, it can be said that the dysarthrics in this study did not demonstrate hoarseness in their voice. The HNR values were not significantly different between the groups in the present study. However, the HNR was suppressed in the hypokinetic and the hyperkinetic groups, in this study, in relation to normals, thereby showing that the pathological voice had more noise energy.

4.4.3.4 Long-Term Average Spectrum (LTAS)

The results on the long term average spectrum (LTAS) also failed to differentiate dysarthric groups from the normals. The difference in the mean energy levels in the 0-1 kHz range were all within the range of 0.09 to 0.86 dB for different vowels, with the dysarthric groups enjoying a slight advantage, many a times.

4.4.3.5 Frequency and Intensity Range

The range of frequency and intensity in phonation revealed that the frequency range in the case of dysarthric groups was on par with that of the normals, but the intensity range in dysarthria, specifically hypokinetic dysarthric group, was significantly less than that in the normals. Frequency range and intensity range in phonation is supposed to reflect on the phonational range required in spontaneous speech and to that extent the hypokinetic dysarthrias can be said to demonstrate monoloudncss in this study. Some Parkinsonics in this study did demonstrate monoloudness (perceptually) while some did not and this is reflected in high standard deviation.

Canter (1965a) found his Parkinsonian patients unable to produce tones as low as those of the control subjects, but the two groups did not differ significantly in the production of high vocal pitches. Kammermeier (1969) reported similar findings on pitch variability in Parkinsonian speaker the intergroup difference were not statistically significant. Canter (1963) reported that reduced intensity variability is not a significant factor in causing listeners to judge Parkinsonian speech as monotonous. In the present study, the Parkinsonian speakers had slightly reduced frequency range on a frequency glide task, but the difference between the groups was not significant. But, the patient with Parkinson's disease were significantly different from both normals and hyperkinetic dysarthrias on intensity range. Among the subgroups of hyperkinetic dysarthria the tardive dyskinetics had the smallest frequency range, while the dystonics had the smallest intensity range. But, the group means were not significantly different because of high standard deviations.

There are very few studies on the speech abnormalities in tardive dyskinesia (Maxwell et. al, 1970; Portnoy, 1979; Darley, Aronson and Brown, 1975). In general, these studies have shown that the most prominent speech deviations in these patients were related to articulatory inefficiency while phonatory dimensions came second. However, Gerratt, Goetz and Fisher (1984) showed that dyskinetic speech was characterised by a marked degree of temporal disorganization and voice production impairment relative to articulatory disturbance. Four of the 5 phonatory variables analysed were among the first 6 dimensions in the ranking by severity of impairment in their study. The results of the present study support the findings of Gerratt et.al (1984) although the mean values of different phonatory variables were not significant between groups. Though, oro-facial dyskinesia was the most widely observed characteristic in the dyskinetics of the present study, they did

show some major deviations from other subgroups on a number of phonatory parameters, most prominently on the extent of frequency fluctuations, HNR and jitter (FO).

Figure 4.9 to 4.14 are illustrations of frequency and intensity glide in different subjects. Note the decreased ability of the Parkinsonics (Figure 4.10) to achieve a wide frequency and intensity range compared to normals (Figure 4.9). Patients with chorea (Figure 4.11) were able to achieve a good range, but both the frequency and intensity ranges were limited in the EVT patients (Figure 3.12) apart from the superimposition of almost rhythmic tremor on the intensity curve. Frequency and intensity range was limited in both the dystonia (Figure 4.13) and tardive dyskinesia patients (Figure 4.14). These are typical illustrations, and in fact, frequency range was not statistically significant between the groups while intensity range was significantly lower in the Parkinsonian group compared to normals and hyperkinetics, thereby, providing some evidence for monoloudness in parkinsonic speech.

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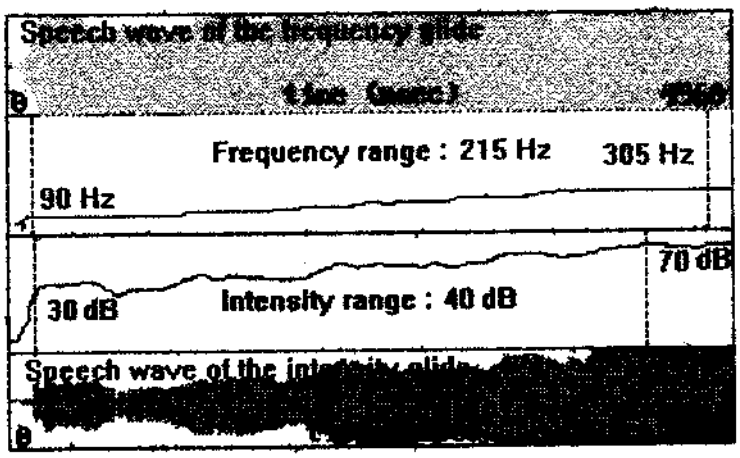


Figure 4.9 : Frequency and intensity glides of a normal male subject (phonational frequency and intensity ranges).

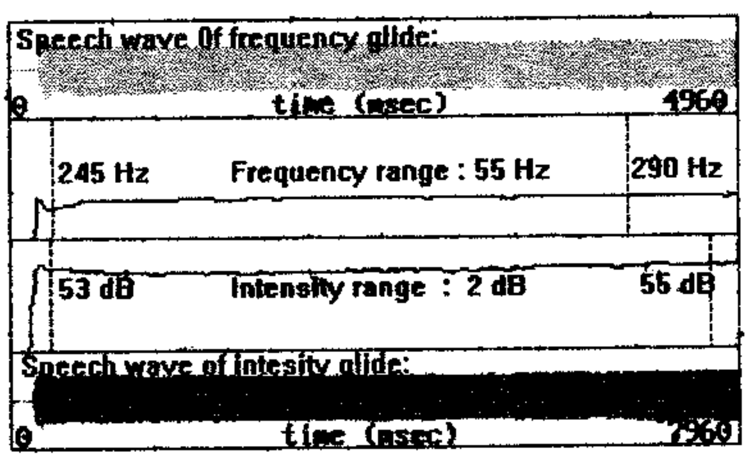


Figure 4.10: Frequency and intensity glides of a parkinsonic female subject (phonational frequency and intensity ranges).

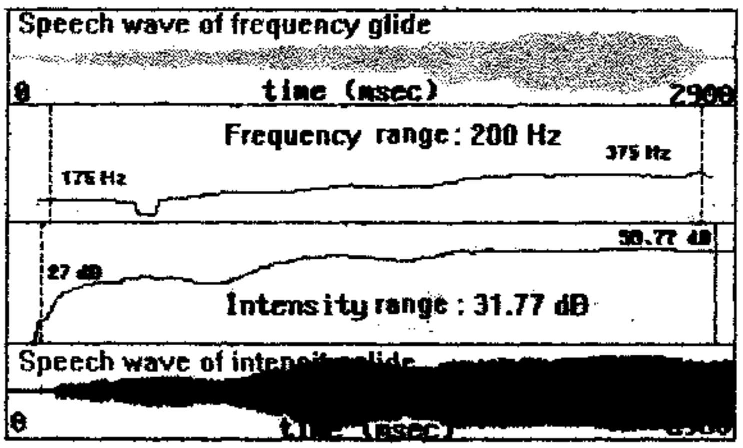


Figure 4.11: Frequency and intensity glides of a female subject with Huntbgton's chorea (phonational frequency and intensity ranges).

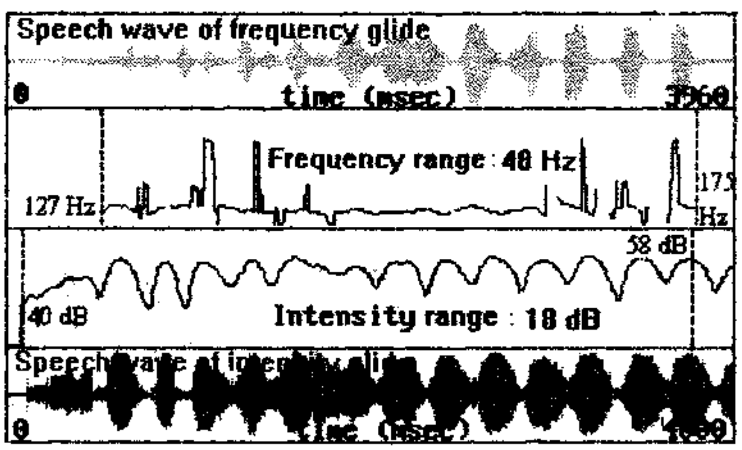


Figure 4.12: Frequency and intensity glides of a male subject with essential voice tremor (phonational frequency and intensity ranges).

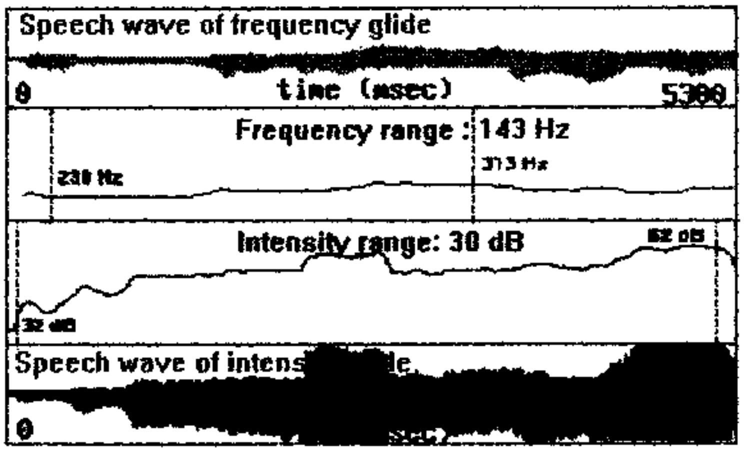


Figure 4.13: Frequency and intensity glides of a female lingual dystonic subject (phonational frequency and intensity ranges).

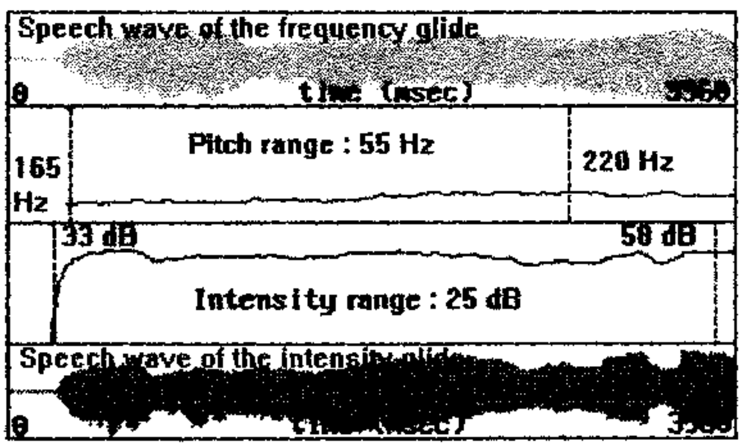


Figure 4.14: Frequency and intensity glides of a male subject with orofacial tardive dyskinesia (phonational frequency and intensity ranges).

4.4.4 Separate Analysis for Male - Female Speakers : Phonation

Most of the analysis of phonatory parameters was done on the combined data of male and female speakers. However, factors like FO, intensity, maximum phonation duration, etc., are definitely distributed differently in male and female speakers. Therefore, analysis of these parameters was carried out separately for male and female speakers. A visual inspection of the data suggested that the male and female dysarthrics were significantly different only on the mean FO. But, the question here was this : when data of male and female speakers are analysed separately, does it lead to different results for the 2 groups, in differentiating/identifying dysarthric groups? The results indicated that, on four factors, analysis of the data from male speakers led to different results from that of an analysis of data from only the female speakers. They were :

a) mean intensity on vowel /a/ : data from male speakers could differentiate between normals and hyperkinetic group, but the data from female speakers failed to do so. Combined data also differentiated between normals and hypokinetic groups (Table 3.14).

b) Jitter (T%) and Jitter (FO) : data from male speakers could differentiate between normals and each of the dysarthric groups and also between the 2 dysarthric groups themselves, but data from female speakers could not do so. Combined data could differentiate between each of the three groups including normals.

c) Shimmer in dB : data from male speakers could differentiate between normal and hypokinetic groups while combined data could differentiate between normal-hypokinetic and normal-hyperkinetic groups (Table 3.20). Data from female speakers could not differentiate between any group.

As said earlier, though there appeared to be group difference between male and female speakers in respect of F0 and maximum phonation duration, the results of separate analysis (male and female) were the same as the results of combined analysis.

The implication of these results is that combining data for male and female speakers on phonation parameters might lead to wrong results. Such an analysis is more likely to identify some female speakers as dysarthric when in fact they may not be (false positives). Further work is warranted on this.

4.4.5 . Segmental Analysis : Phonation

One of the clinical features of dysarthrias is the loss of regulatory control of movements. If there is a failure of laryngeal muscles, then one can expect the dysarthrics to have problems in the initiation and the termination of laryngeal acts. Therefore, in a sustained phonation of vowels, for example, the initial and the final segment of a sample of sustained phonation might be different from the middle segment of the sample which is more likely to be steady. Therefore, an analysis was done where the initial 15 second of the sample, final 15 second of the sample and the remaining middle segment of the sample were separately analysed and the results compared with the results from the analysis of the entire sample. Phonation of vowel /a/ was analysed in this fashion for a number of phonatory parameters (Table 3.25). The main results were as follows :

a) Irrespective of the segment of the sample analysed, the results on FO and jitter (FO) were the same, and

b) component analysis yielded similar results as that of whole sample analysis with regard to intensity, shimmer in dB, frequency fluctuations and intensity fluctuations though some components failed to duplicate the total sample results. For example, on intensity fluctuations, the results from /a/ (first 15 second sample) was different from those of other components as well as those of the total sample.

These results can be interpreted in either of the following ways depending on one's view point.

a) Since for the major part of the analysis, the results from component analysis were not different from that of total sample analysis, it is sufficient to consider the total sample as a whole, or

b) since some components, for example /a3/ - intensity and /a1/ - intensity fluctuations, yielded different results from those of the total sample analysis, the component analysis will bring additional information for the differentiation of the dysarthric groups.

However, as for as phonatory characteristics were concerned, we have seen that majority of them differentiate between normal-hypokinetic and normal-hyperkinetic, and not between hyperkinetic-hypokinetic dysarthrias. This being the case, the utility of the component analysis is doubtful. Similar analysis should be done with regard to subcategories of hyperkinetic dysarthrias where usefulness of component analysis may become more apparent. Clearly more research is called for into this issue.

4.4.6 Conclusions : Phonation

From an analysis of phonatory parameters, the following tentative conclusions can be drawn :

a) Most of the measures relating to phonatory parameters seemed to differentiate normals and on the one hand, and the hypokinetic and the hyperkinetic dysarthrics, on the other hand. Only a few parameters differentiated between hypo- and hyperkinetic dysarthrias. There seemed to be lot of overlapping in the mean scores between the dysarthric groups with the difference being 1 or 2 percentage points. Research is warranted on finding more discriminative measures of phonation.

b) It was not possible to differentiate between hypokinetic and hyperkinetic dysarthrias based on absolute measures of frequency or intensity or maximum phonation duration, among others.

c) Factors related to short term stability of vocal cord vibration like fluctuation in frequency (8 Hz variations), fluctuations in intensity (3 dB variations), jitter (T%), jitter (FO), Shimmer in dB, were some of the more effective phonatory measures which could even differentiate between the hyperkinetic and the hypokinetic dysarthrias.

d) Phonatory parameters had a deviant distribution pattern in patients like dystonia or dyskinesia in whom, as the clinical examination had shown, the lingual system was affected. Therefore, an acoustic analysis of a voice sample can identify involvement of laryngeal mechanism whose involvement would otherwise go unnoticed in the clinical examination.

e) Separate analysis of male and female speakers' voice samples is recommended for a more correct differentiation of dysarthrias. Though, there was no significant difference between males and females on a majority of the phonatory measures except fundamental frequency, a separate analysis of the results from male and female speakers yielded results different from those of the combined analysis. Combined analysis of male and female speakers may result in more number of false positive female dysarthrics.

f) Component analysis of voice samples (initial, middle and final segments of voice samples, separately) did not yield different results compared to analysis of the whole sample though there were some differences with regard to such factors as shimmer (dB), intensity fluctuations, among others. There were indications that component analysis might give additional information which are helpful in differentiating dysarthric groups.

g) The results on phonatory parameters seemed to vary with the nature of the sample analysed. For example, results from the sample of /a/ and *Iil* with regard to frequency information could not differentiate among the subgroups of hyperkinetic dysarthria while the results on sample of /u/ did so. There were many instances like this, warranting further research into this area.

The implications of these findings is that an acoustic analysis of the voice of dysarthria might show evidence of involvement of a group of musculature, such as laryngeal muscles, which is not revealed in clinical neurological evaluation. However, even an objective acoustic analysis might not be able to differentiate the different dysarthrias because of overlapping of the features. A careful selection of the sample may be helpful in this direction.

The above conclusions are subject to many limitations. The most important determining variable seems to be the sample size. Sample size in the study was too small to warrant any definitive conclusions.

The small size of the sample was confounded by the wide variations in the clinical characteristics of the patients including neurological features. There were patients in the hypokinetic group (n = 8) with tremors and without tremors; with rigidity and without rigidity and a combination of presence or absence of tremor and rigidity. It is important that all these clinical features should be identified and controlled for. Most of the times, there was a difference of only a couple of percentage points in the average values, but actually, there was a large variability in the data as reflected in high standard deviations. There is sufficient evidence in the results, of this study that if the source(s) of these variations (clinical features, mainly) are more vigorously controlled, the data on phonatory parameters might be more discriminating in nature than it is now.

4.5 Articulation

4.5.1 Speech Sound Articulation

The tongue consists of two distinct parts, each serving **a** different but specific function. The anterior 2/3 of the tongue is mobile and plays an important role in speech articulation. The posterior 1/3 of the tongue is muscular, but fixed. A lesion of the pyramidal or extrapyramidal pathways can affect the movement of the tongue which in turn may lead to misarticulation of speech sounds. This is also true in respect of other articulators like lips, soft palate etc.

Speech sound articulation was tested on three tasks in this study : on a picture word articulation test (PWAT), reading of an all-phoname passage, and in spontaneous speech. The main results on these three tasks were as follows:

a) Tasks which required spontaneity like spontaneous speech and PWAT resulted in more articulatory errors compared to reading.

b) The sounds which were misarticulated by the dysarthrics seemed to be a function of both the position of the sound in the word and the task on hand. The hypokinetic group misarticulated more on linguodentals, alvcolars and velars in the word-initial position while they misarticulated more on palatals, velars and nasals in the word-medial position. However, the hyperkinetic group misarticulated more on alveolars, palatals and vowels in the reading task irrespective of the position of sound in a word.

c) Among the subcategories of hyperkinetic dysarthria, the dystonics and the dyskinetic dysarthrics had more articulatory errors, on all groups of sounds, and in both PWAT and reading task than the EVT and the chorea groups. This was not surprising because the focus was the lingual system in three of the four dystonics and all the dyskinetics in this study. The patients with EVT misarticulated on vowels and they were predominantly of the distortion type. Perhaps the involuntary movements are responsible for the distortion errors on vowels.

d) The results from the spontaneous speech showed that the hypokinetic and the hyperkinetic dysarthria could be differentiated between each other based on the percentage of misarticulation. However, the results from the PWAT and the reading task have shown that such a differentiation is really a function of the class of sounds. Also, a differentiation based on the percentage of errors is really a matter of severity of dysarthria and that it may not have anything to do with the intrinsic characteristics of the dysarthric conditions.

e) The class of sounds predominantly misarticulated might give some information about the focus of lesion and the system involved.(For example, though all classes of sounds, except vowels, were misarticulated by dystonics, the percentage of misarticulation was consistently high in their misarticulation of alveolar, palatal and velar sounds in all the tasks. This points to the involvement of the tongue and palate and the hypoglossal and palatopharyngeal nerves. Predominant distortion errors on vowels, as in the case of EVT, might point to the involvement of vocal cords and the vagus nerve/)Consistent high misarticulation on alveolars, as in the dyskinetic group, points to the involvement of the hypoglossal nerve.

Logemann and Fisher (1981) demonstrated that a group of patients with Parkinson's disease misarticulated most on stop-plosives, affricates and fricatives. The Parkinsonics in the present study did misarticulatc more on fricatives (alveolars), affricates (palatals) and stop-plosives (bilabials and velars), but so were the hyperkinetic dysarthrics. Logemann and Fisher (1981) also reported that inadequate, tongue elevation to achieve complete closure on stop-plosives and affricates (result being stop to fricative) and inadequate close constriction of the airways to lingual fricatives (result being +plosives to -fricative) could explain the nature of the articulatory deficit. Since the subjects in the present study showed more of distortion type of errors, the explanation advanced by Logemann and Fisher (1981), may not explain the results of the present study. As the hyperkinetic dysarthrics also demonstrated more misarticulation on fricatives (alveolars) and affricates (palatals) in the present study, the explanation given by Logemann and Fisher (1981) to explain articulatory deficits in hypokinetic patients needs to be reviewed or alternate explanations need to be advanced to explain similar errors in the hyperkinetic group.

f) Though misarticulations were in the form of substitutions, omissions and distortions, the distortion type of errors were really predominant. The meaning of this result is that the dysarthrics may not find it difficult to achieve the articulatory configurations for a given sound, but that such configurations may be under- or overspecified. Probably, they do something different in the transitions from one sound to another. There is evidence to show that the dysarthrics, particularly the hypokinetics, have difficulty in achieving the articulatory positions in the word-initial position as evident by the significantly high percentage of substitutions in that position, but once the speech continues then they are likely to be under- or overshoot (more number of distortions in the medial and final sounds of the word).

Past research (Maxwell, Massengil and Nashold, 1970; Portnoy, 1979; Darley, Aronson and Brown, 1975) have generally shown that speech deviations relating to articulatory inefficiency in tardive dyskinesia. In Gerratt, Goetz and Fisher (1984) study, though the articulatory inefficiency was noted, such inefficiency was second in rating behind phonatory difficulties. The results of the present study, in general support the findings of Gerrat, Goetz and Fisher (1984) study in the sense that though the oro-facial dyskinesia was the most prominent clinical characteristic of the dyskinetic patients in this study, they did not show high percentages of misarticulations. In fact, they showed greater percentage of articulatory errors in comparison to the chorea group, but, had lower articulatory errors in comparison with EVT and dystonics. This finding is somewhat surprising in that speech sound articulation requires efficient movements of the oro-facial structures, but these were prominently involved in tardive dyskinesia. Like in Gerrat et.al. (1984) study, articulatory inefficiency seemed to be associated with the overall evaluation of reduction in the intelligibility of speech in this study also. However, it must be noted that there are many methodological differences between this study and that of Gerratt et.al (1984).

The term dysarthria implies a lack of motor control of vocal tract musculature during speech production. Involuntary movements of the articulatory structures during the steady state portion of a vowel can result in a distortion of vowel quality (Gerrat, 1983). The results of the present study on misarticulations demonstrated that majority of the articulatory errors were of distortion type. On this basis, it can be conjectured that during steady state phonation of vowels, the involuntary movements of the articulatory structures distorted the vowel quality leading to distortion type errors. However, this has not been directly investigated in this study. An analysis of formant frequency fluctuations (particularly the second formant) would have thrown more light on this issue. Abnormal movements also may interfere with the accurate placement of the articulators during consonant production, resulting in imprecise consonants. Imprecise consonants could be either substitution errors or distortion errors. Measurement of motor steadiness in the vocal tract is of particular importance in patients who have difficulty maintaining the postural stability of the structures necessary for adequate speech production. Patients with chorea, dyskinesia and even EVT do show this kind of postural instability of the articulations because of involuntary movements.

In the hypokinesia of Parkinsonism, efficiency of articulation is diminished, since the range of movement is narrowed, the speed of single movements slowed, the speed of repetitive movements increased although their range is limited, and the force of movements reduced. Grewal (1957) reported Cramer's findings in 6 patients: syllables were sometimes repeated, sometimes omitted, extrasyllables were added; phonemes lost their identity, plosives sounded like fricatives and vowels becoming undifferentiated. Canter (1965b) has also noted that Parkinsonian speakers often produced plosives like fricatives. Darley et. al., (1969b) have reported imprecise consonants and distorted vowels as the deviant articulatory dimensions in chorea which they attributed to an interference with the muscular adjustments of articulation. The dystonic speakers had the same articulatory deviations addition to irregular articulatory breakdown (Darley et. al., 1969b) which they attributed to spasmodic interference with articulation by dystonic movements. Despite the methodological difference, the results of the present study support the findings already reported in terms of distorted vowels and imprecise consonants

4.5.1.1 Consistency of Misarticulation

There was no criteria available or developed in this study to characterize consistency of misarticulations. Consistency refers to the regularity or irregularity of the occurrence of the articulatory errors on any given sound. In other words, if a sound is misarticulated, then the number of times it is misarticulated out of 100, defines consistency. For example, if the sound is misarticulated 4 out of 5 times (80% of the time) that it occurs, then it is consistently misarticulated. On the other hand, if the sound is misarticulated only 2 out of 5 times (40% of the time) that it occurs, then consistency of error is low. The implication is that if a sound is misarticulated inconsistently, it means that the speaker possesses the articulatory movements required for the production of given sound, and that misarticulations that may occur on that sound are influenced more by other factors, say phonetic context, than a lack of articulatory skills. If a sound is consistently misarticulated then it means that the basic articulatory movements required for the production of a given sound are perhaps lacking or are affected in the speaker. Probably, consistency of misarticulation is also a pointer to the severity of the problem depending on how one views it.

We adopted a wild criterion of 50% to characterize consistency of misarticulation in this study. On this basis,

a) The hyperkinetic dysarthrics seemed to be more consistent in their misarticulations than the hypokinetic dysarthrics. The hyperkinetic dysarthrics were consistent in their misarticulation of linguodentals, velars and vowels sounds. Among the subgroups of hyperkinetic dysarthrics, the chorea group consistently misarticulated on vowels, the EVT group on velars and vowels, the dystonics on linguodentals, alveolars, palatals and velars, while the dyskinetics were consistent in the misarticulation of alveolar sounds. However, this cannot be advocated as a criterion for differentiating the subgroups because the dystonics in this study were all lingual dystonics (except one) and the dyskinetics were all lingual dyskinetics. In other words, as the tongue was involved in dystonics and dyskinetics, they misarticulatcd consistently on sounds requiring tongue. It is probably the clinical feature (involvement of a particular system) that determines what sounds are misarticulated and its consistency. Therefore, a diagnostic differentiation based on the percentage of misarticulation or the class of sounds misarticulated, between the categories seems inappropriate.

The reasons for lack of consistency on the articulatpry errors in the hypokinetic groups needs to be investigated. Cranial nerves were involved in only one of the 8 hypokinetic dysarthrics, while there were

11 hyperkinetic dysarthrics in whom the cranial nerves were involved. The misarticulations in the hyperkinetic group was probably the result of direct involvement of the cranial nerves and therefore, the misarticulations were consistent. Another reason could be the duration of the speech problem in these dysarthrics. The hypokinetic dysarthrics had speech problems for an average duration of 1.34 years while the hyperkinetics, depending on the particular subcategory, had speech problem for as long as 6 years. It could be that the problem was more developed and established in the case of hyperkinetic dysarthrics than it was in the case of hypokinetic dysarthrics.

4.5.1.2 Conclusion : Speech Sound Articulation

From an analysis of the results on misarticulations the following tentative conclusions can be drawn :

a) Though it was possible to differentiate between hypo- and hyperkinetic dysarthrics and among the subcategories of hyperkinetic dysarthrias based on the mean percentage of the misarticulations, it really is a function of severity of the problem, class of sounds under consideration, and the system involved.

b) All the dysarthric patients misarticulated almost on all groups of sounds, but a pattern was visible in this. The hypokinetic group misarticulated more on alveolars and velars while the hyperkinetic dysarthrics misarticulated more on alveolars, palatals, velars and vowels; the chorea and the EVT group misarticulated more on vowels; the dystonics misarticulated on all classes of sounds except nasals, while dyskinetics misarticulated on alveolars and velars. This again seems to be a function of the oropharyngeal involvement because in the dystonics and dyskinetics of this study the lingual system was involved and therefore, it is quite natural that they would misarticulate on alveolars and velars (middle of the tongue to be raised to touch the palate).

c) Majority of the misarticulations were distortion type errors in both groups of dysarthrics.

d) The dystonics seemed to be the most consistent in their misarticulations of different classes of sounds. The hypokinetic dysarthrics seemed to be highly variable and inconsistent in their misarticulations.

e) The dysarthrics with chorea and EVT demonstrated a high percentage of misarticulations on vowels. Majority of these misarticulations were distortion type errors. The role of the articulatory and laryngeal systems in the perpetuation of this kind of error needs to be investigated because there was nothing in the clinical examination which suggested involvement of the laryngeal system in the chorea patients and the involvement of the articulatory system in the EVT patients.

With regard to these tentative conclusions, we again draw the readers' attention to some of the limitations of the study which we have summarised in respect of phonatory factors (page ..). There was large variability in the data with high standard deviations which is a reflection of both the sample size and variability in patient's characteristics (clinical features) in any group.

4.5.2 Diadochokinesis

4.5.2.1 Diadochokinetic Rate of Repetitions

Rapid syllabic repetitions require alternating articulatory movements and, thus provide a test for oral diadochokinesis. The present study performed an acoustic analysis of rapid syllable repetitions. DDK repetitions are usually analysed for rate, irregularities of temporal patterns, and variations in intensity and frequency. This is appropriate because, in dysarthrias, the integrity of neural control of articulators is suspect. In this study, the rate of syllable repetitions, variations in intensity, frequency and duration of repetitions, as well as the interval between successive repetitions were analysed. Rate of repetitions of monosyllables, bisyllables and trisyllables were analysed. Furthermore, two types of trisyllabic sequences were used:

a) CVCVCV sequences where the vowel was held constant in the context of 3 different consonants. For example, /pa ta ka/, and

b) CVCVCV sequences where the consonant was held constant, in the context of throe different vowels. For example, /pi pa pu/. Repeated syllables with different vowels verify the patients ability to distinguish between different members of the vowel space.

Altogether, 10 monosyllabic, 7 bisyllabic sequences and 8 trisyllabic sequences were analysed for rate of repetitions, while the repetitions of only 7 monosyllables were analysed for variations in intensity, frequency and duration. Also, monosyllabic repetitions were analysed with and without bite block for rate.

The mean rate of monosyllabic repetitions for consonants consistently differentiated hypokinetic and hyperkinetic dysarthrias from normals, but not between the 2 dysarthric groups themselves. The repetition rate was lower for all syllables, in the hypo- and hyperkinetic groups compared to the normals, thus showing the influence of neurological involvement. The repetition rate of different vowels was significantly different from that of consonants, but this was true in all the 3 groups including normals, thus indicating that it has no clinical significance. The repetition rates of monosyllables were not significantly different between the subgroups of hyperkinetic dysarthria. The implication is that rate of repetitions of monosyllables, without bite block, is not an effective measure in distinguishing between the subgroups of hyperkinetic dysarthria.

As for as Parkinson's patients arc concerned, controversial findings on DDK rate have been reported including slowed, normal or even accelerated rates (See Ackermann and Ziegler, 1989 for a review). Normal variability of syllable duration have been reported in Parkinson's disease (Tatsumi et.al, 1979) while slowed alternating oro-facial movements have been reported in patients with Huntington's chorea (Ludlow, Connors and Bassich, 1987).

The results of the present study suggested that the DDK rate for all monosyllables (except vowels) was significantly lower in the dysarthric groups compared to normal controls. This was true in the case of bisyllables and trisyllables, but the tendency was not consistent. In general, the results of the present study on DDK rate are similar to those reported for Parkinson's disease and Huntington's chorea. At the articulatory level, the syllable repetition trains consist of successive opening and closing gestures. Thus, the slowed movement execution and delayed transition between successive movements might contribute to the reduced repetition rates.

Bradykinesia and delayed transitions have been documented for upper limb movement control in patients with Huntington's chorea (Thompson et.al, 1988). Conceivably, the same deficits affect the speech apparatus as well in Huntington's chorea as giving rise to slowed articulatory performance. Slowed movement execution (bradykinesia) is also a well known feature of Parkinson's disease, and in fact, bradykinesia has been documented within the speech apparatus in Parkinson's disease (Forrest, Weismer and Turner, 1989).

Kinematic analysis has provided direct evidence of reduced and slowed articulatory movements particularly of the lips and the jaw in patients with Parkinson's disease (Hirose, Kiritani and Sawashima, 1982; Connor et.al, 1989). The impairment in running motor programme seem to be closely related to the degree of clinical bradykinesia (Marsden, 1989). Most of the Parkinson's patients evidenced clinical bradykinesia and this being the case, one would have expected the DDK repetitions of syllables involving lip and jaw movement to have been affected. The hyperkinetic and hypokinetic dysarthrics showed lower mean DDK rate on monosyllables than normals. This indirectly suggest that basal ganglia and motor subcortical structure control of speech movements and other motor movements may be similar. However, in the absence of any direct experimental verification, this must be considered hypothetical.

It was possible to differentiate between hypokinetic and hyperkinetic dysarthrias on the basis of the results of the present study on repetition rate of bisyllables. The average rate of repetitions of bisyllabic vowels was the highest in the hypokinetic group followed by normals and the hyperkinetic group, in that order. Average repetitions of bisyllabic CV sequences in the hyperkinetic group was lower than that of hypokinetic group which in turn was less than that of the normal group. When offset of phonation was not required as in the case of repetitions of monosyllabic vowel repetitions or bisyllabic vowel combinations, the hypokinetic group performed on par with, or even better than, normals. But when the production required phonatory offset and onset (as in /pata/, /paka/), the performance of the hypokinetic group was significantly lower than that of the normal group. Thus, it shows that the laryngeal mechanism was involved in the hypokinetic dysarthrics.

The results on the rate of repetitions of trisyllabic sequences were similar to those obtained on the repetitions of bisyllables. The trisyllabic repetition rate was similarly distributed as the bisyllable repetition rate in the sense that it was possible to differentiate hypokinetic from the normal, hyperkinetic from the normal as well as hypokinetic from the hyperkinetics. The last distinction was possible only with some sequences and it was not consistent.

The mean values of the repetition rate of bisyllables and trisyllables in the different subgroups of hyperkinetic dysarthrias were unremarkable. The subcategories of hyperkinetic dysarthrias could not be differentiated based on the mean repetition rate of bisyllabic vowel or CVCV sequences except on /pa-ka/. A result to be noted is that when phonatory off-on was not involved as in bisyllabic vowel sequences, the EVT group performed better than the dystonic group, but when phonatory off-on was required (CVCV sequences), the performance of the EVT group was poorer than that of the dystonia group.

The results of the present study on repetitive rates of monosyllables are in agreement with those of Dworkin and Aronson (1986), who found that the group of dysarthrics in their study (ataxia, Parkinsonism, spastic, flaccid, ataxies, hyperkinetic and mixed) produced significantly slower and more irregular rates on all CV syllables in comparison to the normals. However, the difference in the mean rates and mean durations or gaps in the present study was not always consistent on all syllables. In the Dworkin and Aronson study, the different subgroups of dysarthrics could not be differentiated from each other based on alternating motion rates.

Canter (1965b) studied the oral DDK in 17 parkinsonic patients and reported 'complete freezing' and 'partial freezing' to refer to the fact that patients were unable to produce the rapid movements discretely. Rather than a series of distinct syllables, a continuant sound was produced. Ewanowski (1964) and Kreul (1972) reported no significant difference between Parkinsonian and normal control subjects on mean DDK rate. Kruel (1972) used two DDK measures not used by other investigators: repetitions of vowel /ee/ and repetition of vowel sequence /oo-ee/. The farmer is a measure of laryngeal rather than of articulatory activity. On both measures Kreul's patients (Parkinsonian) produced significantly slower rates than the two control groups studied (young and old normals subjects). The patients also were dysrhythmic in their productions and maintained intensity level less efficiently.

In the present study, we also found some evidence for 'partial freezing', but it was not consistent, and it also was evident in non-Parkinsonian patients. Unlike Ewanowski (1964) and Kreul (1972), all dysarthrics in the present study including Parkinson's patients, showed significantly slower repetition rate on CV syllables. On the vowel repetitions, there was no difference between normals, hypokinetic and hyperkinetic dysarthrics in the rate of repetition in the present study, but on the repetition of vowel combinations, the hyperkinetic dysarthrics were significantly slow on 2 of the 3 combinations (/a-i/ and /i-u/; the other being /u-a/) than the hypkinetic group.

Figure 4.15 illustrates DDK repetitions in different dysarthrias - normal speaker (/pa/ - A), Parkinson's disease (repetitions of /pa/ -

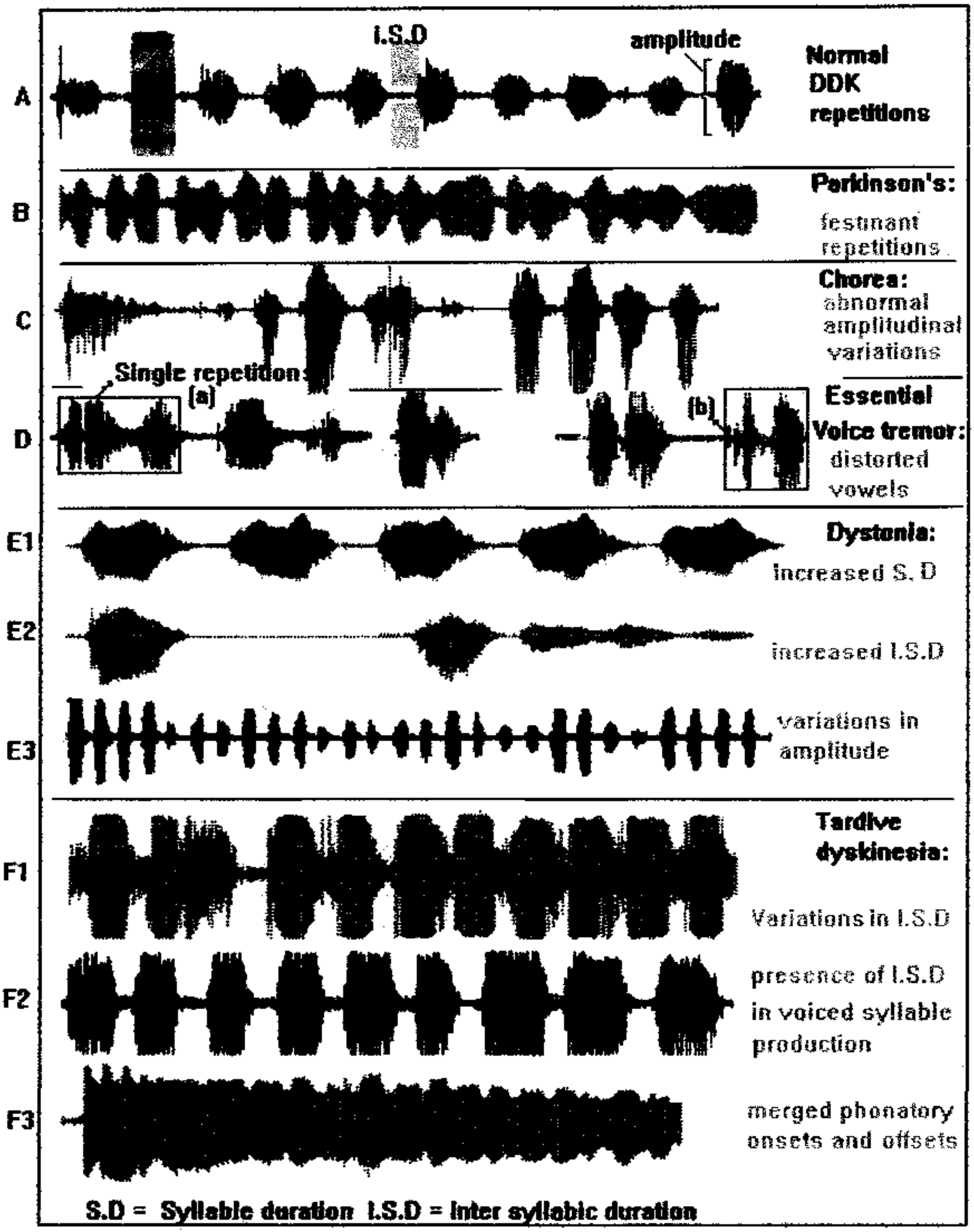


Figure 4.15 : DDK repetitions in normal and dysarthric subjects.

B), Huntington's chorea (repetitions of /ga/ & /ba/ - C), EVT (D), dystonia (/pa/- El to E3). tardive dyskinesia (/ba/ - Fl to F3. Note the increased syllabic duration (SD) in El and the increased intersyllabic duration (ISD) in E2.

Figure 4.16A shows the DDK repetitions along with a speech wave display and a wide band spectrogram. 4.16A shows the **DDK** repetitions of /pa/, in normal speakers. Note the regular syllable (SD) and intersyllabic durations (ISD). Figure 4.16B shows the DDK repetitions of syllable /ka/ in a parkinsonic subject. The syllable duration and intersyllabic gaps were similar to those found in the DDK repetitions of normal speakers. Figure 4.16C shows the DDK repetitions of /pa/ of another parkinsonic subject. This display provides some evidence for festinant repetition rate in some parkinsonic speakers. Figures 4.16B and 4.16C are ample testimony to the wide variability in speech characteristics found in parkinsonic subjects.

Figure 4.17 illustrates the DDK repetitions of /ka/ (top) and /ga/ (bottom) of a subject with essential voice tremor. The point to be noted in this figure is the prolonged syllable duration of each vowel cognate [see speech wave (B) and the corresponding spectrogram (A)], and the superimposition of fine tremor on the repetitions.

4.5.2.2 DDK Repetition Rate with and Without Bite Block

The mean rate of repetitions of monosyllables with bite block was unremarkable except that the rates with bite block were all de-

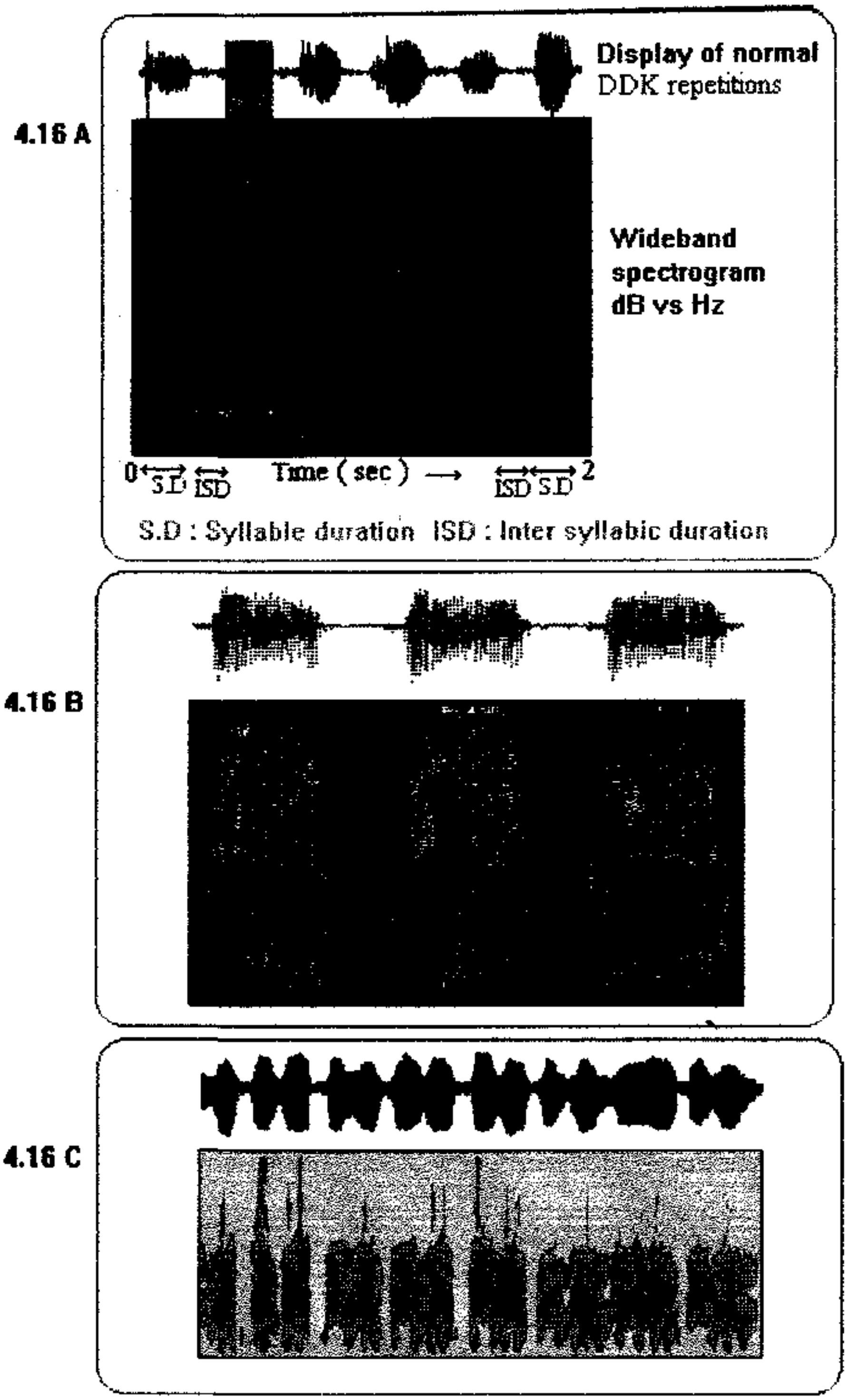


Figure 4.16 : Speech wave display and wide band spectrograms of DDK repetitions of the subjects :

A : Normal subject's monosyllabic repetitions of /pa/

B : Parkinsoric subject's monosyllabic repetitions of /ka/

C : Another parkinsonic's syllabic repetitions of /pa/

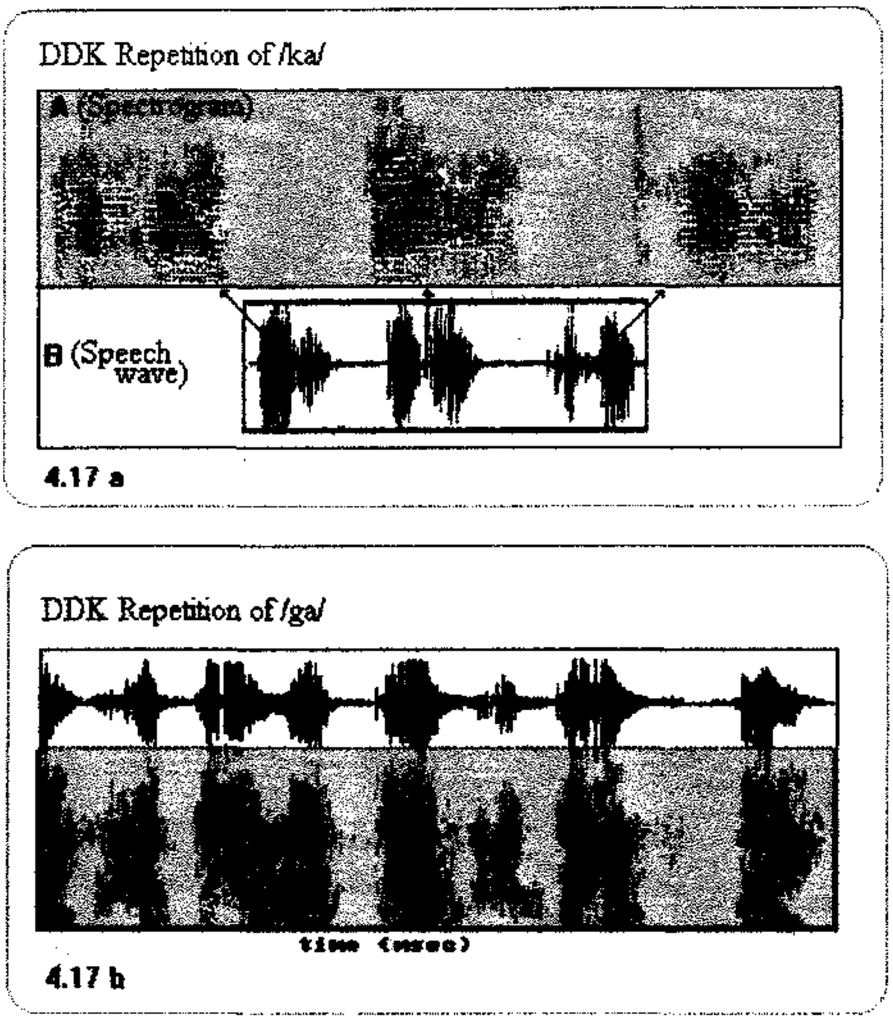


Figure 4.17 a,b : Illustration of the DDK repetitions of /ka/ (top picture) and /ga/ (bottom picture) of a subject with essential voice tremor. Note the elongated syllable duration on each vowel cognate of the syllable [see the speech wave (B) and the corresponding spectrogram (A)], and the superimposition of fine tremor on each repetition.

creased compared to the rates without bite block. This was true of normal speakers also. The mean repetition rates were not significantly different either between the main groups or between the subgroups of hyperkinetic dysarthria. This only shows that all speakers, including normals, make use of the jaw movements in the repetitions and when the influence of jaw was offset by bite block, the repetition rate decreased.

An analysis was also done wherein the repetition rate of monosyllables without bite block, in different segments of the repeated sample, was compared between the groups. Specifically, DDK rate in the first 5 seconds, in the first 1 second and in the last one second were compared. This was done on the premise that dysarthrics may have difficulty in initiating and terminating speech. This analysis was made also to see if patients maintain the same rate of repetition over the production duration. The difference in the rate of first 1 second and last 1 second would provide this information. It has been reported that in some patients the rate might decelerate, while the patients with Parkinson's disease it might accelerate.

4.5.2.3 DDK Rate : Segmental Analysis

The comparison of segmental rates yielded similar results as the entire sample as far as the differentiation of the three main groups was concerned. The segmental means were not statistically different between the subgroups except the ones pertaining to the first one second segment of /ta/ and the last one second segment of /ba/. In general, the segmental analysis of the repetition rates revealed that different portions of the DDK samples will not yield different results than that available form the whole sample as far as rate of repetitions is concerned in a group of dysarthrics. Also, an analysis of the difference in the rate of repetition in the first and last 1 seconds, and its comparison with the rate in the middle segment or the overall rate did not support the often reported observation that the Parkinson's speech shows acceleration. In fact, for majority of syllables tested, the rate in the first 1 second was marginally higher than the rate for the last 1 second, although the differences were not statistically significant.

Figure 4.18 illustrates segmental analysis of the DDK repetitions of a normal speaker (A) and Parkinson's subject (B & C). Figure 4.19 illustrates the segmental analysis of DDK repetitions of two subjects with Huntington's chorea (A & B). Note the sharp reduction in the number of repetitions in the last 1 second compared to the first 1 second in Figure 4.19B. Figure 4.20 pictorially depicts the difference in the number of repetitions in the first 1 second and last 1 second segments of repetition trains of 3 subjects with voice tremors (A,B & C). Figure 4.21 is a similar illustration in the case of tardive dyskinetic speakers. The difference in the number of repetitions in the first and the last segments are sharper in this instance.

4.5.2.4 Durations of Syllables in DDK Repetitions

The repeated syllable task examines the capacity to impose particular durations on the articulation sequence. Following an instruc-

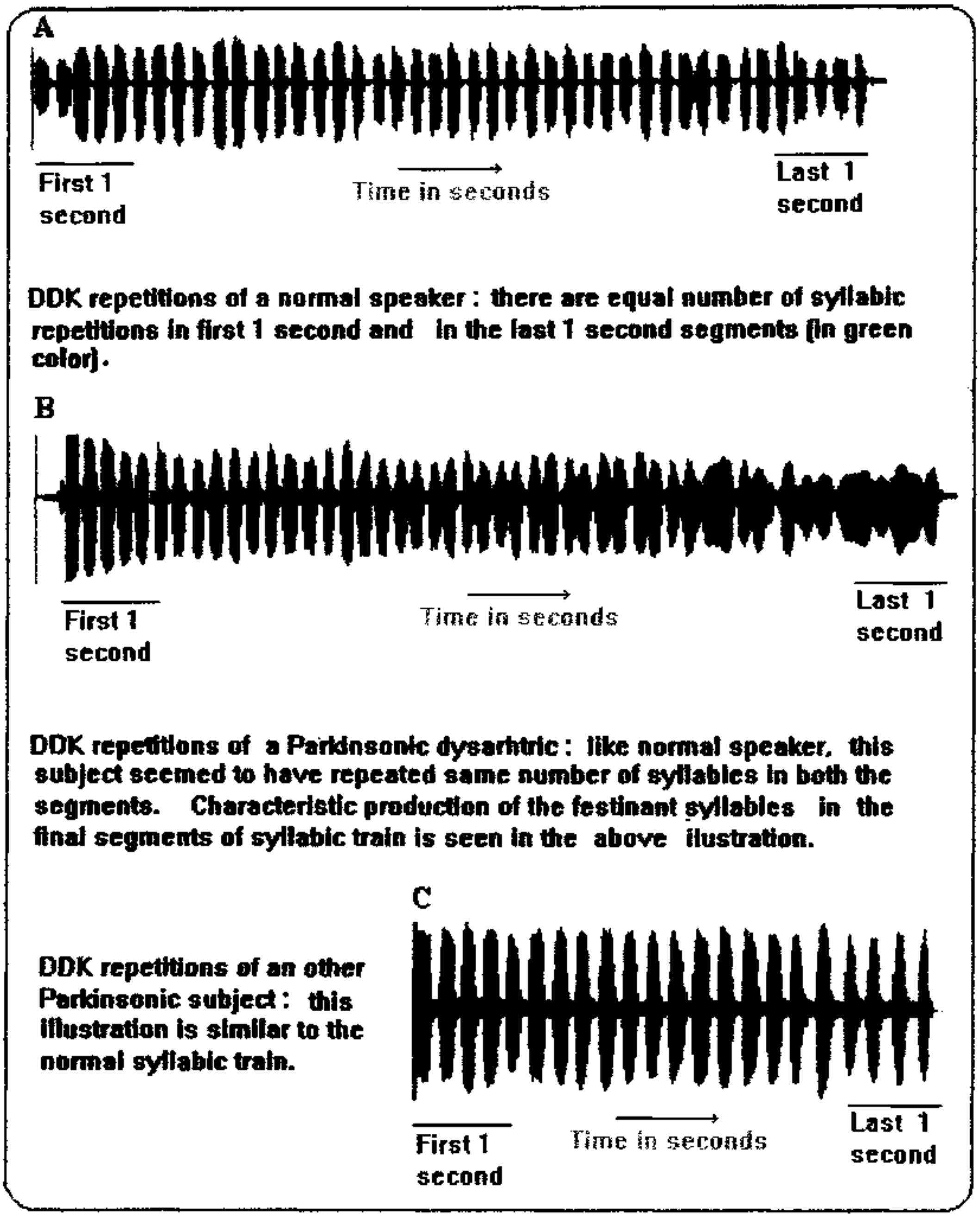


Figure 4.18 : Segmental analysis of the DDK repetitions of a normal speaker (A) and Parkinson's subjects (B & C).

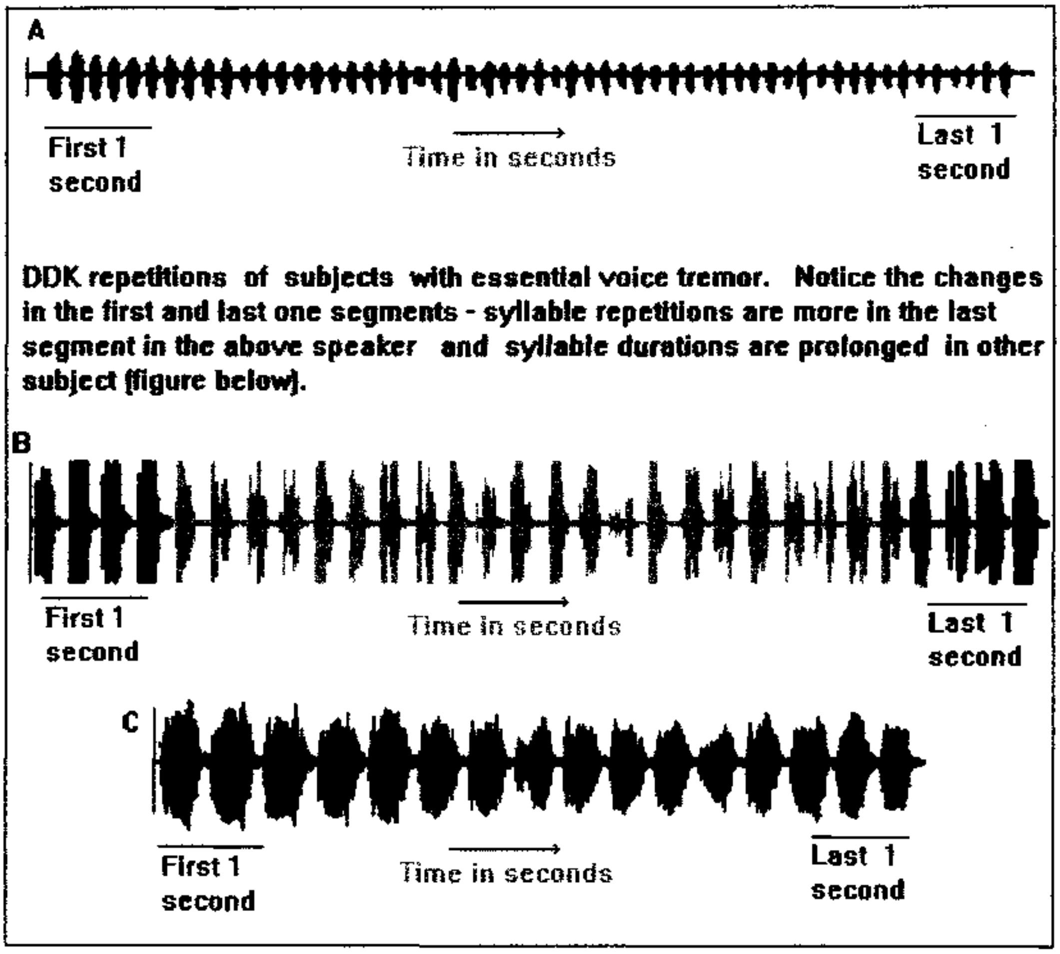


Figure 4.20 : Segmental analysis of DDK repetitions of three subjects with essential voice tremors (A, B and C). Observe the difference in the number of repetitions in the first and last second of the syllable trains.

Figure 4.21 : Segmental anljrsis of the DDK repetitions of two subjects with oro-facial tardive dyskinesia (A and B). Note the reduction in the number of repetitions in the last 1 second segment when compared with the number of repetitions in the first 1 second segment of the syllable trams.

tion to 'speak like a metronome', the normal subjects show a degree of variation on syllable durations, and they produce repetitions at rather regular intervals (Keller, Vigneux and Laframboise, 1991).

The mean syllable durations in monosyllabic repetitions were not significantly different between the groups. There was a difference ranging from 30 msecs to 47 msecs, over different syllables, between the absolute mean values of the normal and the hypokinetic group and from 6 msecs to 25 msecs between the hypokinetic and hyperkinetic groups. Still the difference in means between the groups were not significant probably because of high variability in data in all the groups, more particularly in the hyperkinetic group (high standard deviations).

In spite of the lack of statistical significance, we are of the opinion that the results of the present study on the duration of syllables in a repetition task support the often observed inability of the dysarthrics to maintain constant syllable durations in a DDK repetition task.

Much of this variability in the mean durations in the hyperkinetic group was contributed to by the dystonic group (standard deviation was high in other subgroups too, but especially high in the dystonia group). Therefore, the durations of individual repetitions might be a potential measure which can differentiate between the dysarthric groups provided the source of high variability is controlled by careful selection of a more homogeneous sample. However, this needs to be further investigated.

One of the few studies to consider quantitatively the factor of temporal irregularity in the DDK task was that of Portnoy and Aronson (1982) who recorded syllable repetitions from 90 speakers, 30 in each of the 3 groups of normal, ataxic and spastic dysarthrics. Irregularities of temporal and intensity patterns in repeated syllable sequences were studied by Tatsumi, et. al. (1979) who made the following measures from DDK repetitions of syllable /pa/ for normal, ataxic or Parkinson's diseased speakers : (a) mean syllable duration, (b) standard deviation of syllable duration, (c) standard deviation of the relative values of the maximum vocal intensity, (d) perturbation of syllable duration, and (e) perturbation of maximum syllable intensity. Tatsumi et.al (1979) found that ataxic and Parkinson's speakers were distinguished by these measures. The ataxic speakers tended to repeat syllables at a slow rate and with marked irregularity in both temporal and intensity pattern, while the Parkinson's patients were more like normal speakers. Though there are many methodological differences between this and Tatsumi et.al (1979) study, the results on syllable intensity and syllable duration in this study support the findings of Tatsumi et.al (1979) with Parkinson's subjects.

Durational irregularity during oral diadochokinesis tasks is generally considered a prominent sign of ataxic dysarthria (Portnoy and Aronson, 1982; Gentil, 1990). Pronounced durational variability on DDK tasks has been documented by Ackermann, Hertrich and Hehr (1994) in a group of Huntington's chorea. It has been explained on the basis that choreic muscle twitches within the motor speech apparatus account for this increased variation coefficient.

4.5.2.5 Intersyllabic Gap : DDK Repetitions

Similar high variability was the significant feature of the data on the durations of gaps between the repetitions. However, in this instance the mean gap durations of repetitions of /pa/ and /ja/ could actually differentiate between the normal and the dysarthric groups. Again, there was high variability in the data of the hyperkinetic groups and there was evidence to show that this was contributed to mainly by the high variability of data in the dystonia group.

The results of this study on intersyllabic intervals on a DDK task support the observation that dysarthrics, particularly the hyperkinetic dystonics) fail to maintain regular intersyllabic intervals.

Figure 4.22 illustrates variations in DDK repetitions of lingual dystonic subject in terms of intersyllabic duration which is varying - sometimes increased and decreased (4.22A), increased syllable duration (4.22B) and distorted vowel production (4.22C). The spectrograms help in the accurate measurement of syllable duration and intersyllabic gap.

4.5.2.6 Frequency and Intensity Variations : DDK Repetitions

It was not possible to differentiate between the normal and the dysarthric groups based on the mean peak intensity levels of repetitions of monosyllables except from the data on syllable /ga/ which

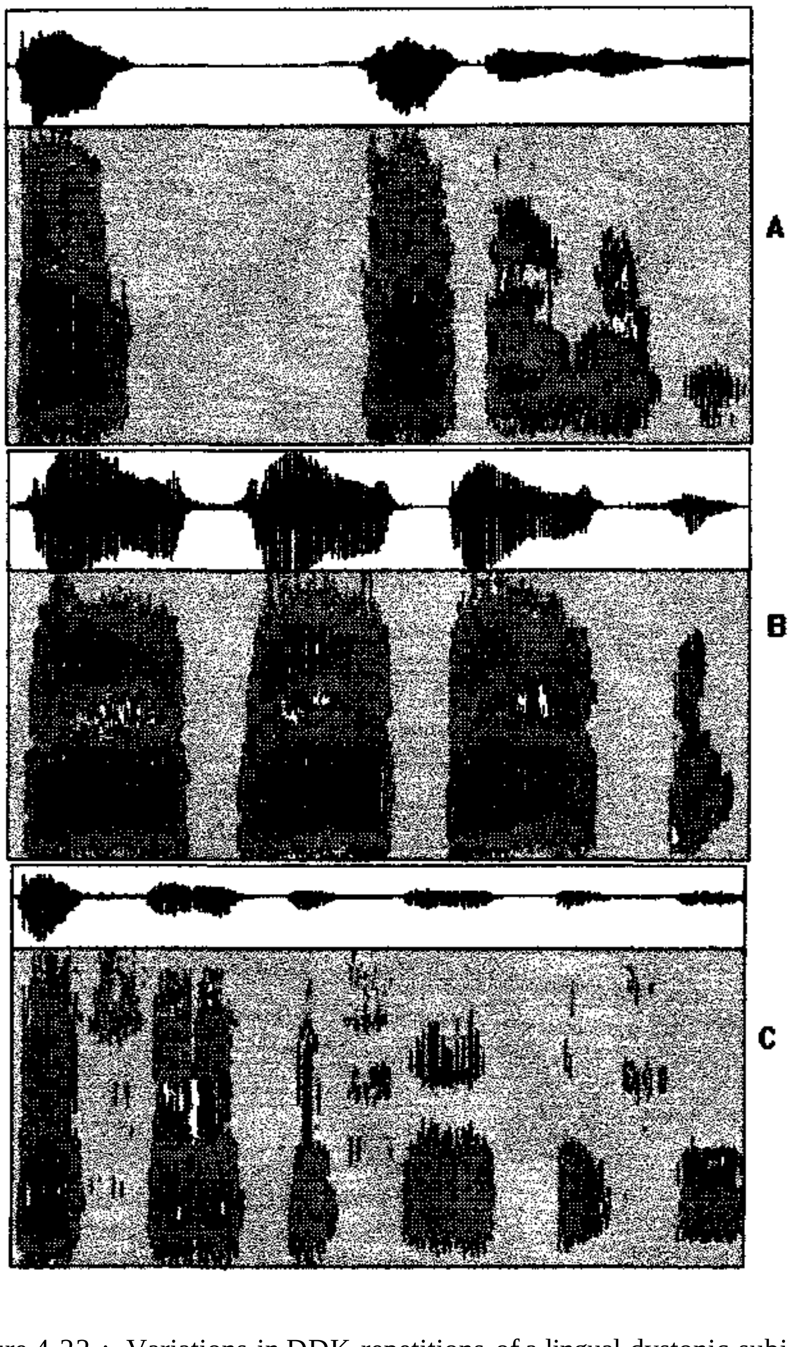


Figure 4.22 : Variations in DDK repetitions of a lingual dystonic subject in terms of intersyllable durattion which is varying - sometimes increased and decreased (picture A), increased syllable duration (picture B) and distorted vowel production (picture C). The spectrgrams help in the accurate measurement of durations.

might be an exception. The difference in the average peak intensity of repetitions for different syllables, between the normal and the different dysarthria groups (including the subgroups) was in the range of 1 to 4 dB.

Mean peak frequency of repetitions was significantly different between the main groups. The difference between the normal - hypokinetic group and the normal - hyperkinetic groups was statistically significant for 5 of the 7 monosyllables. Again, there was high variability in the data, of both the hypokinetic and hyperkinetic groups. Among the subgroups of hyperkinetic dysarthria, the variability in the data was more pronounced in the case of the dystonic group.

Figure 4.23 shows the DDK repetitions of a dystonic speaker. Note the amplitude variations in the repetitions of /ta/ (4.23A) and prolonged syllable duration (and distorted too) in 4.23B. Figure 4.24 illustrates variations in DDK repetition trains of a laryngeal dystonic speaker. Figure 4.24A shows the frequency and intensity analysis of repetitions of /ka/ wherein wild variations in peak frequency and of peak intensities are evident. Figure 4.24B shows increased syllable duration while 4.24C shows the distinct intersyllabic gaps even in the repetition of a voiced syllable like /ba/ on which continuous voicing could be expected.

Figure 4.25 illustrates variations in the DDK repetitions of a dyskinetic speaker. 4.25A shows the distinct gaps (intersyllabic) on the repetition of a voiced syllable /ba/; 4.25B shows the variability in the

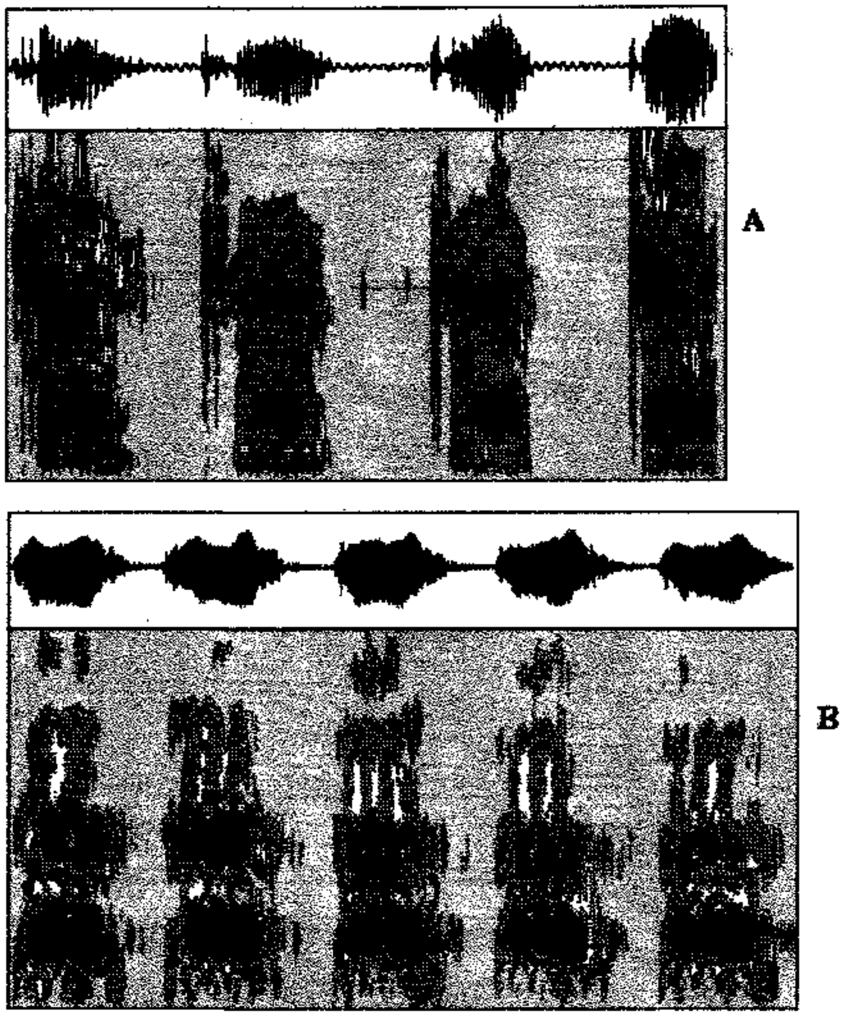


Figure 4.23 : DDK repetitions of a lingual dystonic subject. Note the amplitude variations on the repetitions of /ta/ (4.23 A) and prolonged syllable duratioon (distorted too) in 4.23 B.

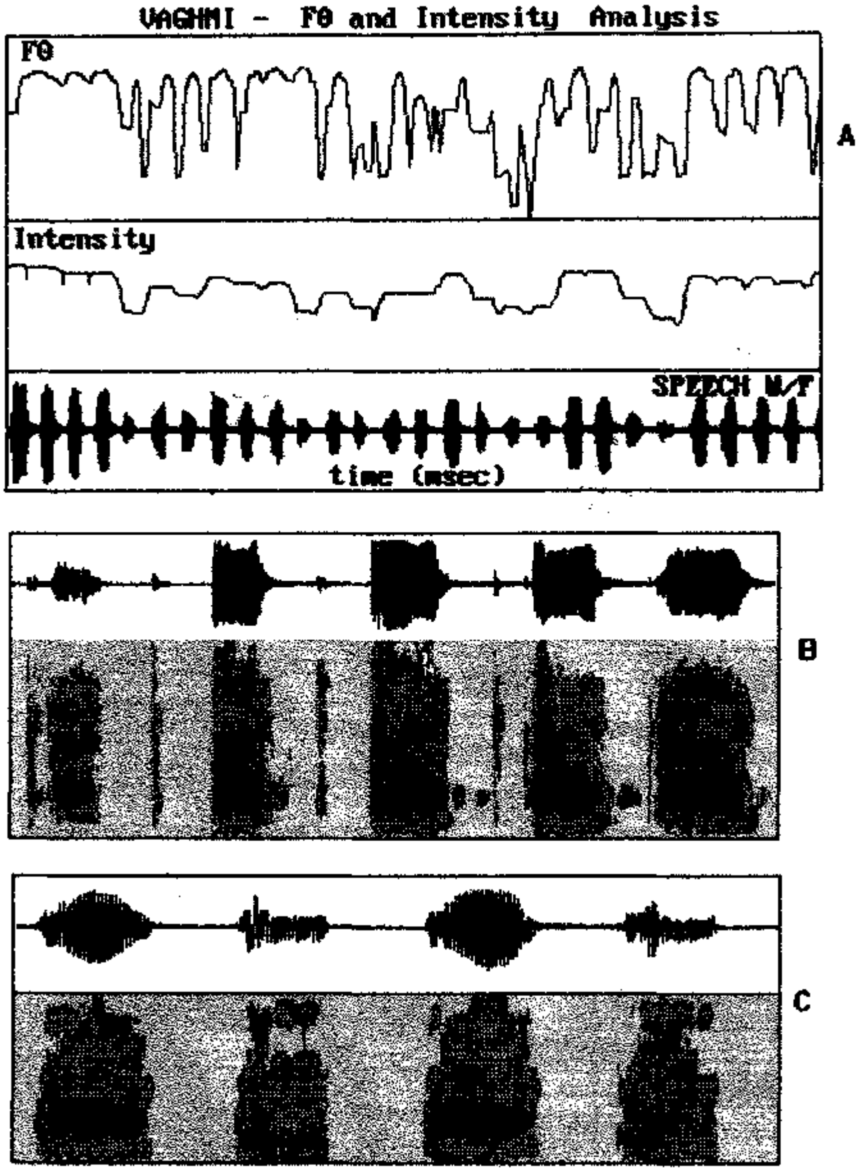


Figure 4.24 : Variations in DDK repetitions of a laryngeal dystonic speaker. Picture A shows the frequency and intensity analysis of repetitions of /ka/ wherein wild variations in peak frequency and peak intensities are evident. Picture B show the increased syllable duration while picture C shows the distinct intersyllabic gaps even in the repetition of voiced syllable /ba/ on which continuous voicing could be expected.

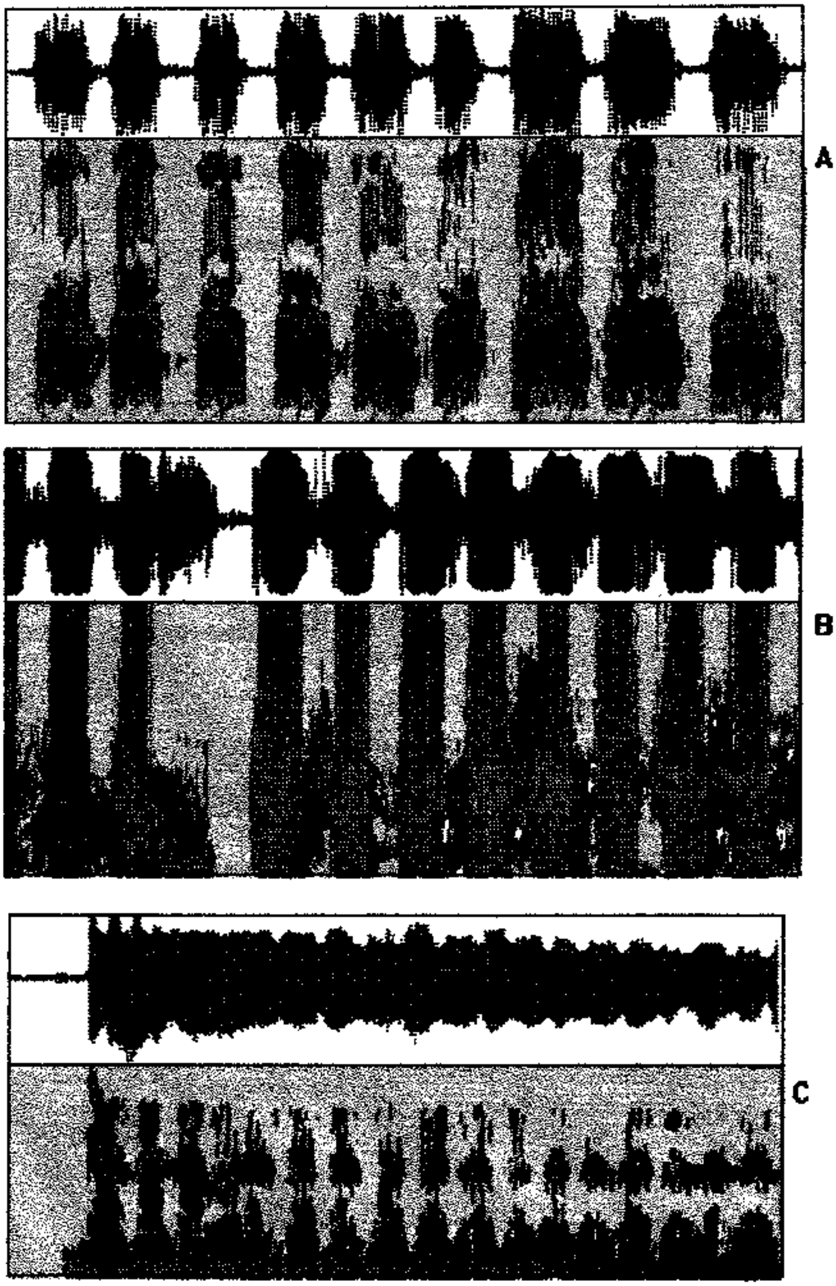


Figure 4.25 : Variations in the DDK repetitions of orofacial tardive dyskinetic subject. Picture A shows the distint gaps in the repetition of voiced syllable /ba/; picture B show the variability in the gap durations on /ta/ repetitons, and picture C shows the continuous voicing in the DDK repetition of vowel /a/.

gap durations on the repetitions of /ta/, and 4.25C shows continuous voicing in the DDK repetition of vowel /a/. Number of repetitions were counted from the spectrogram in this instance.

4.5.2.7 Conclusions : DDK Task

From the results of diadochokinetic measures, it can be tentatively concluded that

a) there was a difference in both temporal and spectral aspects of repetitions between the normal and the dysarthric groups, and between the subgroups of hyperkinetic dysarthrias, though the difference in means were not always statistically significant.

b) the high variability in the data in respect of duration and frequency seems to be the distinguishing feature of the hyperkinetic dysarthrics, particularly the dystonia group, rather than any difference in the mean values between the normal and the dysarthric groups,

c) in general, the repetition rate was lower, duration of syllabic repetitions were longer, intersyllabic gap duration was longer, and peak intensity and frequency were higher in the hyperkinetic group compared to normals and hypokinetic dysarthrics, but the difference was not always statistically significant,

d) though the lingual system was the system predominantly involved in the dystonic and the dyskinetic groups, the mean values of these two groups on the durational or rate aspects of DDK was not significantly different from those of chorea and EVT groups, and

e) an analysis of different samples of DDK repetitions, (segments selected at the beginning or at the end of the repetition sequence) does not give any additional or different information than that available from the analysis of the whole sample.

4.5.3 Voice Initiation and Termination Time

It is said that dysarthrics may have difficulty in initiating and terminating voice because of lack of regulatory control over the movements. Weakness of the muscles, or tremors, or choreiform movements may make initiating and terminating phonation difficult for dysarthrics, particularly, if the laryngeal or respiratory muscles are involved. Voice and speech initiation are different processes because different sets of musculature are involved in addition to the coordination of laryngeal and articulatory systems. Since the focus was the tongue and other oro-facial structures in the dystonics and dyskinetics of this study, deviations in speech initiation times were also predicted for these groups.

The results showed that the hypo- and hyperkinetic dysarthrics had longer voice initiation and voice termination times than normals, but of all the differences only the difference in VIT between the normal and the hyperkinetic dysarthrics was statistically significant. The implication is that the hyperkinetic dysarthrics are slower in activating their laryngeal musculature to initiate phonation. Rigidity of muscles which was a common clinical feature of all the hypokinetic dysarthrics, and choreiform movements in chorea extending to the laryngeal musculature were perhaps determining factors in hypokinetic dysarthria and chorea. But the VIT and VTT was especially longer in the dyskinetic group.

On the speech initiation task, where the oro-facial musculature comes into play, both the hypokinetic and the hyperkinetic dysarthrics were slower than the normals, but only the difference between the normals and hyperkinetic dysarthrics was statistically significant for the sentence starting with voiceless sound. The implication is that the hyperkinetic dysarthrics are, in general, slower in initiating volitional muscle movements and that it may not be restricted to laryngeal musculature only. Among the subgroups, the dyskinetic and the chorea groups were particularly slow in initiating voice and speech but the difference in mean values was significant only for the sentence starting with voiceless sound. It should be pointed out that there was high variability in individual data with respect to all the parameters measured here as reflected in the high standard deviations.

It can be tentatively concluded that the hyperkinetics are slower than normals in initiating voicing and speech and that the slower reaction time may not just be feature of the laryngeal muscles.

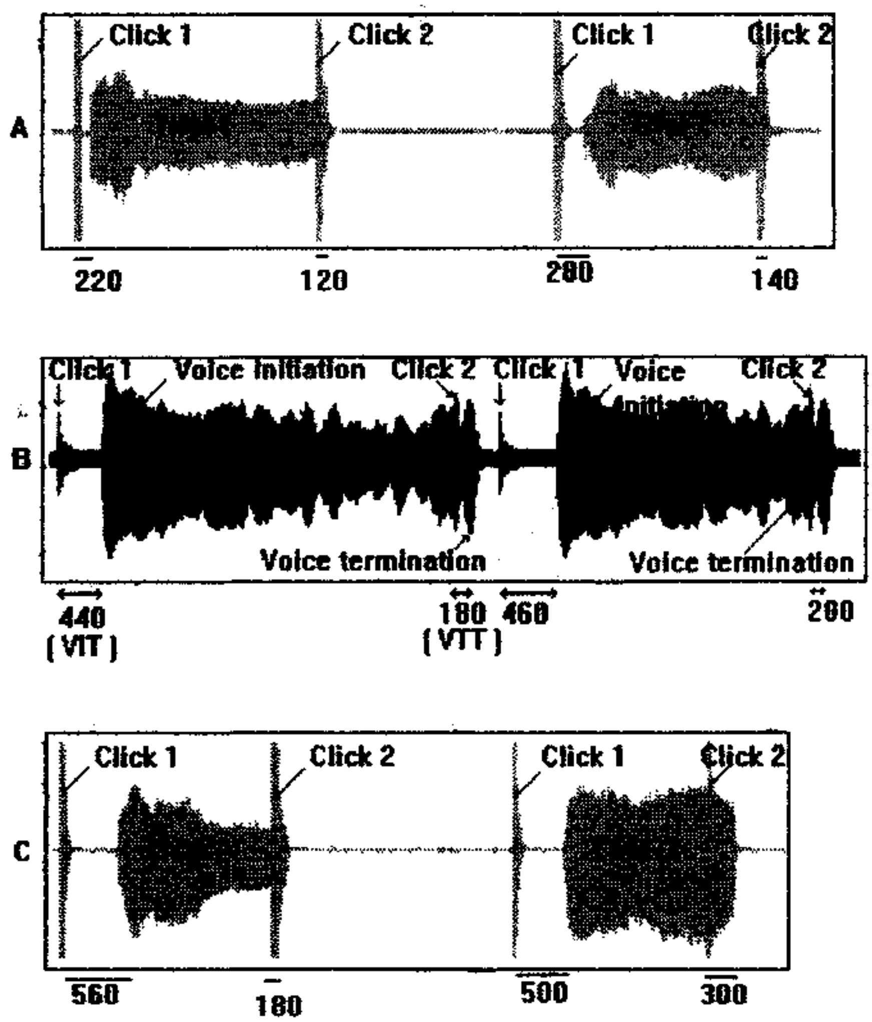
Figure 4.26 and 4.27 illustrate the voice initiation time and voice termination time in dysarthrics. Figures 4.26A is for normals. Compared to the normals, V1T and VTT were longer in the Parkinsonics (Figures 4.26B) and chorea patients (4.26C). The EVT group (4.27A)' was within the normal range. The lingual dystonics (4.27B) and tardive dyskinetics (4.27C) were different from normals not only in terms of the longer reaction times, but also in terms of the high variability between the trials. High variability of data, as reflected in high standard deviations, was the main characteristic of both the hypokinetic and hyperkinetic dysarthrias, especially the hyperkinetic group.

Figure 4.28 illustrates the speech initiation time for sentence starting with voiceless consonant (A) and for the sentence starting with voiced sound (B) in the case of normal speakers. Similarly, Figures 4.29 to 4.33 illustrate speech initiation time for Parkinsonics, chorea, EVT, dystonia and tardive dyskinesia patients, respectively. Compared to the normals, all the dysarthric subjects had longer initiation times for both sentences (starting with voiceless and voiced sound). The speech initiation time was especially longer in the chorea and the tardive dyskinetic groups and particularly for the sentence starting with voiced sounds.

4.5.4 Voice Onset Time

Voice Onset Time (VOT) is the time elapsed from the instant of the release of the stop closure to the onset of voicing. VOT is an important aspect of speech production in that the duration of VOT may

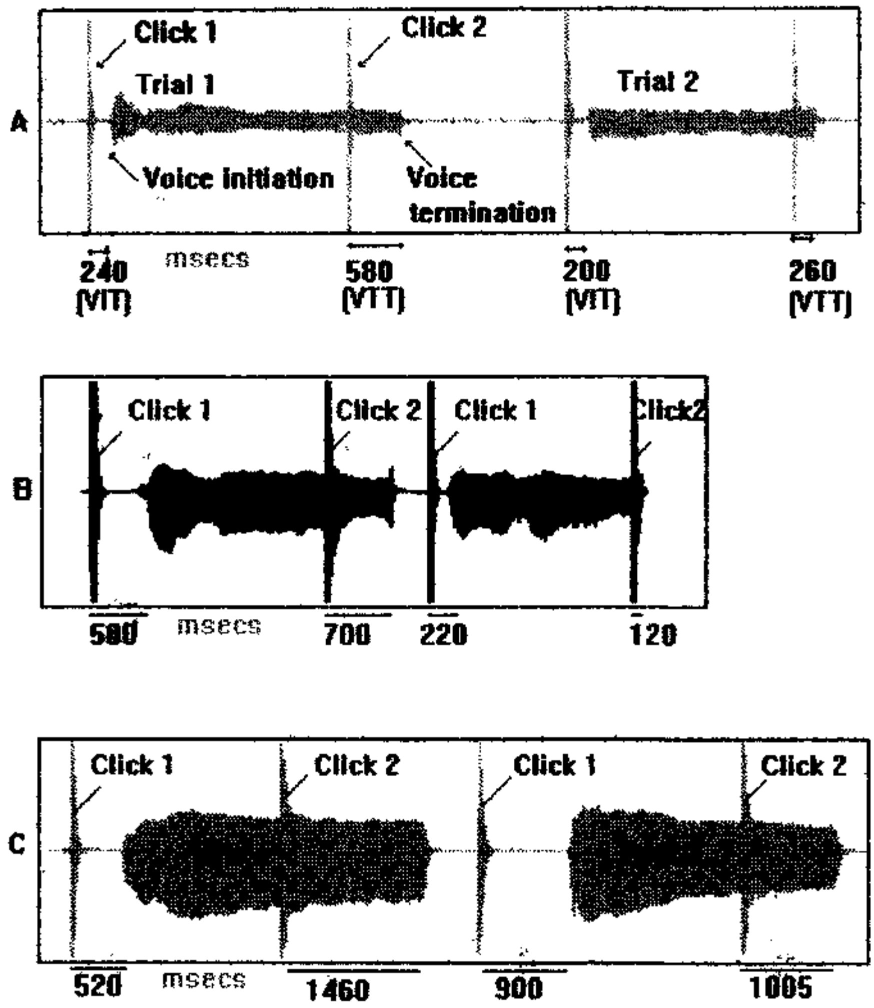
Voice Initiation and Termination time (VIT & VTT) Measurements -1
[in milliseconds]



(A = Normal subject B = Parkinsonic subject C = Chorea subject)

Figure 4.26 A,B & C: Voice initiation time and voice termination time in dysarthrics. 4.26 A is for normals. Compared to the normals, VIT and VTT were longer in parkinsonics (picture B) and chorea (picture C).

Voice initiation and Termination Time (VIT & VTT) Measuements - II
[in milliseconds]



A = Voice tremor case B =Lingual dystonia C = Tardive dyskinesia

Figure 4.27 A, B & C : Voice initiation time and voice termination time in dysarthric subjects.

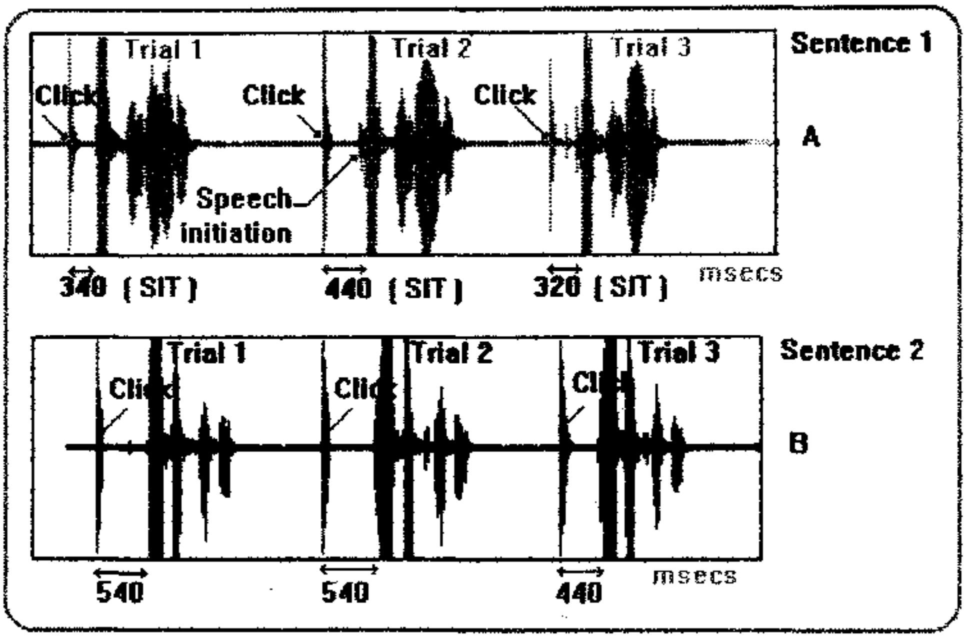


Figure 4.28 : Speech initiation time for sentence starting with voiceless consonant (A) and for the sentence starting with voiced sound (B) in the case of a normal subject.

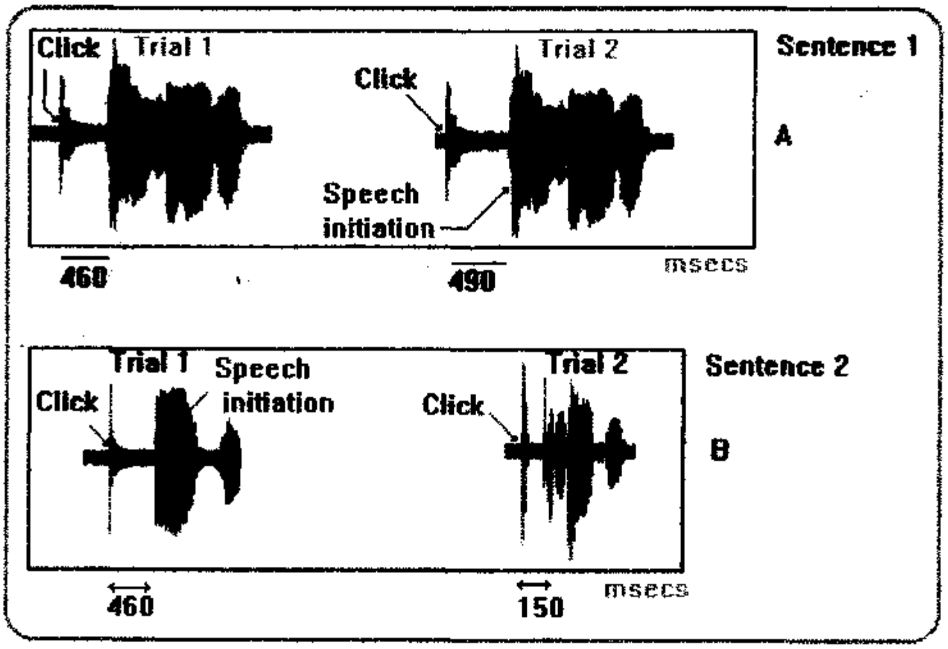


Figure 4.29: Speech initiation time for sentence starting with voiceless consonant (A) and for the sentence starting with voiced sound (B) in the case of a parkinsonic subject.

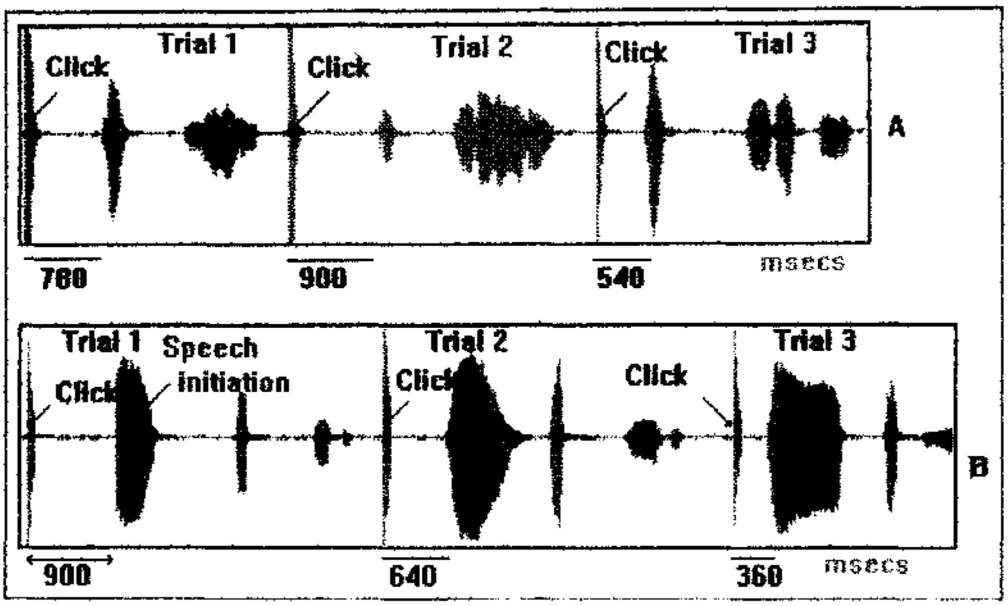


Figure 4.30: Speech initiation time for sentence starting with voiceless consonant (A) and for the sentence starting with voiced sound (B) in the case of a chorea subject.

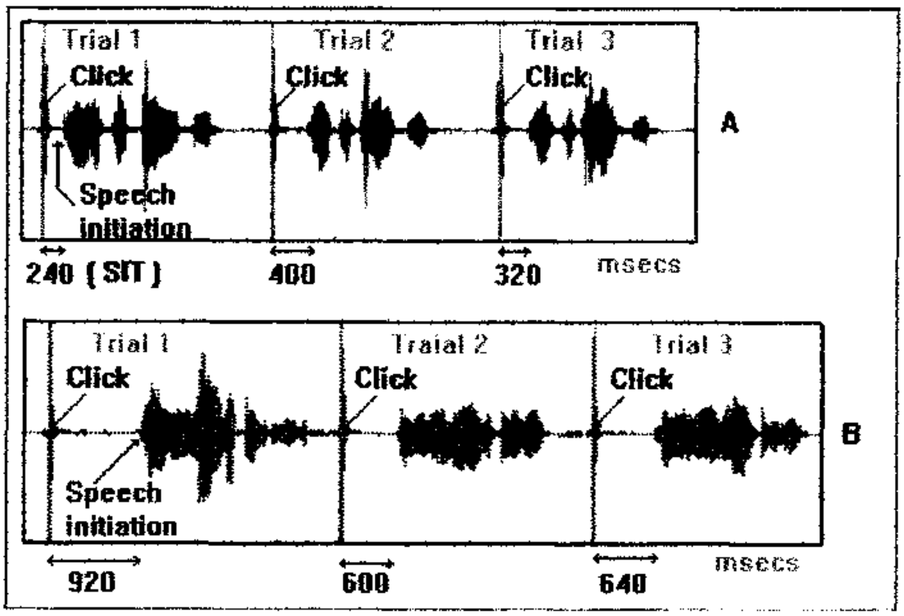


Figure 4. 31: Speech initiation time for sentence starting with voiceless consonant (A) and for the sentence starting with voiced sound (B) in the case of a voice tremor subject.

determine voice - voiceless nature of a stop consonant. Variation in the duration of VOT may contribute to distortion of speech sounds.

Speech requires more of the larynx than simply producing different fundamental frequencies and holding them stable for fixed intervals. Phonation must be stopped over very brief intervals in near perfect synchrony with the movements of other vocal tract structures. In short, the larynx must function as one element in a perfectly coordinated articulatory system. However, there are so many aspects of laryngeal/articulator coordination. One such aspect is the VOT which gives an adequate index of the intersystem coordination.

In the present study, 36 VOT's were analysed - 6 stop consonants, each in the context of 3 vowels, each vowel followed by a voiceless or voiced stop. The stop consonants analysed were labial, linguodental and velar voiceless and voiced stops in the context of vowels /a/, *lil* and /u/.

The VOTs for voiceless stops were not significantly different between the main groups. The mean VOTs for voiceless stops were generally longer in the dysarthric groups, but the difference in means were not significant between the main groups. The mean VOTs for voiced stops were significantly different between normal - hyperkinetic groups and hypokinetic - hyperkinetic groups.

The negative VOTs for voiced stops were longer in the case of hyperkinetic group compared to the hypokinetic group. In other words, initiation of voicing was earlier than expected in the case of hyperkinetic dysarthrics. In fact, the negative VOT for linguodental and velar stops did not occur in the case of hyperkinetic dysarthrics.

Among the subgroups, the VOT's were generally longer in the dystonic group for the voiceless stops and shorter (negative VOT) in respect of voiced stops. However, none of the differences in mean VOT was significantly different between the subgroups in respect of voiced stops while only some differences were significant in the case of voiceless stops.

In an earlier study of VOT in a group of dysarthrics (spastic, flaccid, ataxic and hypokinetic), Morris (1984) found that the dysarthric speakers exhibited VOT patterns (on voiceless consonants) which differed from those produced by normal speakers. Generally, many of the VOT's produced were of short duration than would be normal for voiceless stops. They were termed phonetic errors. When we analysed the VOT's of the present study for voiceless consonants, a general trend was observed, that the VOT's for voiceless consonants were longer than the normal speakers though the difference was not statistically significant because of high standard deviation. Thus the results of this study are different from those of Morris (1989). The VOT's on voiced consonants were occurring much faster in the dysarthric speakers compared to normals in the present study. The longer VOT's for voiceless consonants suggest that voicing was initiated much earlier than the normal speakers while the shorter VOT's (many a times -ve VOT's) for voiced consonants that voicing was initiated much before the stop release. Morris (1989) who reported that there were only slight variations in the VOT phonetic error pattern exhibited by their hypokinetic speakers which again was not supported by the findings by the present study. The slower VOTs for voiceless consonants is again in consonance with the pathophysiology of the Parkinsonism, namely, slow movement and paucity of movements, this time in respect of the laryngeal muscles.

A tentative conclusion from this data is that the VOT for voiced stops could generally discriminate hyperkinetic from normal and hypokinetic from normals. In the hyperkinetic group, voicing appeared to occur much faster, in respect of voiced stops, than in the hypokinetic and normal speakers. The mean VOT's for voiceless consonants appeared to be longer in the hypokinetic speakers than in normals, but the difference was not statistically significant. However, there was high variability in the individual data, particularly in the hyperkinetic group.

Figure 4.34 illustrates voice onset times (VOT) in each of the 6 categories of subjects studied which includes normals (A), Parkinsonism (B), chorea (C), EVT (D), dystonia (E) and dyskinesia (F), for the initial syllable /pu/ in the word /pukka/. Note that the parkinsonic's had longer VOT than normals, patients with chorea even longer than normals but shorter than Parkinsonics, absence of VOT in EVT, very short VOT in dystonia and longer VOT than normals in the dyskinesia group.

Figure 4.35 is a similar illustration of VOT in the 6 groups, for the consonant /th/ in the word /thaggu/. /th/ is a alveolar voiceless

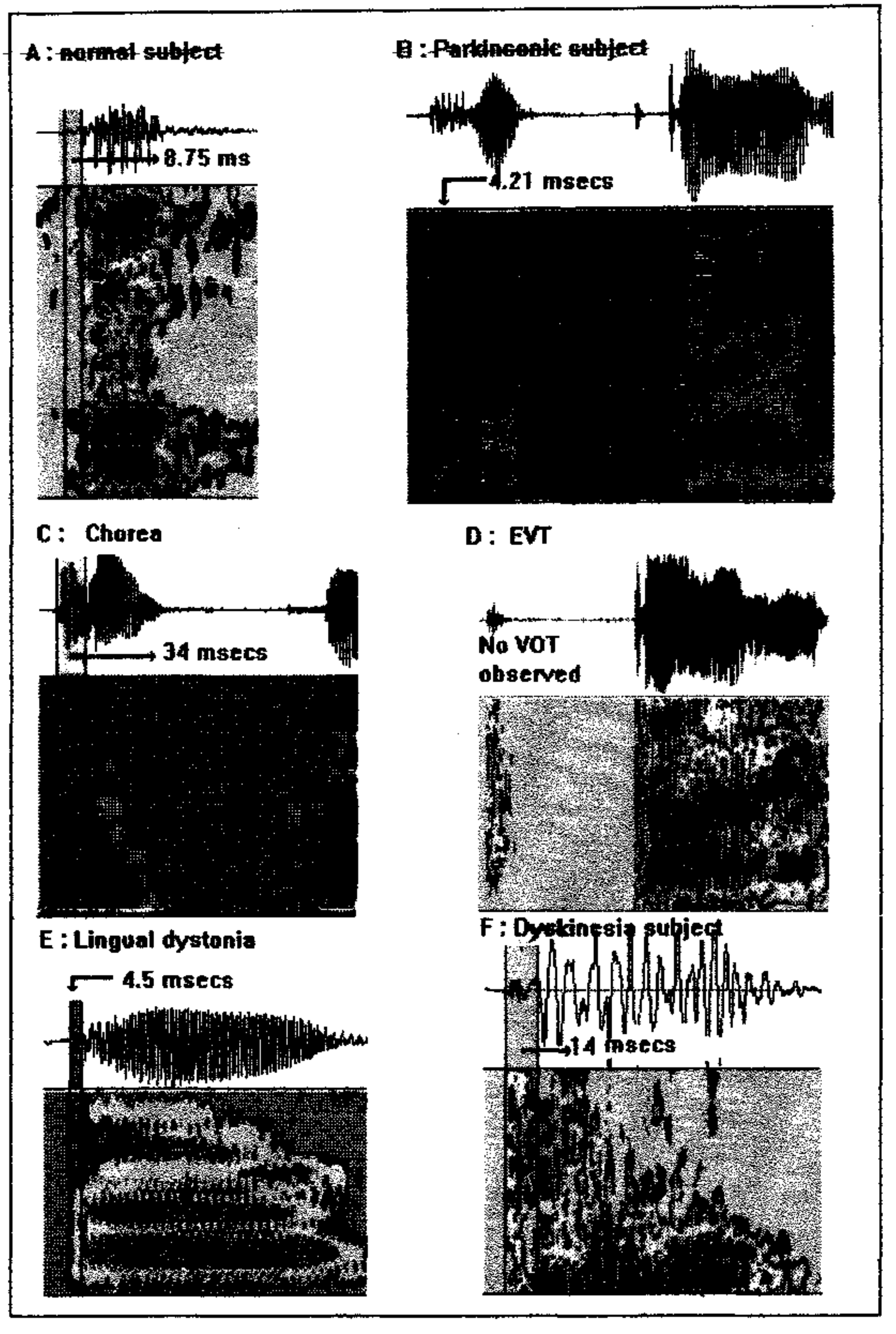


Figure 4.34 : Voice onset time (VOT)values in each of the 6 categories of subjects of the study, for the initial syllable /pu/ of the word /pukka/. VOT values in msecs are marked with respect to each diagnostic category.

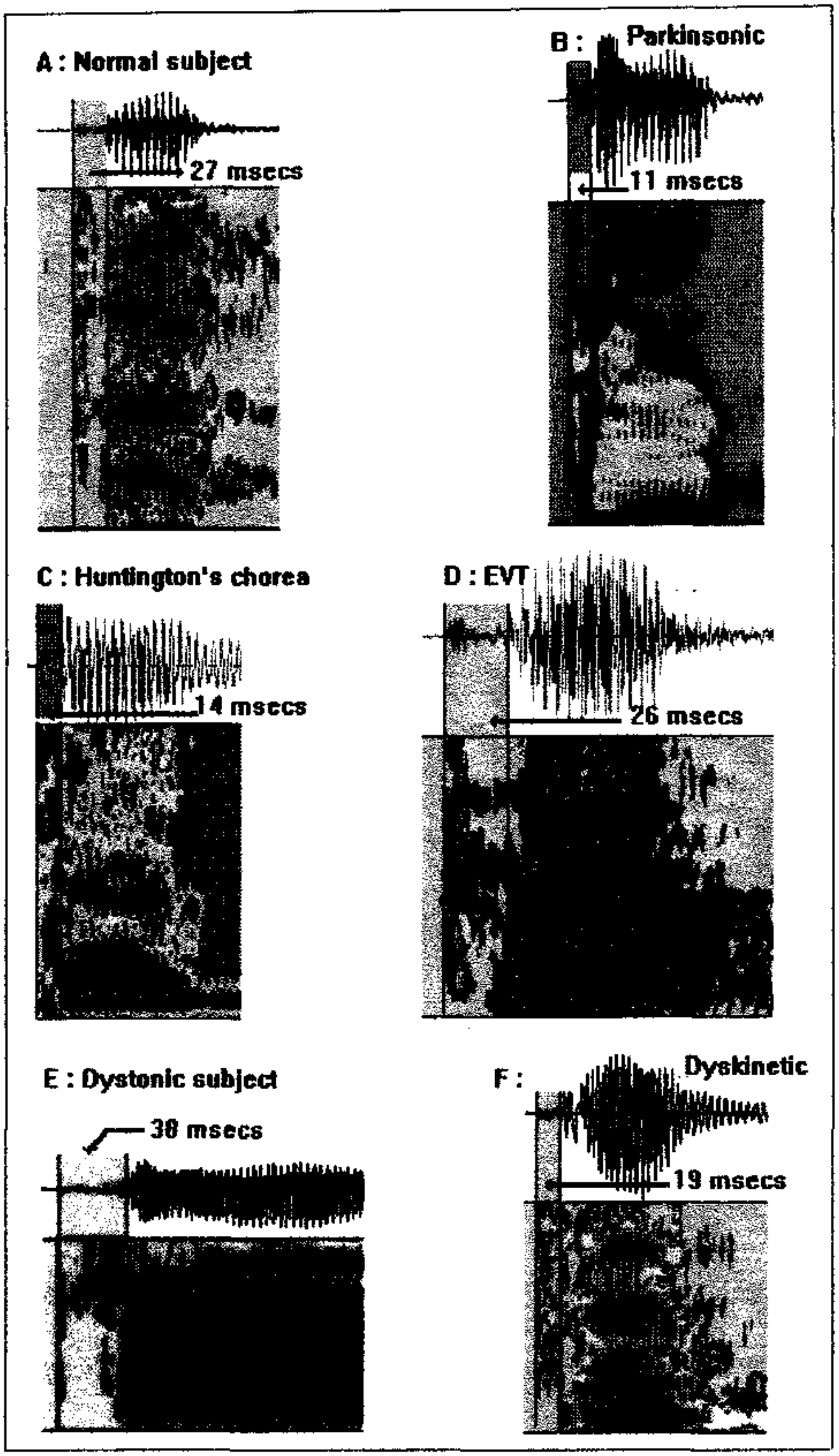


Figure 4.35 : Voice onset time (VOT) values in each of the 6 categories of subjects of the study, for the initial syllable /th/ of the word /thaggu/. VOT values in msecs are marked with respect to each diagnostic category.

consonant. Figure 4.36 illustrates VOT's for the consonant /dh/ in the word /dhatta/. /dh/ is a voiced alveolar consonant. The VOT in this instance was negative in the hyperkinetic dysarthria, but positive, although very short, in Parkinson's disease speaker. Figure 4.37 is an illustration of VOT for /dh/ in the environment of vowel /u/. VOT's for /dh/ in the vowel consonant of /u/ was more or less similar as the VOT for /dh/ in the context of vowel /a/ (Figure 4.36) in all the six groups.

4.6 Prosodic Aspects

4.6.1 Sentence Production at Two Rates

The analysis of prosodic aspects in the speech of dysarthrics had a very narrow scope in this study. The subjects were asked to produce two sentences, each sentence with two clauses, at two rates : normal and fast. Speaking and articulatory rate, variations in duration of words and gaps between words, and variations in peak frequency and intensity on the sentence as a whole were measured. Whether the dysarthrics can manage production of speech at a faster rate than usual in the presence of loss of regulatory control over oro-facial musculature and if they indeed manage to do this, will there be any deviation from normal speakers was the question sought to be answered. In particular with reference to the Parkinsonics whether they would be able to produce sentences at a faster rate in view of the known weakness of muscles and slow movements underlying the condition was sought to be analysed. Though two sentences were analysed, results from only one

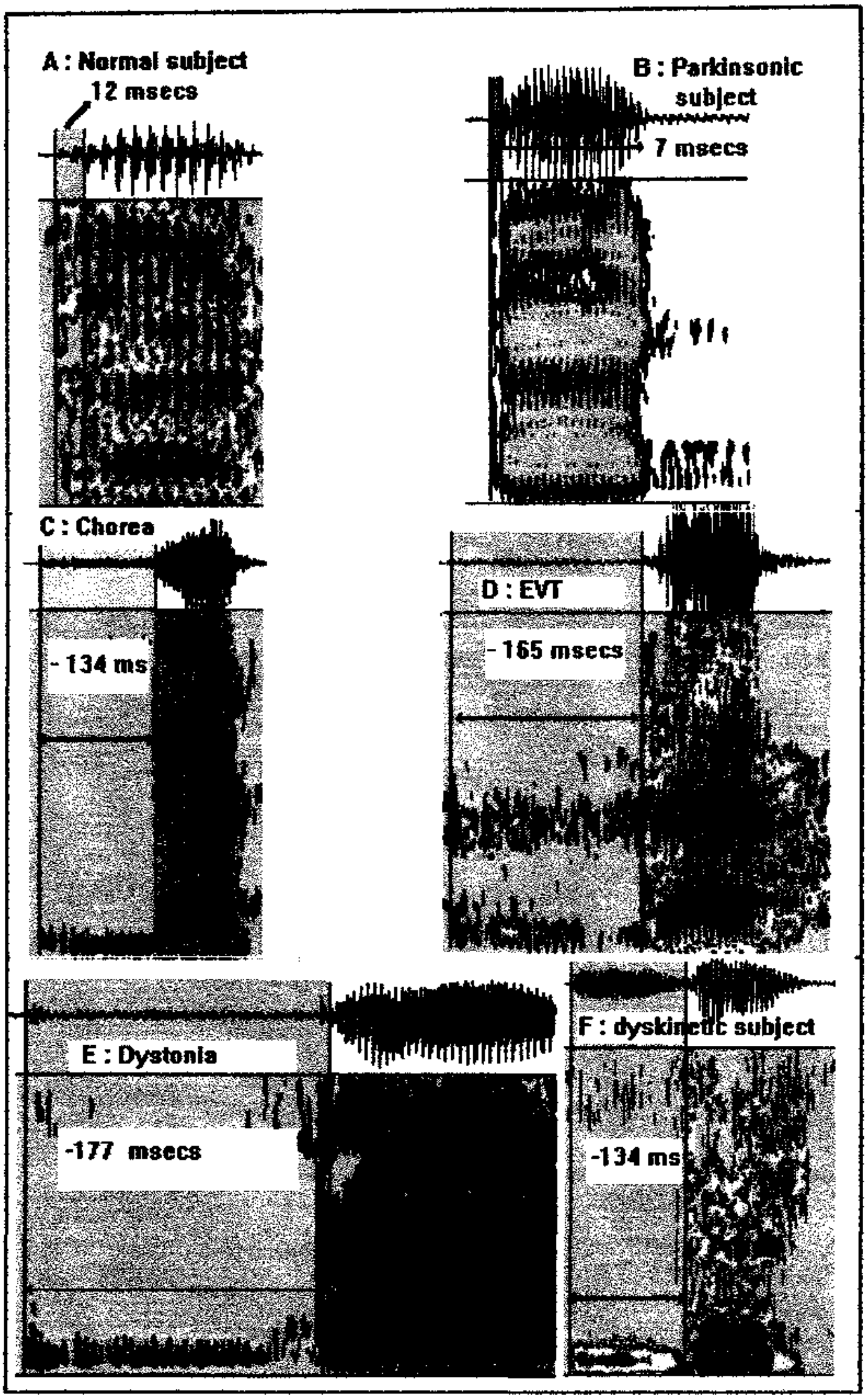


Figure 4.36: Voice onset time (VOT) values in each of the 6 categories of subjects of the study, for the initial syllable /dh/ of the word /dhatta/. VOT values in msecs are marked with respect to each diagnostic category.

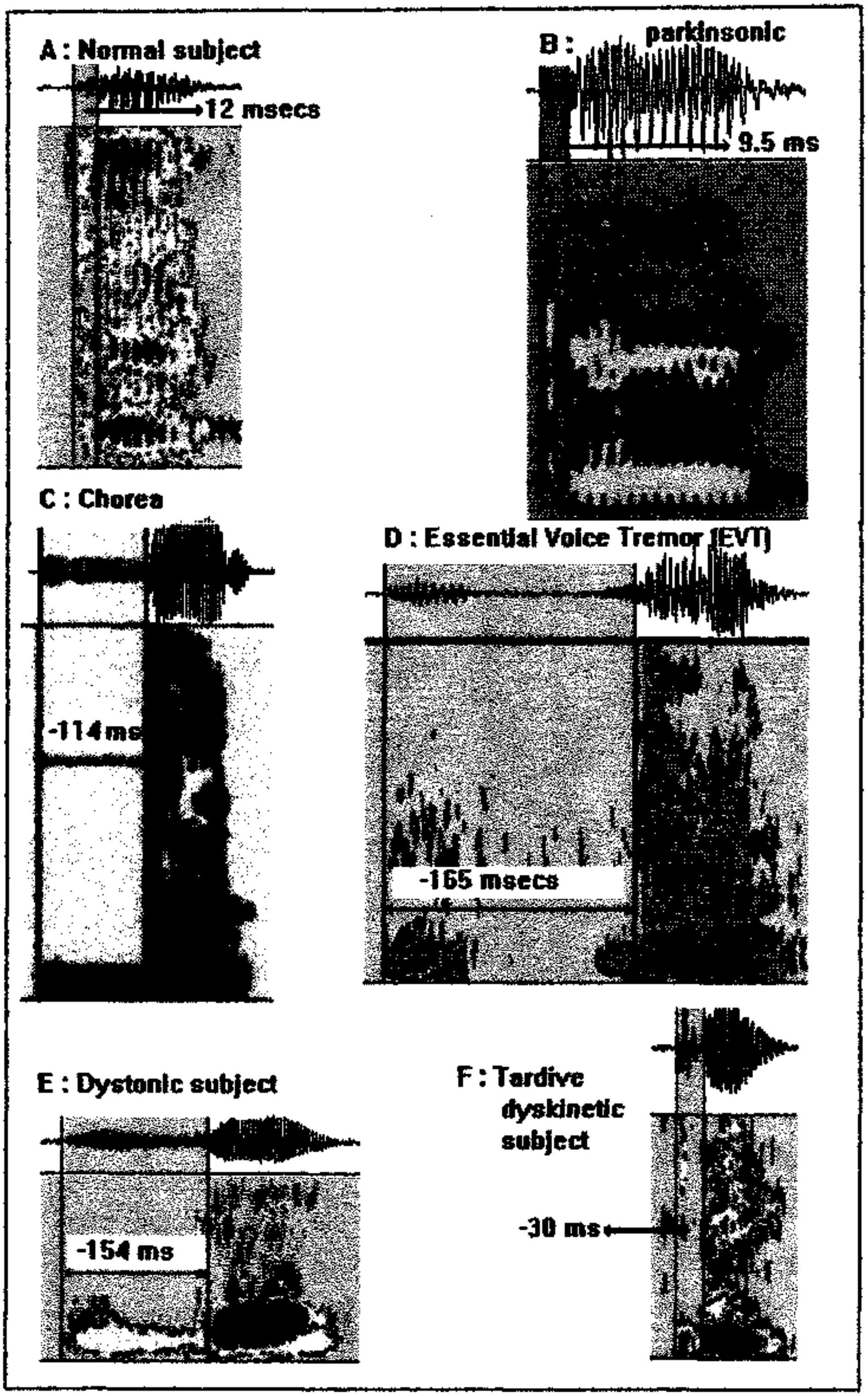


Figure 4.37 : Voice onset time (VOT) values in each of the 6 categories of subjects of the study, for the initial syllable /dh/ of the word /dhutta/ . VOT values in msecs are marked with respect to each diagnostic category.

sentence, the sentence in which the words started with voiceless consonants have been reported here. The results from the analysis of the second sentence in which words started with voiced sounds have not been reported because that would have caused lot of confusion. However, it must be mentioned here that the results from the second sentence were not much different from those reported for the first sentence.

A visual inspection of the data suggested that the rate of production, in the normal and fast modes, was not very significantly different for the dysarthric speakers except in the EVT group. However, this has not been subjected to any statistical test of significance. There neither seemed to be a significant difference in the articulatory rate between the normal and the fast rate of production in the dysarthric groups except in the EVT group. The implication is that the dysarthric speakers were not able to achieve a faster rate of sentence production in this study. However, this cannot be attributed to any neurological deviations in the dysarthrics because even the normal speakers were not able to achieve a faster rate. Probably, this has something to do with the method of the study particularly with the instruction given to the subjects. Also, there did not seem to be much difference between the speaking rate and articulatory rate (syllable duration rate after the gap durations have been subtracted), in either mode of sentence production, and in any of the three groups. The measures of the results is that the internal gap duration was not much in either mode in sentence production.

In consonance with the results on the speaking rate at 2 modes, the mean duration of words also changed. The duration of words in the dysarthric groups were longer (slower speaking rate) than those normals and it was possible to separate dysarthrics from normals. There were 5 words in the sentence and an inspection of the duration of words (and comparing the average duration of syllable; duration of words/ number of syllables) in the dysarthric groups did not reveal any evidence for festinant speech in the dysarthric groups, but this is outside statistical significance.

The results of the duration of interword gaps were unremarkable as also those on frequency and intensity variations. Though the results on intensity variations indicated that there may be a sudden drop or burst of intensity on some words in the dysarthric groups, but, in general, it can be said that dysarthric speakers have the same pattern of variations in duration, intensity and frequency in their speech as the normals.

From the results of the analysis of the sentence production at two rates, the following tentative conclusions are drawn :

a) that the dysarthric speakers show the same pattern of rate, duration, intensity and frequency obtained in their speech as do the normal speakers, and

b) the subjects in this study, including the normal speakers were not able to produce speech at a faster rate than normal, except the patients with EVT. It may be that the subjects did not get **a** clear idea of the tasks at hand through the instruction given.

Figure 4.38 to 4.42 are the wideband spectrograms (as well as speech waves) illustrating the production of the sentence 'Shiva tea kudidhano sebu thindhano' at two rates of production: normal and fast. The gap between the two clauses are highlighted in each figure. Note the increase in the rate at fast rate of production. The increase in the rate was the least in the case of Parkinsonian speaker (Figure 4.39). The illustrations in Figure 4.38 (normal speaker), 4.39 (Parkinsonism), 4.40 (Chorea), 4.41 (EVT) and 4.42 (Dystonia) happen to be of ideal productions showing an increase in the rate at fast rate of production. It so happened that there was not much of a difference at two rates of production in any of the subject groups. The difference between the two rates of production, in any group, was not statistically significant.

4.6.2 Characteristics of Speaking and Reading

Brain damage often results in an alteration of speech prosody (Le Dorjze, Ouellet and Ryalls, 1994), and speaking rate may be one of the prosodic aspects affected. Dysarthric speakers generally present a rate disturbance. According to Darley et.al (1975), speaking rate is generally slower in all types of dysarthria, except in hypokinetic dysarthria, which is perceived to present a faster rate than normal speech rate. Instrumental studies have confirmed these perceptual data (Hammen, Yorkston and Beukelman, 1989; Ludlow and Bassich, 1983).

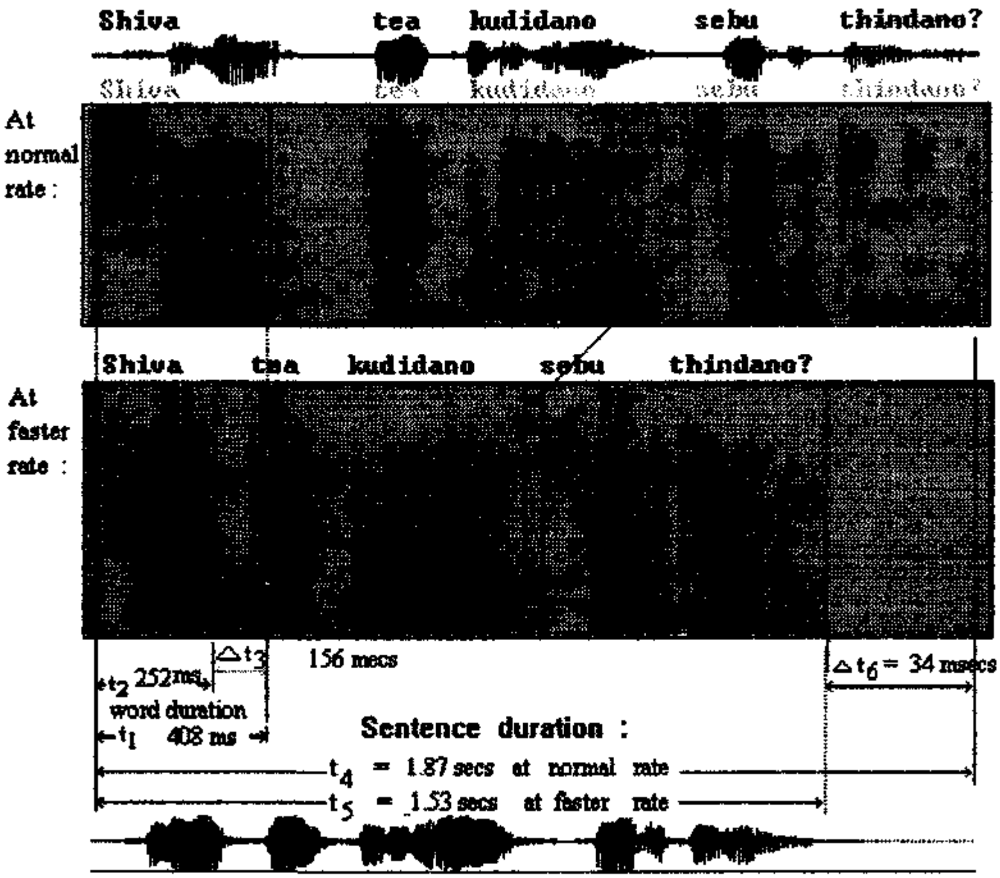


Figure 4.38: "Wide band spectrograms showing the rate of production of the sentence, Shiva tea kudidhano, sebu thindhano ? ' at normal and faster rate by a normal speaker. The sentence duration, word duration of the word " Shiva" and fee clause duration at both the rates of production and the respective differences in durations are shown in the above figure.

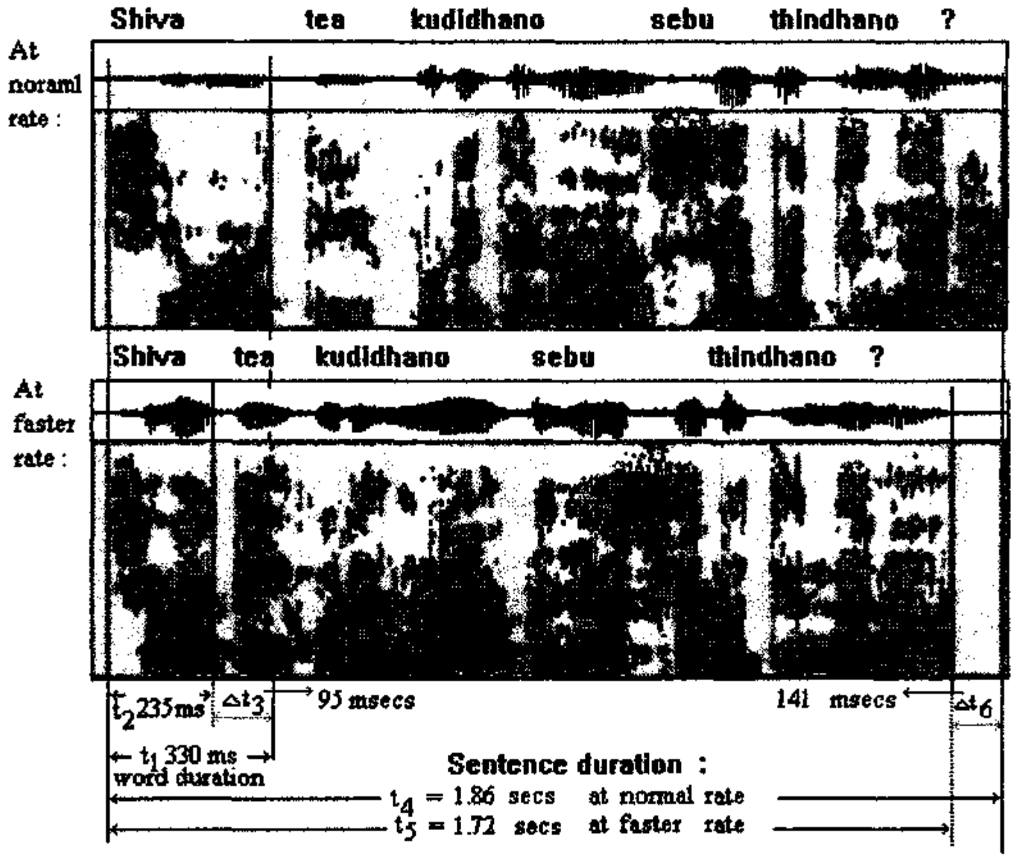


Figure 4.39 : Spectrographic illustration of the rate of production of the sentence, ' Shiva tea kudidhano, sebu thindhano ? ' at normal and fast rates by a parkinsonic subject.

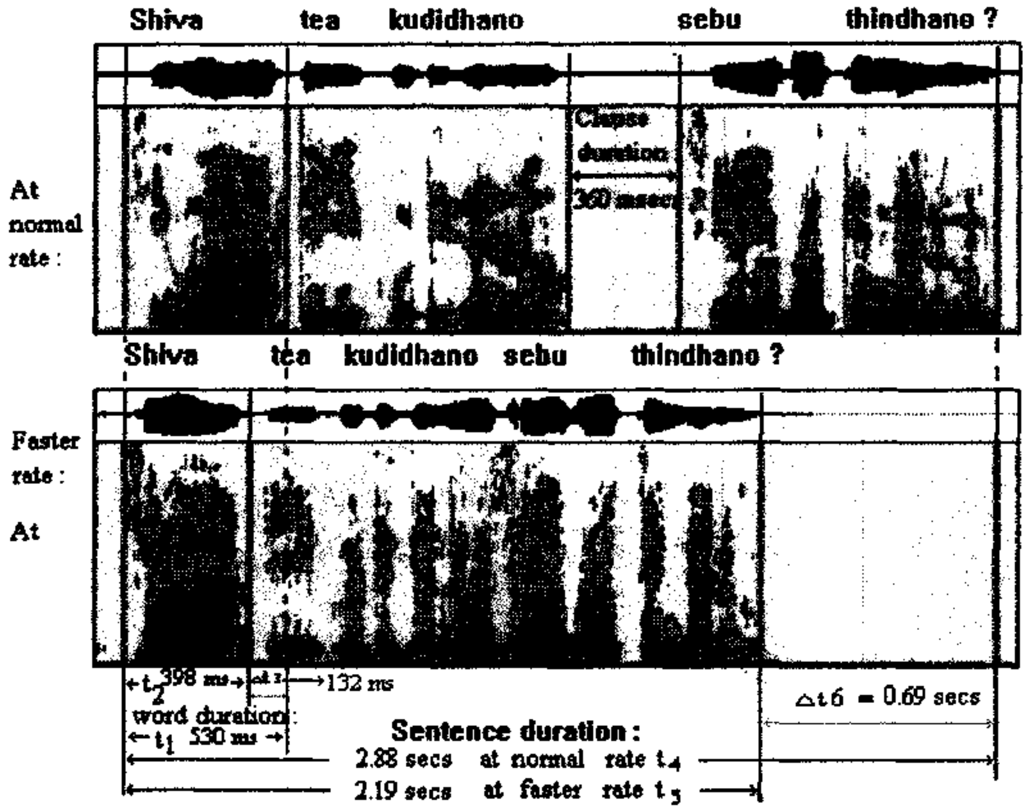


Figure 4.40: Spectrographic illustration of the rate of production of the sentence, 'Shiva tea kudidhano, sebu thindhano ? ' at normal and fast rates by a subject with Huntington's chorea.

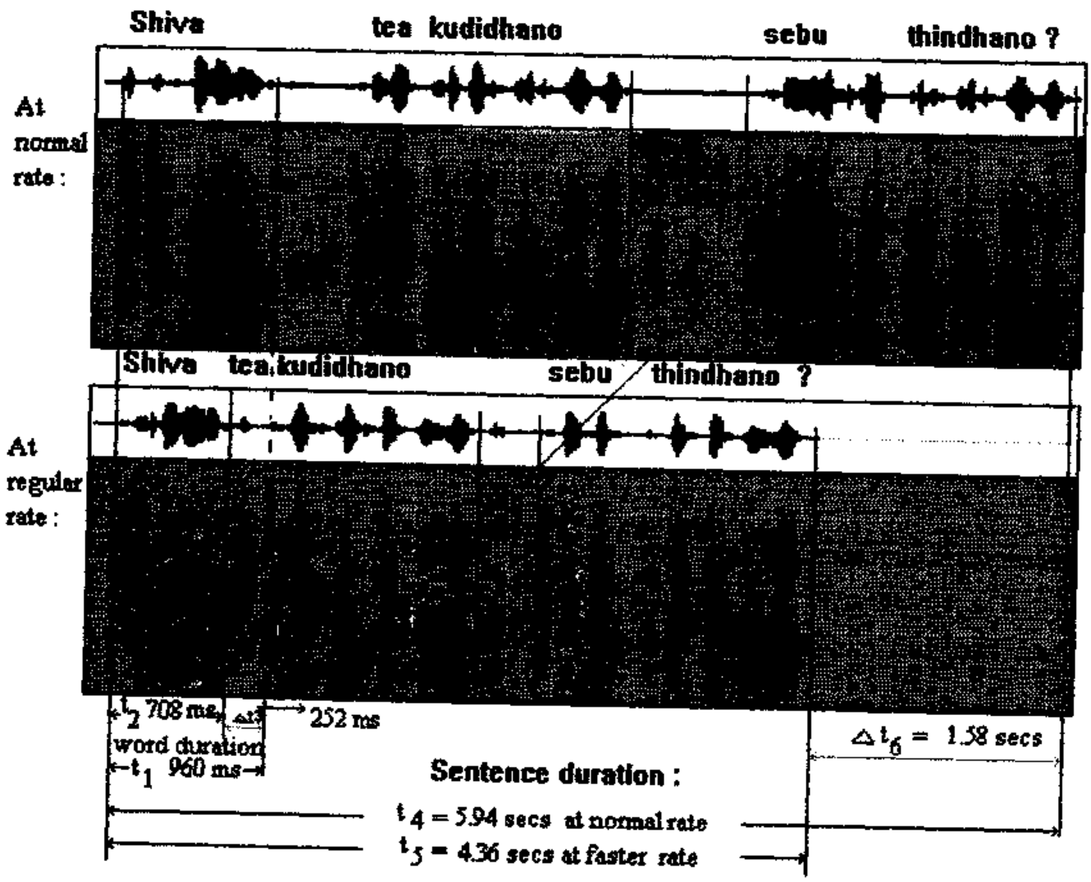


Figure 4. 41: Spectrographic lustration of the rate of production of the sentence [1] Shiva tea kudidhano. sebu thmdhano ? ' at normal and fast rates by a subject with essential voice tremor.

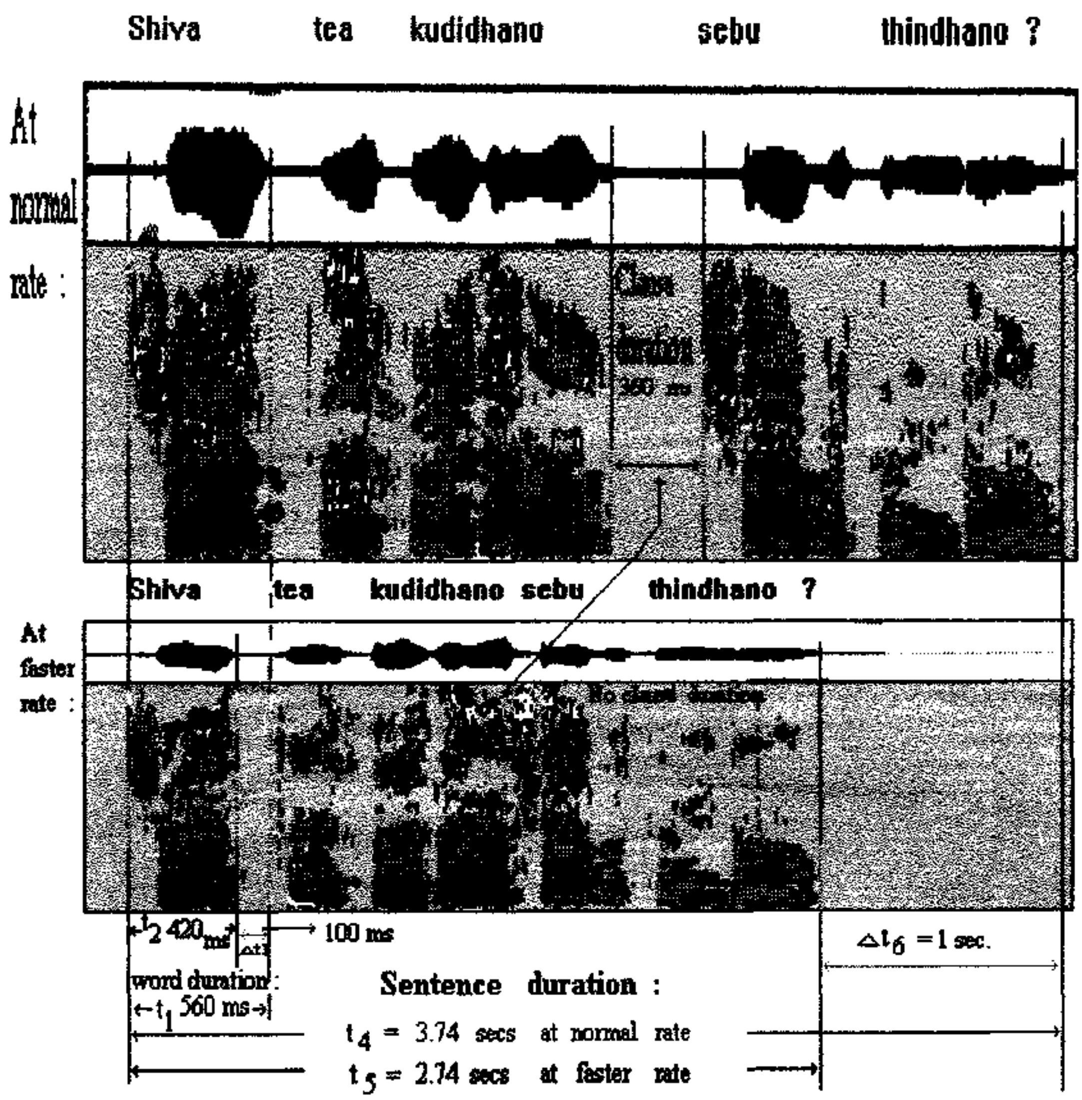


Figure 4.42: Spectrographie illustration of the rate of production of the sentence, ' Shiva tea kudidhano, sebu thindhano?' at normal and fast rates by a subject with lingual dystonia.

ing in Parkinson's patients, but weakness was evident only in 2 of 8 patients. Reasons for the decreased rate in the hyperkinetic group seem obvious if one goes by the 'cause and affect' principle. Superimposition of the choreiform movements in the chorea group, tremor in the EVT group, dystonic movements along with weakness in the dystonia group, and involuntary movements of the oro-facial structures in the dyskinetic group over those required for articulation may have decreased the rate of utterance. However, this appears to be an oversimplification of the entire issue.

Besides, all these explanations can, at best, only be conjectures for two reasons : one, a direct physiological study of the rigidity or weakness of the oro-facial or laryngeal muscles has not been carried out in the present study, and two, when phonation was eliminated, as in the whispering mode, the speaking rate did not increase thereby minimizing the involvement of the laryngeal muscles. However, the possibility of the clinically demonstrated rigidity of the oral musculature influencing speaking rate is still valid.

An interesting feature of Parkinsonic dysarthria that makes it nearly unique among the dysarthrias is that speaking rates have been observed to be faster than normal. However, the perception of 'short rushes of speech' or 'accelerated speech' might be based not so much on an actual increase in the rate of articulatory events as on reductions in the range of articulatory movements (Kent and Rosenbek, 1982).

Netsell et. al (1975) commented that it is difficult to understand how an individual with balanced hypertonus could increase the rate of articulatory movements. They proposed that the short rushes of speech might be based on the phenomenon of articulatory undershoot. Even with normally timed neural control signals, the articulators might fail to reach their target positions in time because of the rigid musculature. The undershoot, then, should contribute to the perception of accelerated speech. Although this hypothesis is certainly reasonable, it should be noted that the relationship between hypertonus and impairment of movement is not clear (Kent and Rosenbek, 1982). It has been reported that stereotaxic surgery may abolish rigidity while leaving the hypokinesia (Adams, 1973). Thus, reduced range of movement does not appear to be completely explained by rigidity.

Irrespective of the physiological basis of the increased speaking rate in Parkinson's disease, the important thing is that the patients with Parkinson's disease or hyperkinetic dysarthria in this study did not show increased speaking rate compared to normals. In fact, the mean speaking, reading and whispering rates were significantly lower in hypokinetic and hyperkinetic dysarthrics than in normals.

In contrast to the slow speech of most of the dysarthric speakers, speech is abnormally rapid in some Parkinsonian patients (Canter, 1963; Darley et. al., 1975). But the results of the present study do not support this contention. Slowed speech is consistent with bradykinesia (Hunker, Abbs and Barlow, 1982). An increase in the rate of speaking, on the other hand, is less easy to make compatible with the pathophysiology of Parkinson's disease (Netsell, Daniel and Celesia, 1975). However, accelerated speech need not be inconsistent with bradykinesia because movements extraneous in the realization of articulatory targets are generally reduced in Parkinsonian dysarthria (Hirose et. al., 1981; Calguri, 1987). Both the hypokinetic and the hyperkinetic dysarthrics showed lower rate of speaking, reading and whispering compared to the normals and the difference is significant between normal - hypokinetic (parkinsonic disease patients) and normal - hyperkinetic dysarthrics (chorea, EVT, dystonia and dyskinesia). The hypokinetic dysarthrics had sufficiently higher speaking, reading and whispering rate in comparison to the hyperkinetic dysarthrics.

The results of the present study indicated that Parkinson's patients had faster speaking, reading and whispering rates than a group of hyperkinetic dysarthrics, but the rates were slower than in the normals. Therefore, the results of the present study do not support any of the formulations mentioned to above on speaking rate in hypokinetic dysarthria. In fact, our results support the finding of Ludlow and Bassich (1984) that high individual differences exist in Parkinson's disease with respect to speaking rate.

The results of the present study on speaking rate in hyperkinetic dysarthrias support the findings already reported. For example, in chorea, it has been predicted that bradykinesia and delayed transition between successive movements (Thompson et. al, 1988) should lead to slow rate of speech production along with vowel lengthening. In fact, the results of Hertrich and Ackermann (1994) supported this prediction. Besides Huntington's disease, Parkinson's disease represents the most important paradigm of basal ganglian disorder. In contrast to Huntington's disease dysarthria, Parkinsonian patients show a normal or even accelerated speech tempo in terms of segment durations (Ackermann and Ziegler, 1991; Ludlow and Bassich, 1984; Weismer, 1984).

Further research should aim to pinpoint the reason for decreased speaking and reading rate in hypokinetic dysarthria (Parkinson's disease) by controlling the subject speech sample carefully for elimination of confounding variables.

Darley et al (1975) conclude, after a review of studies on oral reading rate in Parkinsonian speakers that it is difficult to generalize about the oral reading rate in Parkinsonian speakers; the range of rates reported is wide and intersubject variability is high. The results of the present study are clear : oral reading rate in Parkinson's subjects was less than in normals, but more than in the hyperkinetic dysarthrias, both differences being statistically significant.

4.6.2.1 Frequency and Intensity Variations in Speaking and Reading

9-second speech samples and 12-second reading samples were used to measure speaking FO and average intensity of speech. The average speaking FO and intensity, in both speaking and reading tasks, were not different between the groups. The meaning of this result is that, on an average, dysarthrics have the same frequency and the intensity distribution in their speech as do the normals. In fact, the frequency and intensity characteristics in speech (or reading) in dysarthria was almost a repetition of their performance on the phonation of vowels (particularly /a/) in isolation with the dystonic dysarthric showing high FO (but not statistically significant) in both instances.

Metter and Hanson (1986), in a study of mean FO in reading, have reported that mean FO for each hypokinetic dysarthric patient was within the normal range though there was a tendency for FO to increase with increased clinical disability and with increased severity of the dysarthria. Though this and the present study are not comparable, by and large, the results of the present study on mean FO in speaking and reading are in agreement with those of Metter and Hanson (1983), on mean FO in reading.

Metter and Hanson (1986) also reported that mean relative intensity measures in reading tasks showed no apparent difference between the hypokinetic patients and controls. The results of the present study are similar to those of Metter and Hanson (1986). However, Metter and Hanson reported that Parkinsonian patients with severe dysarthria demonstrated decreased variation in intensity as compared to normals but this aspect was not analysed in the present study.

Canter (1963, 1965a) found that a group of Parkinsonian subjects had significantly higher median FO (on oral reading) than a group of normal speakers. Kammermeier (1969) reported a similar result, but differences between dysarthric groups were not statistically significant in this study. However, the data on speaking and reading FO of Parkinsonian patients in this study do not support the findings of Canter and Kammermeier.

4.7 Nasal Resonance

Velopharyngeal functioning in Parkinson's disease is controversial. Some researchers (Darley et. al., 1969; Mueller, 1971; Tanner, 1976; Logemann et. al., 1978) have minimized the problem suggesting that even if hypernasality exists, it is mild. Other researchers (Morrison, Rigrodsky and Mysak, 1970; Netsell, Daniel and Celesia, 1975; Hirose et. al., 1981; Kent and Rosenbek, 1982; Ludlow and Bassich, 1983) have provided evidence that velopharyngeal problems occur systematically in Parkinsonian speakers. There is general opinion that hypernasality may represent the most prominent dysarthric symptom in certain individuals. Hoodin and Gilbert (1989a) have reported that increased air flow is present in parkinsonic subjects, but it is a function of disease severity (more severe dysarthrics show higher airflow) and speaking rate (higher rate of speaking - air flow decreased). The problem of velopharyngeal control in Parkinson's disease is one of deteriorating motor control. Hoodin and Gilbert (1989b), in another study, indicated that although hypernasality is not a typical symptom of Parkinson's disease, it can occur in Parkinson's disease and that it can be severe.

Weakness of the oro-facial structures, particularly the soft palate and the posterior laryngeal wall or involuntary movements of the oral structures affects the coupling of the oral - nasal cavities. The result may be nasality in speech. Two measures of nasality were measured in this study : TONAR (The Oral Nasal Acoustic Ratio) is obtained by dividing oral energy by nasal energy while nasalance is a complimentary measure of TONAR expressed in percentage.

Conventionally, the TONAR (Fletcher, 1970) is obtained by dividing the nasal energy by oral energy. However, in this study, the VAGHMI software (Ananthapadmanabha, 1990 - Voice and Speech Systems) computes the TONAR by dividing oral energy by nasal energy. Therefore, higher TONAR values indicate less nasality and vice versa. Typically, in the calculation of TONAR value, the input from the nasal and the oral microphones are individually amplified and conditioned by identical bandpass filters. If the filtering is inactivated then one gets an output which is a simple oral/nasal ratio. But filtering results in a more complex output product: the ratio of the amplitude in a limited range of the speech frequency spectrum. This measure is known as nasalance, and it has been found to correlate moderately with perceived nasality (Fletcher and Bishop, 1973). Higher the nasalance, higher the nasality and vice versa.

Nasality was analysed in this study on the phonation of the vowels /a/ (a low-back vowel), /i/ (a front-high vowel) and /u/ (high-back round vowel), */e/* (a high-back vowel) and /o/(a central-round vowel), and two consonants */ml* and /z/ (requiring high elevation of the tongue tip), and two sentences, in one of which there were nasal sounds (NS) while in the second there were no nasal sounds (NNS).

The results showed that the mean TONAR values were not significantly different between the groups for any of the phonetic units except the non-nasal sentence. But, high TONAR (low nasality) values were noted for the hyperkinetic dysarthric group even for those sounds /m/ and sentences (NS) which are nasalized. The higher values for these units in the hyperkinetic group seems to have been contributed to by the EVT and the dyskinesia group. The implication is that even those sounds and sequences which are normally nasalized in speech were not nasalized in the speech of hyperkinetic dysarthrics (principally, the EVT and the dyskinetic dysarthrics) in this study. The production of these sounds was denasalized. Similarly, the TONAR values for the hypokinetic group were lower than that in normals as well as the hyperkinetic dysarthrics. Though the difference in mean values were not significant, the meaning of this result is that hypokinetic speech tended to be nasalized. In general, the higher TONAR values for the hyperkinetic group on all units suggested that speech tended to be denasal.

The nasalance values for the different groups confirmed the results on TONAR. The nasalance values were lower for the hyperkinetic group (except on /m/ and nasal sentence) and higher in the hypokinetic group. Lower nasalance values indicate lower nasality and higher nasalance scores indicate high nasality. However, it must be noted that there was high variability in the data.

The evidence of hypernasality in hypokinetic dysarthrics in this study, though not substantiated by statistical significance, is in consonance with evidence from past research.

4.8 Speech Intelligibility

Reduced speech intelligibility is one of the prominent sequence of the neurological involvement. Articulatory problems, most of them being distortion type errors, as we have seen in this study, is another important factor influencing speech intelligibility. Since speech is social tool, it's most significant measurement should start with an assessment of the degree to which it can be understood.

Intelligibility was rated in this study by a panel of independent judges on a 7-point rating scale, an adoption of Langmore and Lehman (1994) with '1' standing for completely intelligible speech and '7' reflecting completely unintelligible speech. Speech intelligibility of the dysarthric groups was significantly lower than that of normals but a differentiation was not possible between the two dysarthric groups. Among the subgroups, the dysarthrics had the lowest intelligibility ratings and were significantly different for chorea, EVT and the dyskinetic groups. It may be recalled that the dystonic patients had the highest percentage of articulatory errors besides being most consistent in their articulatory errors and therefore, it is plausible that the poor speech intelligibility in this group is a direct reflection of the higher percentage of articulatory errors. Speech intelligibility levels of patients with chorea and dyskincsia was nearer to that of normals.

In addition, decreased altered motion rate (DDK repetitions) in the dysarthric groups compared to normals might be a contributing factor for the low speech intelligibility in dysarthrics (Dworkin and Aronson, 1986). Dworkin and Aronson (1986) found a significant relationship between altered motion rates and speech intelligibility ratings. Though there are many methodological differences between this and the Dworkin and Aronson study it can be said that if the accuracy of alternating repetitive tongue movements are reduced during isolated CV syllable testing, then the ballistic adjustments of the tongue required for normal contextual speech may be similarly slow and imprecise. However, caution must be exercised in interpreting strong correlations as evidence of causation.

4.9 Severity of Dysarthria

Severity of dyskinetic speech was also judged on a 7-point scale with '1' standing for normal speech to '7' reflecting profound severity. Results indicated that hypokinetic and hyperkinetic dysarthrias were significantly different from normal, but on the basis of severity ratings, it was not possible to discriminate the two dysarthric groups. Among the subgroups, the dystonics had the poorest ratings and were significantly different from chorea, EVT and dyskinetic dysarthrics.

The hyperkinetic dysarthrics, and the dystonics among them, had the highest percentage of articulatory errors. The intelligibility ratings by the groups seem to have been a reflection of the percentage of articulatory errors. Similarly, there is a close parallel between the percentage of articulatory errors, intelligibility ratings and the severity ratings given by the judges. It is plausible that while rating the severity, the judges would have done so primarily on the basis of the extent of articulatory errors even though, an elaborate set of criteria was provided to the judges to base their judgement. But, this is less probable because the judges for the severity rating were different from those who participated in the intelligibility rating except the experimenter. It appears that the two sets of judges who judged intelligibility and severity based their judgement on the number of articulatory errors.

4.10 CT Scan findings

Different indices were computed to analyse cortical or subcortical atrophy based on standard measurements (Erkinjutti et.al., 1987). They included the number of sulci in the upper CT cuts (cortical atrophy); bifrontal index, bicaudate index, maximum width of the third ventricle, cella media index, and the ratio of the maximum width of the third ventricle to transverse diameter of the skull (subcortical atrophy); ratio of the APD of pons to the APD of the 4th ventricle and transverse diameter of pons to CP angle cistern (brain stem involvement - pontine atrophy).

The CT features confirm the presence of subcortical and cortical atrophy in the hypo- and hyperkinetic groups, but the differentiation of the subgroups was not possible on this basis. It is probable that a greater delineation of the lesion is possible through MRI studies. There are a number of studies (Terao et. al., 1991) which have employed MRI in the diagnosis of hyperkinetic dysarthria. In general, MRI has been shown to be sensitive in identifying bilateral/unilateral lesion of the putamen, globus pallidus, caudate nuclei, substantia nigra and other subcortical structures and their role in precipitating dysarthria.

It is well-known that structural changes in the brain appear quite at later stages of the illness while the functional changes, without concomitant changes in the gross anatomy can and do occur in the initial years of illness.

This is plausible, but when we examined the onset and duration of the problem in our patients, we found that the hypokinetic patients had dysarthria for an average duration of 2.75 years while the corresponding figures for the subgroups of hyperkinetic dysarthria were as follows : 4.75 years (chorea), 6.5 years (EVT), 6.75 years (dystonia) and 10.75 years (dyskincsia) for an average of 6.44 years for the hyperkinetic group. Though there is no particular durational limit by which time structural changes should appear, an average duration of around 6.5 years as in the hyperkinetic groups is a reasonable time by which anatomical changes should appear. The point is that there may not be well localized structural changes at all underlying different dysarthrias, and the underlying abnormality could well be only functional (physiological) in nature. Continued research is warranted in this area.

Resting tremor is one of the characteristic features of Parkinson's disease. However, there are a number of patients who typically have resting tremors alone for at least 5 years without development of other Parkinsonian signs (Chang et al., 1995). Chang et al (1995) did a PET study and demonstrated a markedly decreased striatal uptake of fluoro-dopa to the range of Parkinson's disease which suggested a subtype of Parkinson's disease. MRI was also performed which showed typical findings of Parkinson's disease with smudging of decreased distance between substantia nigra and the red nucleus. Quantitative analysis also showed a significant decrease of the above-noted distance when the resting tremor group was compared to the EVT group.

The pathological basis for the dystonic muscular overactivity is unknown. A small number of autopsy studies of patients with idiopathic dystonia revealed no consistent pathology (McGeer and McGeer, 1988). CT and MRI revealed no lesions in the large majority of patients who have dystonia without other neurological findings. Two autopsy studies found similar abnormalities of norepinephrine in the brainstem and basal ganglia of three patients with idiopathic dystonia (Horny Kiewicz et. al., 1988; Jankovic and Svendsen, 1987). Analysis of patients with secondary dystonia associated with discrete lesions indicated that dystonia arises from dysfunction in the caudate, putamen, thalamus, or brainstem (Marsden et. al., 1975; Pettigrew and Jankovic, 1985). The results of the present study seem to corroborate the findings of Pettigrew and Jankovic (1985).

Better localization of neurological lesions and correlation of neurological symptoms and lesion probably requires more dynamic studies like positron emission tomography. This study is perhaps the first in this country which has attempted to study and correlate speech and voice deviations in dysarthria with CT scan observations.

It is worth noting that in both the hypo- and hyperkinetic groups not only was there subcortical atrophy, but significant cortical atrophy as well indicating different nature of the lesions in the two groups.

4.11 Correlation Between Neuro-, CT Scan Findings and Speech Variables

Metter and Hanson (1986) compared clinical syndromes, neuroanatomy and glucose metabolism with speech characteristics in varying degrees of hypokinetic dysarthria. In this study, 7 male patients with Parkinsonism secondary to Parkinson's disease or progressive supra-nuclear palsy, underwent clinical neurological, X-ray CT, positron emission tomography (PET) with (F-18) - flurodeoxyglucose (FDG), speech and acoustical examination. Extensive variability observed in speech features, both clinical and acoustical, seemed to be independent of the severity of any Parkinsonism sign, PET, FDG or CT findings. CT scans did not show any distinct changes that could be related to any clinical feature of dysarthria. Most subjects showed some degree of cortical atrophy, but this was consistently mild. What appeared to be important for the appearance of the abnormal acoustic features was the degree of overall severity of dysarthria.

Metter and Hanson's (1986) results showed that severe dysarthria can occur in the presence of only mild clinical symptoms. No relationship was found between the degree of rigidity or bradykinesia and speaking rate, but dysarthria severity appeared to be a more important determining factor.

Correlations were run between neurological findings and speech features, and between CT scan findings and speech features to understand the neurological basis of some of the deviant speech dimensions in this study. The analysis of results for the hypokinetic group did not show a strong relationship between speech features and neurological findings. However, there was a suggested relationship between motor weakness and reading/speaking rate, and between hypokinesia and misarticulations. Incoordination was related to reading rate but the correlation was not statistically significant. In the hyperkinetic group, higher mental functions seemed to be the bases for poor intelligibility, higher articulatory errors and high severity of dysarthric speech. Motor weakness, incoordination, and involuntary oral movements were associated with poor DDK rate. However, as said earlier, correlations, even if they are strong and significant, should not be taken to infer a 'cause and effect' relationship. The poor correlation between most of the factors were probably the result of small sample and high variability of the data in each group.

Correlation between CT and speech findings suggested poor relationships in the hypokinetic group: one, a relationship between speech intelligibility, on the one hand, and thalamic atrophy in the subcortical region, and pontine atrophy in the brainstem and cerebellum (greater atrophy associated with poor intelligibility). The exact pathophysiology of this needs to be understood; and two, percentage of articulatory errors increased with increased cortical atrophy. In the hypokinetic group, increased pontine atrophy (in the brainstem and cerebellum region) was strongly associated with lower speech intelligibility, high misarticulations and higher level of severity of dysarthric speech. This also indirectly explains the relationship, observed in this study, between speech intelligibility, dysarthric severity (speech), and higher percentage of articulatory errors. Probably, an analysis of this nature on a larger and more homogeneous sample will reveal a more definite relationship particularly between CT scan and speech features.

Correlation within different speech findings revealed basically two things: one, higher misarticulatory errors resulted in poor ratings of both speech intelligibility and speech severity. Probably the listeners judged these two, based on the number of misarticulations; two, lower reading and speaking rates were associated with higher percentage of articulatory errors. One explanation for this could be that occurrence of higher percentage of articulatory errors probably reduces reading and speaking rates. An alternate explanation is that deviation in the duration (decreased duration - but not directly tested here) of syllables, particularly the vowel space, has been judged to be distortion type of articulatory error by the judges. A third explanation is that the cortical atrophy and pontine atrophy (which was observed in both types of dysarthrias) probably determine all the deviations with respect to intelligibility, rate of utterance, misarticulations and severity of speech.

It has been postulated that Parkinson dysarthria is related to the function of the basal ganglia, notably the striatum (caudate nucleus and putamen) and pallidum (globus pallidus). Hirose (1986) in his study on the pathophysiology of motor speech disorders quotes that the lesion most specific to Parkinsonism is considered to be the degeneration of the melanin-containing neurons in the compact zone of the substantia nigra and, to a lesser degree, other melanin-containing brain stem nuclei, such as the locus ceruleus. Each basal ganglia nucleus is anatomically uniform in structure, but specific regions tend to receive greater innervation from specific cortical regions, and in fact, cortical regions having strong cortical interconnections, will tend to innervate similar regions of the caudate and putamen (Yeterian and Van Hoesen, 1978). This implies that if the local areas of the basal ganglia are differentially affected, then, selective involvement of speech functions could occur. This could explain the wide variability among hypokinetic dysarthrias in terms of the speech features affected as also the poor correlation between clinical features and speech systems involved.

The exact role of the substantia nigra for the functioning of the basal ganglia is not yet fully understood. However, the substantia nigra may be regarded as a nodal point for the extrapyramidal motor system, probably exerting a modulating influence on the activity of higher striatal control centres. More recently, new information on the biochemical properties of the extrapyramidal system is available. It is now known that the most prominent biochemical feature of the basal ganglia is an high content of neurotransmitters of the monoamine group. In particular, dopamine has been demonstrated in high concentration in the nigrostriatal dopamine pathway which originates from the compact zone of the substantia nigra and ends synaptically in the striatum. Further, it has been confirmed that the depletion of dopamine produces akinesia, rigidity of the skeletal muscles and tremor, all of which are characteristic of Parkinsonism. This conclusion has been further attested by excellent results achieved after of the administration of L-dopa to patients with Parkinsonism.

In a correlational study of the speech parameters and neurological findings in 81 subjects with Parkinson's disease, Seguier et al., (1974) concluded that the two major factors underlying all clinical symptoms were (a) tremor and (b) a general severity of all the other symptoms. Seguier et. al (1974) did not find, in their study, that speech impairments were related to tremor, but, on the other hand found a relationship between speech impairment and other characteristics such as masklike face and gait difficulty.

Speaking rate in Parkinsonian dysarthria, a prosodic parameter is reported to be faster than normal. This accelerated speech pattern is due to the phenomenon of articulatory undershoot (Netsell et al, 1975). Even with normally timed neural control signals, the articulators might fail to reach their target positions in time because of the rigid musculature. This 'undershoot' could be a contributing factor in the perception of accelerated speech. However, it appears that articulatory undershoot is not uniform, and is influenced by linguistic demands.

4.12 Correlation between Speech Features

A series of correlations were run to understand the relationship between factors like speech intelligibility, reading rate, severity of dysarthric speech, speaking rate, misarticulation etc. Pearson's Product-Moment correlations were computed between a given set of two factors. Separate correlations were run for the hypokinetic and the hyperkinetic group, but significance of correlations were not tested because of the small sample size.

In the hypokinetic dysarthria group, speech intelligibility and percentage of misarticulations were positively correlated meaning that lower misarticulations were associated with higher intelligibility ratings and vice versa (rating of '1' - most intelligible - was positively correlated with lower percentage of misarticulation and intelligibility rating of '7' - most unintelligible - was correlated with higher percentage of misarticulations). Intelligibility was negatively correlated with reading meaning that higher rating of intelligibility was associated with lower rates of reading. Speech intelligibility was positively correlated with severity of dysarthria. The inference is that higher ratings of intelligibility (poor ratings) correlated with higher ratings (profound severity) of dysarthria.

Intelligibility ratings were negatively correlated with reading rate meaning that higher intelligibility was associated with higher reading rates. In other words, lower reading rates where the phonemes were prolonged or the interword/intersyllabic gaps were longer, led to poor ratings of intelligibility (ratings of 5, 6, or 7 which indicate poor intelligibility). It may also mean that reading rate was influenced by misarticulations. Specifically, higher percentage of misarticulations reduced the reading rate, and consequently speech intelligibility suffered. Therefore, it may be reasonable to infer that it was not the reading rate, per se, which influenced speech intelligibility, but it was the higher percentage of misarticulations.

Reading rate and misarticulations were negatively correlated meaning that higher rates of reading were associated with lower percentage of articulatory errors. This relationship holds good with the hyperkinetic group also. On the face of it, this relationship appears illogical. One would expect that faster rate of reading leads to higher misarticulations. Therefore, the probable meaning of this relationship is that greater percentage of misarticulation reduces the reading rate. However, caution should be exercised in this conclusion because such a relationship was not seen with reference to speaking rate. In fact, speaking rate was not particularly well correlated with any other factor in the hypokinetic group.

Severity of dysarthria was positively correlated with misarticulations and negatively with reading rate. The meaning is very clear. High percentage of misarticulatory errors makes the dysarthric speech problem more severe. This relationship when interpreted along with the ratings given for intelligibility and severity of dysarthria puts the relationship between these 3 factors in proper perspective : greater the percentage of misarticulatory errors, poorer were the intel1igibi1-

ity ratings and poorer were the severity ratings. In other words, the judges have based their judgement of both intelligibility and severity solely on the basis of number of articulatory errors.

The relationships described so far for the hypokinetic group also holds good for the hyperkinetic dysarthric group except in 2 respects: first, unlike in the hypokinetic group, speech intelligibility and speaking rate were negatively correlated in the hyperkinetic group. The explanation that has been advanced to explain the relationship in the hypokinetic group applies to the hyperkinetic group also; second, there was a strong relationship between speaking rate and percentage of misarticulation (negative correlation), with reading rate (positive) and with severity of dysarthria (negative). The relationship between speaking rate and misarticulations can be interpreted in the same way as the relationship between reading rate and misarticulations in the hypokinetic group. The occurrence of a large number of misarticulations probably reduces the speaking rate. The relationship between the speaking rate and intelligibility, and speaking rate and severity can also be explained as in the hypokinetic group - reduction in speaking rate and the concomitant changes like prolonged syllables and prolonged gaps attracted poor ratings of intelligibility as well as dysarthria severity.

4.13 Multivariate Analysis

Canonical Discriminant Function (CDF) analysis, a multivariate technique was employed to analyse the data pertaining to selected deviant speech-voice dimensions. The purpose of CDF analysis was to

a) classify a given patient to one of the two diagnostic categories of hypokinetic or hyperkinetic dysarthrias,

b) identify the structural configurations of a set of deviant speech-voice dimensions in multidimensional discriminant space, and then to identify the underlying hypothetical speech-voice dimensions associated with diagnosis, and

c) describe the prominence of a given parameter for identification among several parameters of speech-voice.

As the sample size was less and the number of speech parameters analysed was very large, some pruning in the number of parameters to be considered for CDF analysis was to be done. One hundred and fifty four of the total of 209 parameters were selected for the first stage of analysis. There were no specific criteria in the selection of these 154 measurements though one of the factors considered pertained to whether or not those factors had shown a significant difference in their distribution in the two dysarthric categories on the one-way ANOVA. The measurements selected for CDF analysis included phonatory (36), resonatory (10), articulatory (96) and prosody (12). Though it may appear that more importance has been given for articulatory measurements than others, their selection was a function of the number of measurements available in each category, and a function of number of measurements which showed significantly different distribution in the ANOVA. In any case, as the second stage of CDF analysis has shown, absolute number of measurements selected under any category was in itself, not relevant.

4.13.1 Phonatory Measurements

In the step-wise analysis, the CDF analysis selected 7 of the 27 Phonatory factors related to voice parameters. The CDF analysis computed the standardized canonical coefficients for parameters selected in the step-wise analysis. The standardized coefficients show the relative importance of the different measurement in distinguishing between, different groups. The CDF analysis showed that, of the phonatory measurements - factors like RAP-5 point, DLT (frequency), jitter (frequency), fundamental frequency, and fluctuations in frequency - were having more loads than the remaining variables, and thus they were more prominent in differentiating the two dysarthric groups. It may be pertinent to note that all these measurements, except FO, relate to the short-term stability of the vibratory mechanism.

In the next stage, multiple group discriminant functions (Anderson, 1957) were computed based on which classification was computed for trial analysis and Jackknifed classification. The results of classification matrix showed that the 7 measurements selected were good enough to discriminate between the groups, but the correct classification was only 76.5%. Two of the normals and one hypokinetic dysarthric were grouped under the hyperkinetic dysarthria while 3 hyperkinetic dysarthrics were distributed in the hypokinetic and normal groups. In a similar analysis pertaining to 3 of the 9 measurements related to phonational range, the correct classification was only 50%. The extent of correct classification was 87.5% for normals, 25% for hypokinetic dysarthrics and 50% for hyperkinetic dysarthrics.

4.13.2 Resonatory Measurements

The CDF analysis selected 4 of the 10 resonatory measurements (nasalance on /a/, /o/, and nasal sentence, and TONAR on /i/). However, the trail analysis and Jackknifed classification showed that the correct classification was a very poor 47%, with more number of hyperkinetic dysarthrics being wrongly categorised under the hypokinetic or normal groups and nearly 40% of the hypokinetic dysarthrics wrongly classified under the hyperkinetic dysarthrias.

4.13.3 Articulatory Aspects

CDF analysis with respect to articulatory aspects was done at 3 levels with the first level pertaining to voice initiation measurements (2 out of 4 were selected by CDF analysis); second level pertaining to VOT measures (11 out of 36); and the third level pertaining to DDK repetitions of monosyllables (10 out of 56 measures were selected). Initiation measures (voice initiation time and speech initiation time for the sentence starting with voiceless consonant) yielded a classification score of just 53%; VOT measures resulted in a correct classification of 88%; while DDK measures correctly classified subjects to the extent of 82%. Among the VOT measures, the VOT for stop consonant /pa/ in a different vowel context appeared to be more load bearing than others. VOT measures and DDK measures appeared to classify hypokinetic dysarthrics into the correct group, while initiation measures placed the hypokinetics into either normal or hyperkinetic groups.

4.13.4 Prosodic Measurements

The CDF analysis selected 6 of the 12 measurements related to prosody. Jackknifed classification led to correct classification to the extent of 91% with 2 hyperkinetics wrongly placed in the hypokinetic category.

4.13.5 Second Stage of CDF Analysis

The second stage of CDF analysis consisted of pooling all the 43 variables selected from the first stage of CDF and making a step-wise analysis. In addition, some variables which were included in the first stage of CDF analysis were included in the second stage of analysis. For example, though the first stage of CDF analysis selected only 4 out of 10 resonatory variables, all the 10 measurements, were included in the second stage of analysis. This was done because the number of certain variables selected for the second stage analysis were too small. In the second stage, 31 measurements were eliminated and the remaining 12 measurements were found to yield 100% correct classification of the subjects. Factors related to short term stability of the vibrating system, TONAR and VOT measures seem to be more load bearing for correct classification than other measurements.

4.13.6 Conclusions : CDF Analysis

What is all the significance of the results of CDF analysis for diagnosis of dysarthria? The CDF analysis has shown that of all the measurements made, just 12 measurements are sufficient to correctly classify the subjects into one of the two dysarthric groups. But, here the classification is based on a prior knowledge of the diagnostic category to which the patients belong *tot.* But, the question of the extent to which, in a clinical situation, the results of CDF analysis, can be applied in the 'diagnosis[7] of the problem of a given patient, can be answered only with further research.

The 12 measurements which are sufficient for correct classification of dysarthric categories are spread over the speech protocol. Those 12 measurements span across phonatory (2), resonatory (2), articulatory (6) and prosodic (2) aspects. Thus the speech protocol employed in this study is justified. There are some incongruences in the results of univariate and CDF analysis. For example, the second part of CDF analysis showed that TONAR on *Izl* is one of the measures leading to correct classification of subjects. But, we find that in the one-way ANOVA, the mean TONAR on *Izl* did not differentiate between the three main groups. The meaning of this discrepancy needs to be understood.

The final result of CDF analysis need to be correctly understood in the light of several limitations. First, the selection of variables. The small sample size and the large number of measurements necessitated some pruning in the number of measurements selected for CDF analysis. No definite criteria were followed in the selection of measurements for the CDF analysis although one of the factors considered was whether these parameters had shown a significance difference between the three main groups in the one-way ANOVA. The result is that some variables which showed a significant difference in means between the three groups, in the 1-way ANOVA, were selected and some were rejected. Similarly, some measures which did not show a significant difference between the groups were selected and some were left out. In hindsight, the selection of measurements seems to be extremely random, but whatever it is, it remains a limitation of the analysis.

Another consequence of this 'random' sampling was that some results pertaining to articulatory errors or rate of production (prosody)' were not included in the CDF analysis and thus their importance was under emphasized. Similarly, by including all the 36 VOT's (only a handful of these measures showed a significant difference between the groups) and 56 DDK measures, the importance of these measures have been over emphasized. A similar overemphasis can be found in the inclusion of the same measures in two forms. For example, inclusion of four measures like 'time taken to speak' (this is not a variable at all), 'the number of syllables spoken', 'speaking rate' and 'speech rate' (all reflecting on the same speech aspect) where only one measure of speaking rate would have sufficed. Of course, inspite of this, the CDF has selected only 12 measures as relevant/sufficient for correct classification and thus, the merits of CDF analysis cannot be set aside. But, the point is that the entire analysis could have been done in a more systematic manner.

Chapter 5

SUMMARY AND CONCLUSIONS

Dysarthria represents a group of disorders characterized by disturbances in speech muscular control due to paralysis, paresis, weakness, slowness, incoordination, and/or altered tone. One or more of the motor processes of speech production including respiration, phonation, articulation, resonance and prosody may be involved.

The extrapyramidal level of motor organization consists of the basal ganglia deep with in the cerebral hemispheres plus the paired substantia nigra and subthalamic nuclei of the upper brain stem. Each basal ganglia is composed of the corpus striatum and the globus pallidus. Each corpus striatum is made up of the caudate nucleus and the putamen. The extrapyramidal system receives input from the cerebral cortex, the thalamus and undoubtedly from other sources as well. The chief extrapyramidal output is dual: from the pallidus to the thalamus and from there to the cortex, and from the pallidus to the reticular formation of the brainstem. There arc also projections from the pallidus to the hypothalamus.

The output from the extrapyramidal system is apparently from the pallidum via an ascending path to the thalamus and cortex and by a descending path to the brainstem. The ascending path is the major one in size and its predominant effect seems to be inhibitory. The descending path appears to be inhibitory on tone and facilitatory for movements. Normal function of the basal ganglia is dependent upon proper balance between the inhibitory influence of dopamine and the facilitatory influence of acctylcholine in the striatum. Relative deficiency of dopaminc results in hypokinctic states. Marked limitations of range of movements as in the hypokinesias and the involuntary movements of the hyperkinesias are the outstanding characteristics of hypo- and hyperkinetic dysarthrias, respectively, as they affect speech.

Much of our knowledge on the speech-voice dimensions which are deviant in hypo- and hyperkinetic dysarthriahas come from perceptual studies. A single most important contribution to the study of speech disorders in dysarthria was the identification of clusters of deviant speech-voice dimensions by Darley, Aronson and Brown (1969 a,b). They analysed the perceptual judgments of dysarthric speech and came out with unique clusters that underlie each type of dysarthria. Perceptual analysis has a role in the investigation of dysarthria, but it alone is inadequate as it is subjective in nature and thus lacks specificity, uniformity and reliability. Objective identification of deviant speech dimensions which allows identification and accurate measurement of a given variable is important.

Objective studies on dysarthria are restricted to the study of one or two aspects of speech production. Univariate comparison that emphasizes a single feature as characteristic of the whole group may be misleading. It is well-known that it is not unusual for patients to have dysarthria related to more than one motor processes of speech production: phonation, articulation, resonance, prosody and respiration. Therefore, multivariate approaches are more appropriate for a comprehensive assessment of dysarthria. Information on the specific aspects of motor processes affected in a given patient would help in planning appropriate treatment strategy besides providing valuable diagnostic information.

The purpose of the present study was to analyse the deviant speech-voice dimensions in a group of hypokinetic and hyperkinetic dysarthrias. The latter group included patients with chorea, EVT, dystonia and tardive dyskinesia. In addition, the analysis addressed the question of which deviant speech-voice dimensions are important for the identification of a given dysarthric condition. Correlation analysis was also carried out between CT scan and neurological and speech findings to understand the neurological basis of deviant speech dimensions.

Accordingly, speech samples were recorded from the subjects on a comprehensive speech protocol designed to include speech motor processes of phonation, articulation, resonance and some aspects of prosody. The recorded speech samples were subjected to acoustic analysis wherever required. Statistical analysis of the data was done at two levels : comparison of means between the three main groups of normals, hypokinetic, and hyperkinetic dysarthrias; and a comparison between the four subgroups of hyperkinetic dysarthrias.

5.1 Phonation

Investigation of phonatory parameters included FO, intensity, perturbation factors (both frequency and intensity), fluctuations in frequency and intensity, maximum phonation duration, s/z ratio, among others. From the results of the analysis of phonatory factors, the following tentative conclusions are drawn:

a) Factors related to perturbation (jitter and shimmer) and fluctuations in frequency (8 Hz fluctuations) and intensity (3 dB variations) were differently distributed in the dysarthric groups, though not consistently.

b) Most of the measures relating to phonatory parameters seemed to differentiate between normals on the one hand, and hypo- and hyperkinetic dysarthric groups, on the other hand. Only a few parameters like fluctuations in frequency per second, maximum intensity, and jitter (T%) differentiated hypokinetic from the hyperkinetic dysarthrias. There seemed to be a lot of overlapping in the mean scores between groups with the difference being one or two percentage points. This coupled with high variability in the individual data masked the chances of a statistically significant difference.

c) Phonatory factors were affected in patients with dystonia or dyskinesia in whom the clinical examination had indicated that only the lingual system was affected. Therefore, acoustical analysis has the potential to unravel the subclinical involvement of the system which may otherwise go unnoticed in the neurological examination.

d) The results of subgroup analysis (subgroups of hyperkinetic dysarthrias) was largely unremarkable except that again phonatory factors related to perturbation or fluctuation could differentiate the subgroups. But, the pattern of differentiation of subgroups was by no means consistent.

e) Component analysis of voice samples (initial, medial and final segments) did not yield significantly different results from that of the whole sample in terms of differentiation of dysarthric groups. However, there were indications that component analysis may yield additional information over and above that provided by the whole sample analysis. For example, segment/ a1/ yielded different results on intensity fluctuations compared to the whole sample analysis and this result could differentiate each of the three main groups from each other.

f) Separate analysis of male and female speaker's voice showed that a combined analysis may result in the identification of more number of female dysarthrics (false positive). Analysis of mean intensity, jitter (period), jitter (frequency) and shimmer (dB), separately for the two sexes, yielded additional information.

5.2 Articulation

Four aspects of articulation were investigated in this study. They included speech sound articulation, diadochokinetic rate, voice initiation and termination time and voice onset time. Speech sound articulation was analysed on three tasks of spontaneous speech, reading and picture-word articulation test in Kannada.

5.2.1 Speech Sound Misarticulation

From the results on speech articulation, the following tentative conclusions are drawn :

a) It was possible to differentiate dysarthric groups from normals, and between the dysarthric categories, based on the mean percentage of articulatory errors. But, there were indications that mean percentage of articulatory errors reflect on (i) the particular system involved (lingual, palatal etc.), in a given patient and (ii) the severity of the problem. The dystonics in whom the lingual system was affected had the highest misarticulations.

b) Majority of the articulatory errors were of distortion type in all the dysarthric groups. The nature and type of misarticulations were not unique to any dysarthric group.

c) The hypokinetic dysarthrics seemed to be most inconsistent in their misarticulations compared to the hyperkinetics. Among the hyperkinetic dysarthrias, the dystonics seemed to be most consistent in their misarticulations.

d) Patients with chorea and EVT demonstrated a high percentage of misarticulations on vowels, majority of them being distortions. The role of the laryngeal and articulatory systems in perpetuating this kind of error needs to be investigated because there was nothing suggestive, in the clinical examination, of the involvement of the laryngeal system in chorea and articulatory system in EVT.

e) In general, the hypokinetic dysarthrics misarticulated more on alveolars and velars; the hyperkinetics on alveolars, palatals, velars and vowels; patients with chorea and EVT on vowels; and dystonics on all sounds except nasals while the dyskinetics misarticulated alveolar and velar sounds.

5.2.2 Diadochokinesis

DDK was analysed on the repetitions of monosyllabic, bisyllabic and two types of trisyllabic sequences (CVCVCV sequences in which the consonant or the vowel was held constant) DDK rate was analysed on the repetitions of all types of sequences while durational and spectral parameters were analysed only on monosyllabic repetitions. From the results on DDK the following tentative conclusions are made:

a) It was possible to differentiate hypo- and hyperkinetic dysarthrics from the normals on the basis of repetition rate of monosyllables. The repetition rates on bisyllables and trisyllables, in addition, differentiated hyperkinetic from hypokinetic dysarthrias. In general, the results of the present study are consistent with that reported in the literature in respect of repetition rate of voiceless stops.

b) On DDK tasks which did not require phonatory offset-onset, (for example, vowels, bisyllabic vowel sequences, and CVCVCV sequences with voiced stops), the hypokinetic dysarthrics performed on par with normals. But when the production required off-on switching of the laryngeal system, the performance of the hypokinetic dysarthrics was lower than that of normals. This implicates the laryngeal system in hypokinetic dysarthrics and also implies that the hypokinetic dysarthrics had difficulty in coordinating phonatory and articulatory activities.

c) Monosyllabic repetition rate with bite block was unremarkable, in any group, except that the rate was lower compared to 'without-bite block' condition. But the mean differences were not statistically significant.

d) No additional or new information was available when the initial and final segments of repetition sequences (1 second each) were compared for repetition rate.

e) Despite the lack of statistical significance of the mean difference in syllable duration and duration of intersyllabic group, we are of the opinion that the results of the present study, on these two factors, generally agree with the results of past research. Portnoy and Aronson (1982), and Tatsumi et. al (1979) reported temporal irregularities on repetition sequences in many different dysarthric groups.

f) Mean peak frequency (Hz) of repetitions was significantly different between the main groups while there was no statistically significant difference in the mean peak intensity of repetitions. This is some evidence to show that the spectral characteristics of DDK repetitions vary in the dysarthric groups. However, the variability with respect to both frequency and intensity was very high.

5.2.3 Reaction Time

Voice initiation and termination time in response to click sound was also analysed. Besides, speech initiation time on two sentences - one sentence starting with a voiceless consonant and a second one starting with a voiced sound, was analysed. The tentative conclusions from this analysis are:

a) Both the hypokinetic and the hyperkinetic dysarthrics were slower than normals in initiating and terminating voice but only the difference between normals - hyperkinetic dysarthrics was statistically significant. Slowness of movements being the most predominant characteristics of Parkinsonics, it was surprising to find that the Parkinsonics in this study were not statistically slower than normals in their VIT and VTT.

b) The hypokinctic and the hyperkinetic dysarthrics were slower than normals on SIT, but again, only the difference between the normal - hyperkinetic dysarthrias was significant for the sentence starting with voiceless consonant. This shows that, irrespective of statistical significance, the dysarthrics have difficulty not only in initiating quick movements, but also in coordinating the laryngeal and articulatory movements.

5.2.4 Voice Onset Time

VOT was measured for six consonants in the environment of 3 vowels, with each vowel followed by a voiceless or voiced stop consonant. Thus 36 VOT's were measured. The following tentative conclusions are drawn :

a) VOT's for voiceless consonants failed to differentiate between dysarthric groups. VOT's for voiced consonants were especially short (-ve) in the case of hyperkinetic dysarthrics which means that voicing was occurring much earlier than in the other groups. This is intriguing because on the VIT task (a voice reaction time task), though the modality and processing of the two tasks are different, the hyperkinetic dysarthrias were slower. The results of the present study on VOTs for voiceless consonants (which were longer in the present study) differs from those of Morris (1984) who reported shorter VOT's.

b) The VOT's were especially longer (voiceless consonants) and shorter (voiced consonants) in the dystonia group though the difference in mean VOT's were not always significant among the subgroups of hyperkinetic dysarthrics.

c) In general, the VOT's for voiced stops could differentiate between dysarthric groups particularly if the sample is homogeneous.

5.3 Prosody

The analysis of prosodic aspects was restricted to production of two sentences at two rates and an analysis of the temporal and spectral characteristics of these productions. Besides, an analysis of speaking, reading and whispering rate was carried out on a sample of spontaneous speech and reading of an all-phoneme passage. The following conclusions are drawn from the data :

a) Both normals and the dysarthric groups failed to achieve sentence production at a fast rate. Duration of words and interword gaps were longer in the dysarthric groups compared to normals, though the difference was not always statistically significant. Thus, the results do not provide any evidence for supporting 'festinant speech' in Parkinsonics as it has been reported by some investigators.

b) The dysarthric speakers manifested the same level of frequency and intensity distributions as the normals in their production of sentences at two rates. There was no evidence of monoloudness or monopitch in their speech.

c) The Parkinsonics in this study had slower speaking, reading and whispering rates than the normals, but faster than hyperkinetic dysarthrics. Slowed speech is consistent with the pathophysiology of Parkinson's disease. There was not much of a difference in the speaking (with voicing) and whispering (without voicing) modes in any of the dysarthric groups. This shows that the changes in the rate of speaking and the difficulty the patients may have in maintaining rate is not influenced by laryngeal factors or are related to coordination of laryngeal and articulatory movements.

d) Analysis of spectral characteristics (frequency and intensity) in speech indicated that the dysarthric groups had the same type of average frequency and intensity distribution in their speech as the normals.

5.4 Nasal Resonance

Nasal resonance was analysed on the production of vowels, consonants and two sentences - one of which had nasal sounds and the other none. TONAR and nasalance were measured. In general, the results of the study indicated that the Parkinsonics were hypernasal although the mean TONAR and nasalance values were not significantly different between the groups. Velopharyngeal functioning in Parkinsonics disease is controversial. Our results support the general notion that Parkinsonics arc hypernasal. The hyperkinetic dysarthrics were within the normal range though the patients with chorea sounded denasal on some phonetic units.

5.5 Intelligibility of Speech

Speech intelligibility was tested by a panel of judges who rated the samples of spontaneous speech on a 7-point rating scale where ' 1' represented completely intelligible speech and '7" represented completely unintelligible speech. The hypokinetic and hyperkinetic dysarthrics[1] speech was less intelligible than the speech of normals, but there was no difference between the dysarthric groups.

Among the subgroups of hypokinctic dysarthria, the dystonics speech was the least intelligible. There seemed to be a strong relationship between the percentage of articulatory errors and the intelligibility ratings, and the judges seemed to have rated intelligibility based solely on the extent of articulatory errors.

5.6 Severity of Dysarthric Speech

Similarly severity of the dysarthric speech was rated by a panel of judges on a 7-point rating scale with ' 1' reflecting normal speech and '7' standing for profound severity. The results were similar to the results on intelligibility of speech. It appears that judges have based their judgments of both severity and intelligibility of speech on the severity of articulatory errors.

5.7 Neurological Basis

Different indices were computed from CT scans to indicate cortical and subcortical atrophy. The results showed that the dysarthric groups could not be differentiated based on CT scan findings and that all the different groups of dysarthrics had some kind of cortical and subcortical atrophy. In general, the CT scan findings were not suggestive of structural damage in any dysarthric group. A cautious conclusion is that (a) the CT scan may not be sensitive enough to identify the structural changes and that MRI or PET scan may be more sensitive tools in this regard, or (b) that structural changes may appear quite at later stages of the illness, or (C) that there may not be structural changes at all underlying all types of dysarthria and it may be that the pathology is more physiological than structural in nature.

Correlations were run between neuro- and CT findings and some speech deviations to understand if there is a neurological basis for the speech deviations. The analysis of results for the hypokinetic group did not show a strong relationship between speech features and neurological findings. However, there was a suggested relationship between motor weakness and reading/speaking rate, and between hypokinesia and misarticulations. Incoordination was related to reading rate but the correlation was not statistically significant. In the hyperkinetic group, higher mental functions seemed to be the bases for poor intelligibility, higher articulatory errors and high severity of dysarthric speech. Motor weakness, incoordination, and involuntary oral movements were associated with poor DDK rate. However, as said earlier, correlations, even if they are strong and significant, should not be taken to infer a cause and effect' relationship. The poor correlation between most of the factors were probably the result of small sample and high variability of the data in each group.

Correlation between CT and speech findings suggested poor relationships in the hypokinetic group. A relationship between speech intelligibility, on the one hand, and thalamic atrophy in the subcortical region, and pontine atrophy in the brainstem and cerebellum (greater atrophy associated with poor intelligibility) was visible. The exact pathophysiology of this needs to be understood. A second relationship observed was the one between articulatory errors and cortical atrophy; percentage of articulatory errors increased with increased cortical atrophy. In the hypokinetic group, increased pontine atrophy (in the brainstem and cerebellum region) was strongly associated with lower speech intelligibility, high misarticulations and higher level of severity of dysarthric speech. This also indirectly explains the relationship, observed in this study, between speech intelligibility, dysarthric severity (speech), and higher percentage of articulatory errors. Probably, an analysis of this nature on a larger and more homogeneous sample will reveal a more definite relationship particularly between CT scan and speech features.

Correlation within different speech findings revealed basically two things: one, higher misarticulatory errors resulted in poor ratings of both speech intelligibility and speech severity. Probably the listeners judged these two, based on the number of misarticulations; two, lower reading and speaking rates were associated with higher percentage of articulatory errors. One explanation for this could be that occurrence of higher percentage of articulatory errors probably reduces reading and speaking rates. An alternate explanation is that deviation in the duration (decreased duration - but not directly tested here) of syllables, particularly the vowel space, has been judged to be distortion type of articulatory error by the judges. A third explanation is that the cortical atrophy and pontine atrophy (which was observed in both types of dysarthrias) probably determine all the deviations with respect to intelligibility, rate of utterance, misarticulations and severity of speech.

5.8 Multivariate Analysis

A CDF analysis was done, in two stages, the purpose of which was twofold : one, to classify a given patient into one of the diagnostic categories and two, to describe the prominence of a given parameter for identification among many speech-voice parameters. As the number of subjects was too small, and the number of parameters (measurements) was too high, some selection had to be made in the measurements to be included in the first stage of CDF analysis.- One hundred of fifty four of the 206 parameters were included in the analysis.

The results of the first stage of CDF analysis showed that consideration of any one process of motor speech will be sufficient for the correct classification of subjects. Frequency and intensity related measures led to a correct classification of only 76.5% with some of the normals and hypokinetics grouped under the hyperkinetic dysarthria category with an equal number of hyperkinetic dysarthrics wrongly grouped under normal or hypokinetic groups. Of the phonatory measures considered, variables like F0, jitter (frequency), fluctuations in frequency were more load bearing. A similar analysis of measures relating to phonational range resulted in a correct classification of subjects to an extent of only 50%. An analysis based on resonatory measurements yielded correct classification of just 47%. Corresponding figures for articulatory aspects were : **DDK** - 82%; voice initiation measures - 53%; Voice Onset Time - 88%; and prosodic measurements -91%.

The second stage of CDF analysis pooled all the 43 variables selected in the first stage of analysis and made a step-wise analysis. In the final analysis, it selected 12 variables which were most prominent (load bearing) and which yielded 100% correct classification of subjects. The meaning of the result is that of all the parameters measured, just 12 parameters spanning across phonatory (2), articulatory (6), resonatory (2) and prosody (2) are sufficient for correct classify cation of subjects. The significance of this finding for the correct diagnosis of a given patient needs to be further investigated.

5.9 Variability of Data

There are indirect suggestions in the presentations of Darley et.al (1975) that speech abnormality in hypokinetic dysartliria may be an uniform syndrome.

Though some uniformity can be found in the description given by Hanson and Metter (1980), and Bluementhal and Miller (1969), in progressive supranuclear palsy (also an hypokinetic dysarthria), they are all descriptions from selected subjects with severe dysarthria. Some speech features may vary greatly in Parkinsonian patients who may have less severe dysarthria (Metter and Hanson 1986) and as we have also seen in this study. Marked variations are also seen in patients with respect to other clinical features like tremor, rigidity and bradykinesia. A feature that consistently underlies the results on articulatory, phonatory, resonatory and prosodic processes in this study is the high variability in the data in both the hypokinetic and the hyperkinetic dysarthrias. Many a times statistically significant differences in mean scores were not observed only because of the high standard deviations. The implication of this result is this : emphasizing a specific feature such as rate of speaking or perturbation, or any other factor to characterize hypokinetic, or hyperkinetic dysarthria may not be appropriate. A greater emphasis should be placed on the extent of variability between patients. According to Metter and Hanson (1986), a most meaningful understanding of hypokinetic dysarthrias may result from an evaluation of a large mixed sample of Parkinsonic subjects, including patients displaying a range of severity. In other words, univariate comparisons that emphasizes a single specific feature as characteristic of the whole group may be misleading. Multivariate approaches more accurately differentiate subcategories of patients and should be of greater utility in identifying degrees of impairment.

Visual inspection of our data suggested that, in most instances, it was the high intcrsubject variability in the patient groups which prevented significant statistical results. According to Leuschel and Docherty (1996), this type of high variability in data has been a common finding in the field of motor speech disorders, although, it has not always been the main focus of discussion. Various explanations have been forwarded, in the literature, to explain the high interspeaker variability. It has been said that inter- and intraspeaker variability are often inherent characteristics of disordered speech and prevent any generalization being made from the results (Weismer and Liss, 1991 ; Yorkston et.al, 1984). Some others have tried to explain the high amount of variability within subject groups or the discrepancy of their results with other studies (Hertrich and Ackermann, 1993; Portnoy and Aronson, 1982). Aetiology and severity of the subjects are other commonly invoked factors to account for variability. These factors are difficult to control and are therefore likely to have affected subjects performance. With regard to the present study, differences in both severity and etiology seem to be appropriate explanations for the high degree of variability in the data ./The re fore, we are also of the opinion that, quantification of dysarthric speech in terms of group performance should not be considered as a conclusive evidence and still further, should not be generalized. The results of the present study should be interpreted with this perspective in the background.

One of the reasons that the issue of intersubject variability has been neglected in past research would appear to be the number of subjects included in the previous studies. The investigation of Darley et.al (1969 a, b) included 30 subjects in each group. With such high subject numbers, it is more likely that, statistical tests will identify certain trends that characterize the different groups of dysarthric speakers and that intersubject variability will be relegated to a secondary issue. However, studies of more recent times and particularly, those which studied smaller groups (Yorkston et.al, 1984; Metter and Hanson, 1986; Ludlow and Bassich, 1 983; Weismer and Liss, 1993; Liss and Weismer, 1992) have tried to give greater attention to interspeaker variability. Therefore, the need is for more rigorously controlled sample groups, individual detailed assessment of each speaker, followed by a multivariate approach to assessment considering a list of factors wherein each factor would be analysed as a function of several levels of another factor.

5.10 General

Acoustic analysis is the process of extracting and quantifying precisely defined and salient features of the speech signal through objective instrumental means. Advances in both instrumentation and signal processing have made this task eminently feasible. Also true is the fact that improved understanding of the laryngeal physiology and vocal disorder fostered the development of many specific acoustic measures and indices of vocal function. The acoustic signal - the voice per se - is the net product of all the physiologic events and conditions prevailing in the vocal system at a given instant. This is not to imply that there is necessarily, or even usually, a direct or immutable correspondence between any given anatomical or physiological variable and any particular parameter of the vocal signal. In the words of Baken and Orlikoff (1992), the interactions are too complex, and the degrees of freedom too numerous to allow for an unambiguous mapping of physiology on to acoustics. Therefore, the results of the study on deviations in speech, and more particularly the phonatory aspects and their physiological/neurological basis should be considered/interpreted keeping in mind formulation enumerated above.

From the results of the present study only tentative conclusions have been drawn for two reasons : one, the small sample size does not warrant any absolute conclusions, and two, though, most of the times, there was a difference in mean scores between groups, the difference was not statistically significant and when the difference was significant, it was not consistent across phonetic units or between different groups. For example, mean FO was significantly higher in the hyperkinetic group compared to normal, but, only on the phonation of vowel /i/. On the phonation of vowel /a/ and /u/, it was not significant. Besides, when so many comparisons are made, possibility of a Type I error is very high though a reasonable level of confidence (0.05) was specified. Therefore, a statistically significant difference being a chance occurrence is very high.

One another aspect to be considered is the heterogeneity of the sample. The patients selected in the study varied widely in terms of clinical characteristics, in terms of the system (speech related) involved, in terms of the duration of the dysarthria or the speech problem, among others. In a clinical set up, it would be very difficult to select a very homogeneous group considering the various inclusion and exclusion criteria followed, but future studies should consider selection of a more homogeneous groups in a study of this nature.

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Appendix 1

PATIENT CONSENT FORM FOR PARTICIPATION IN THE STUDY

I,____exercising my free power of choice, hereby give my consent to be included as a subject in the study on "Deviant speech-voice dimensions of dyskinctic dysarthrias". I understand that I will not be administered any medicine as part of the study. I have been informed to my satisfaction by the attending physician on the purpose of the study and about my role in the study. I have also been informed that my participation in the study may not result in improvement of my condition.

I am also aware of my right to opt out of the study at any time during the course of the study without having to give reason for doing so.

Signature - Physician　　　　　　　　Signature - Patient

INFORMATION TO BE GIVEN TO THE PATIENT

I would like to give you the following information on the purpose of this study.

We are trying to understand more about the condition from which you are suffering. We are endeavouring to understand the exact relationship between your neurological problems and the speech problems that you are manifesting. It does not involve any surgical procedure or the administration of medicine. Your participation in the study will not be much different from the examination you would undergo as a patient in the hospital, except that you would spend little more time with us than usual (about 60 minutes more).

Your participation in the study will neither entitle you to any more benefits than usual nor your non-participation will affect your regular examination or treatment at this institute. Your participation in the study will be purely for a scientific purpose. After joining the study, you arc at liberty to withdraw from the study at any time without giving any reasons to us. We would be more than pleased to answer any of your questions, about the study and your participation in it, now or any other time during the course of the study.

Speech-language Pathologist

Appendix 2

NEUROLOGICAL EVALUATION FOR DYSARTHRIA

Name : Age (Yrs) :

Sex :

Address :

Neuro No. : Case No. :

Occupation: Education:

Final Diagnosis Date of Assessment:

Card - 1

Duration of symptoms (months)

Onset :
1. Sudden
2. Subacute
3. Chronic

Progression : 0. No

1. Yes

Card - 2

Motor Symptoms :

Code 1 : 0 - No 1 - Yes

Code 2-4 Duration in months

Code 5 : 1. Distal weakness

2. Proximal weakness

3. 1 + 2

Code 6 : 1. Wasting

2. Stiffness

3. Fasciculations

4. 1 + 2

5. 1 + 3

Right upper limb

Left upper limb

Right lower limb

Left lower limb

Sensory Symptoms :

Code 1 - 4: Same

Code 5 : 1. Distal

2. Proximal

3. 1 + 3

Code 6 : 1. Parasthesias

2. Sensory loss

3. 1 + 2

Right upper limb

Left upper limb

Right lower limb

Left lower limb

<u>Card 3</u>

Cerebellar and Extrapyramidal symptoms

Code 1: 0 - No, 1 - Yes

Code 2-4 : Duration in months

Code 5 : 1. Rest tremors

2. Action tremors

3. Intention tremors

4. 1 + 2

5. 2 + 3

6. 1+2 + 3

Code 6 : 1. Chorea

2. Dystonia

3. Myoclonus
4. 1 + 2
5. 2 + 3
6. 1 + 3
7. 1 + 2 + 3

Right upper limb

Left upper limb

Right lower limb

Left lower limb

Head

Face

Tongue

Jaw

Neck

Slowness movement

Gait Swaying on walking

Short shuffling step

Propulsion

Retropulsion

Deceased arm swing

Falls (specify)

Spastic gait

Difficulty in initiation

Postural instability

Card 4 : OTHERS

Dysarthria

- Decreased volume
- Slow, monotonous
- Slurred
- Explosive
- Nasal twang

Dysphagia

Nasal regurgitation

Facial weakness

Code 5 1 - Right
2 - Left
3 - B/L

Cognitive Disturbance

- Memory disturbances
- Personality change
- Emotional liability
- Language disturbance

Seizures

Others

Bladder disturbances

Bowel disturbances

Vertigo

Syncope

Sexual dysfunction

Respiratory

Gastrointestinal

CVS

Past and Family History   Code 1 : 0- Absent
1 - Present

Hypertension

Diabetes

Stroke

Smoking

Alcoholism

IHD

Family History of similar disorder

Other

Card 5 : Clinical Examination

Code 1 : 0 - Absent
I - Present

Pallor

Jaundice

KF ring

Contractures

Scoliosis

Kyphosis

Short neck

Restricted neck movements

Neck body ratio

Hepatomegaly

Hypertension

Thickened nerves

Facies (Specify)

0 - Normal

1 - Abnormal

Neurologic Examination 0 - Absent

1 - Present

Higher Mental Functions :

Memory impairment

Impaired judgment

Impaired abstract

Language disturbance

Word output

Comprehension

Repetition

Naming

Reading

Writing

Apraxia

Visuospatial disturbance

Emotional liability

Speech 0 - normal/absent

1 - abnormal/present

Description Linguals Scanning

Labials Nasal twang

Gutturals Explosive

Palatals Loudness

Increased effort

Pitch low

Monotonous

Type

Code 1 -	Cerebellar	Code 2	1 - mild
2 -	Spastic	degree of	2 - mod
3 -	Extrapyramidal	impairment	3 - severe
4 -	Hypotonic		
5 -	Mixed		

Cranial nerves

Fundus

Saccades

Pursuit

Gaze palsy

Nystagmus (specify)

OKN

Convergence

Facial weakness

Code 2 -	1 - Rt	Code 1	0 - Normal
	2 - Lt.		1 - Abnormal
	3 - B/L		
Code 3 -	1 - UMN		
	2 - LMN		

Bulbar palsy Palatal movement

Code 2 : Pharyngeal movement

Pharyngeal reflex

1 - Rt.

2 - Lt. Palatal reflex

3 - B/L

Tongue Code 2 : 1 - Right

2 - Left

Tone 3 - Bilateral

Movement

Wasting

Fifth cranial nerve

Motor

Sensory

Any other

Card 6

Motor

Wasting RUL

Code - 1 0 - Absent/normal

1 - Present/abnormal Rt UL

Code - 2 1 - Distal Rt leg

2 - Proximal Lt leg

3 - Generalized

Code- 3 1 - Mild

2 - Moderate

3 - Severe

Tone

Code 1 to 3 score   Rt UL

Lt UL

Code 4   1 - Hypotonic   Rt leg

2 - Spastic   Lt leg

3 - Lead pipe rigidity

Power

Code 1 to 2   Same   Rl UL

0 - gr 0   Rt UL

1-1   Rt leg

2-2   Lt leg

3 - 3

4-4

Sensory

Code 1 & 2 same   Rt UL

Code 3 -   1 - Mild   Rt leg

2 - Moderate   Lt leg

3 - Severe

4 - Complete

Code 4 - 1 - Pain

2 - Temperature

3 - 1 + 2

4 - Touch

5 - Position sense

6 - Vibration

7 - 5 + 6

8 - 3 + 4 + 7

9 - 4 + 5 + 6

DTR Code 1 - Rt

2 - Lt Biceps

O - N

1 - Brisk Superior

2 - Clonus Triceps

3 - Decreased Ankle knee

4 - Absent

Plantars

Code - 1 : Rt

2 : Lt

0 - Absent

1 - Flexor

2 - Extensor

3 - Equivocal

Abdominals

1 : Rt

2 : Lt

0 - Absent

1 - Normal

Jaw Jerk

0 - Normal

1 - Brisk

Finger Flexion

1 - Rt.

2 - Lt.

0 - Absent

1 - Present

Hoffman

Code 1 : Right

Code 2 : Left

0 - Absent

1 - Present

Card?

Release Reflexes

Code 1 : 0 - Absent

1 - Present

Glabellav

Snout

Sucking

Palamonemtal

Grasp

Forced grouping

Tremors

Code 1	0 - Absent	Rt. UL
	1 - Present	Lt. UL
Code 2	1 - Rest	Rt. Leg
	2 - Action	Lt. Leg
		Lower jaw
		Tongue

Titulation

0 - Absent

1 - Present

Impaired FN test	Left
	Right
Dysdiadochokinesia	
	Left
	Right
Shin heel test	Left
	Right

Rebound

Postural instability

Stance ataxia

Gait ataxia

Initiating difficulty

Short steps

Propulsion

Retropulsion

Tandem gait

Romberg's sign

Dystonia

Code 1 - 0 - Absent Rt. UL

1 - Present Rt. Ul

2 -	1 - Distal	Rt. leg
	2 - Proximal	Lt. leg
	3 - Gen.	Truncal
3 -	1 - Mild	Nuchal
	2 - Mod	facial ms
	3 - Severe	

Code 1 & 2 (same as 3 above)

Chorea

Code 1 & 3	Rt. UL
	Rt. leg
Face	Lt. UL
	Lt. Leg

Autonomic Functions

Blood pressure	Sitting	Standing
Heart rate	Sitting	Standing
Valsalva		
Sweating		
Isometric contraction		
Pupils		

<u>Card 8</u>

Lab Investigations

0 - Nor.	Blood sugar		
1 - Abnor.	Urea		
2 - Not done	S. Creatine		
	LFT		
	S.Ca		
	S.P.		
	Cholesterol		
	Triglycerides		
	Hemogram Hb		
	TLC		
	VDRL	DLC	
		P/smear	
	CSF -	sugar	
		protein	
		cells	
	S.Cu		
	S.ceruloplasmin		
	Slit lamp		

ENMG

NCV Motor

Sensory

EMG

Evoked potential testing

VEP

BAER

Psychometry

Code 0 - Normal/absent

1 - Abnormal/present

(specify)

CT Scan

1. Bifrontal index
2. Bicaudate index
3. Max width of 3rd V
4. Cella media index
5. Max width of 3rd ventricle TD of skull
6. No. of sulci (seen in 2 upper CT slices)
7. Vermin atrophy
8. Cerebeilar hemisp. atrophy
9. CP angle cistern
10. Sulcus score (av. width of 4 widest sulci in 2 uppermost CT slices
11. Presence and size of cistern magna
12. Superior cerebellar cistern
13. Lateral cerebellar cistern
14. Quadrigeminal cistern
15. Ambiens cistern
16. APD of pons / APD of 4th ventricle
17. TD of pons / CP angle cistern

Neurologist

DYSARTHRIA EVALUATION : SPEECH

Name: Age: Speech No.:

Neuro No.:

Mother Tongue : Education: Date :

1. Complaint:

2. Onset of the problem:

3. Course of the problem: Increasing/same/unchanged.

4. Associated problems :

5. Exposure to smoke, chemical fumes etc :

6. Any history of URI :

7. Speech mechanism:

Organ	Structure	Function
a) Lips	Normal/cleft repaired/ unrepaired. If repaired satisfactory/deviated/ scarred	Normal/abnormal- retraction/symmetrical/ asymmetrical/paresis/ paralysis

b) Teeth	Normal/missing/super-numerary/cross bite/ overbite/	—
c) Tongue	Normal/microglossia/ macroglosia/bifid tongue/tongue bite/tongue thrust/spastic/atrophic	Normal/abnormal protrusion/retraction/lateral/ elevation: Front, back paresis/paralysis
d) Hard palate	Normal/repaired/unrepaired/fistula/scarred/high-arched/low arched	—
e) Soft palate	Normal/repaired/unrepaired/fistula scarred/ short/submucous cleft	Normal/abnormal elevation:symmetric asymmetrical/deprcssion/ immobile/ paresis/paralysis
f) Uvula	- do -	Normal/repaired/unrepaired/ bifid/missing/short/ elongated
g) Pharynx	Normal/abnormal	Pharyngeal movement normal/abnormal

h) Nose Normal/abnormal —

i) Jaw Normal/abnormal —

j) Velopharyngeal port mechanism : Adequate/inadequate

8. Diadochokinetic rate : Normal/reduced

9. Speech function (Vegetative/bulbar)

a) Sucking	Present/absent
b) Swallowing	Present/absent
c) Chewing	Present/absent
d) Blowing	Present/absent
c) Eating	Present/absent
f) Drinking	Present/absent
g) Drooling	Present/absent

10. Speech evaluation (general description) :

Scanned/slurred/explosive

Rate of speech: Normal/reduced/increased

11. Voice: a) pitch

All Phoneme Passage

dzi.vana, ankara rama: laliØia. nimma lata.pati dzagala sa:kuma:di . nammade.ada ondu lavalavikeja a:tava:da kuntebillejannu kalisuØØe:ne. idondu vinodada a.ta. idannu a.dalu nelada me:le si:me sunnadinda dere hu:vina ri:Øi bareda halava.ru t aukagalu maØØU ondu sa.dharana hant ina u;riddare: sa.ku. be.re ja.vude: gundagina tjappate vasØuva:da:ru sari, i: gatte u:rige na.vu bat t a endare be:re u.rugalalli dummanna ennuØØa.re. mannina nelakkinØa ta:r rasØeja me.le a:duvudu sulabha. aidarinda e:lu dzana a.duva i .pandjaddalli dza:naØana maØØu ve:ga ava ya. ta:s geddavanu a:ta uruma:di auta.da nanØara ulidavara saradi. dummanannu modala ko.nege esedu, kuntuØØa. o.di, adannu ka.lininda odedu konejinda konege Øallabe:ku. o.duva.ga gere Øa:gidare a.Øhava. da.tidare aut. hanti ina bakarejannu koneja t aukakke dabbidaga guri Øalupidan Øe. ja.ru ella: ko.negalannu hannu ma:duØØa:ro: anØhvarige vidzaja. Øaruva:ja pakkada t saukkake ese0a. hi.ge a:ta sa:guØØade. nanna pri.tpdja i hjare i:ga abda ma.dade deverige vandisi pa.tha o.di . anivarada radzejalli a:dona.

VOT WORD LIST (cvccv)

Carrier Phrase: "________________endu he:li"

	/a/	/i/	/u/
/p/	Pakka / pagga	Pikka / pigga	Pukka / pugga
/ØØ/	Øakka / Øaggu.	Øikka / Øigga	Øukka / Øugga
/k/	kaØØU / kaddu	kiØØu / kiddu	kuØØu / kuddu.
/b/	baØØu / baddu	biØØu / biddu	buØØu / buddu
/d/	datta / dadda	ditta / didda	dutta / dudda
/g/	gatta / gadda	gitØ / gidda	gutta / gudda

APPENDIX - 4

CT SCAN ANALYSIS

CT Scans were done on GE-9000 Scanner. Contiguous 10mm sections were taken parallel to the orbitomeatal line from base to the vertex. All the CT sections were magnified on a magnifier and measurements were made on them with the use of a vernier caliper (accuracy of 0.02mm). Both qualitative and quantitative assessments were done:

I. QUALITATIVE ASSESSMENT

a) Vermian atrophy (visualization of > 2 Vermian sulci)

b) Cerebellar hemispheric atrophy (visualization of any sulcus except the primary fissure)

c) Presence and size of cisterna magna.

d) Superior cerebellar cistern

e) Lateral cerebellar cistern

f) Quadrigeminal cistern

g) Ambiens cistern

h) Cerebello pontine angle cistern

II. QUANTITATIVE ASSESSMENT

a) Maximum bifrontal distance (A) : Distance between the tips of the frontal horns (see Figure 1)

b) Maximum skull distance (B - B) : TD of the skull along the line - A (see Figure 1).

c) Maximum bicaudate distance (C) : Transverse distance between the caudate nuclei at the level of the midportion of its head (see Figure 1).

d) Maximal inner diameter (D - D') of skull through the line of C (see Figure 1).

e) Cella media (E) : Combined minimum width of both cella mediae separated only by septum pellucidum (see Figure 2).

f) Maximal inner interparietal diameter of skull (F - F) along the line of E (see Figure 2)

g) Maximum width of the third ventricle (G) (see Figure 3).

h) TD of skull (H - H) along the line of G (sec Figure 3).

i) APD of the 4th ventricle (I) (see Figure 4).

j) APD of pons (J) (see Figure 4).

k) TD of Pons, (K) (see Figure 4).

1) Cerebello pontine angle cistern (L) (see Figure 4).

m) Number of sulci (NOS), seen in the 2 uppermost CT slices,

n) Sulcus score (SS), that is, average width of the 4 widest sulci in two uppermost CT slices.

III. The following ratios were determined, by using the above CT scan's quantitative measurements.

1) Bifrontal Index (A / B).
2) Bicaudate index (C / D).
3) Cella media index (E / F-F).

4) Maximum width of the third ventricle divided by transverse diameter of skull (G / H-H').

5) APD of pons divided by APD of the 4th ventricle (J / 1).

6) TD of pons divided by CP angle cistern (K / L).

24 CT scans were studied. The qualitative and quantitative (n=24) data were compared with the control group (n=3 1).

Abbreviations used in the Figure next page

A : Maximum bifrontal distance (Figure 1).

B - B' : Maximum skull distance (Figure 1).

C : Maximum bicaudate distance (Figure 1).

D - D' : Maximal inner diameter of skull (Figure 1).

E : Cella media (Figure 2).

F - F' . Maximal inner TD diameter of skull (Figure 2)

G : Maximum width of the third ventricle (Figure 3).

H - H' TD of skull along the line of G (Figure 3).

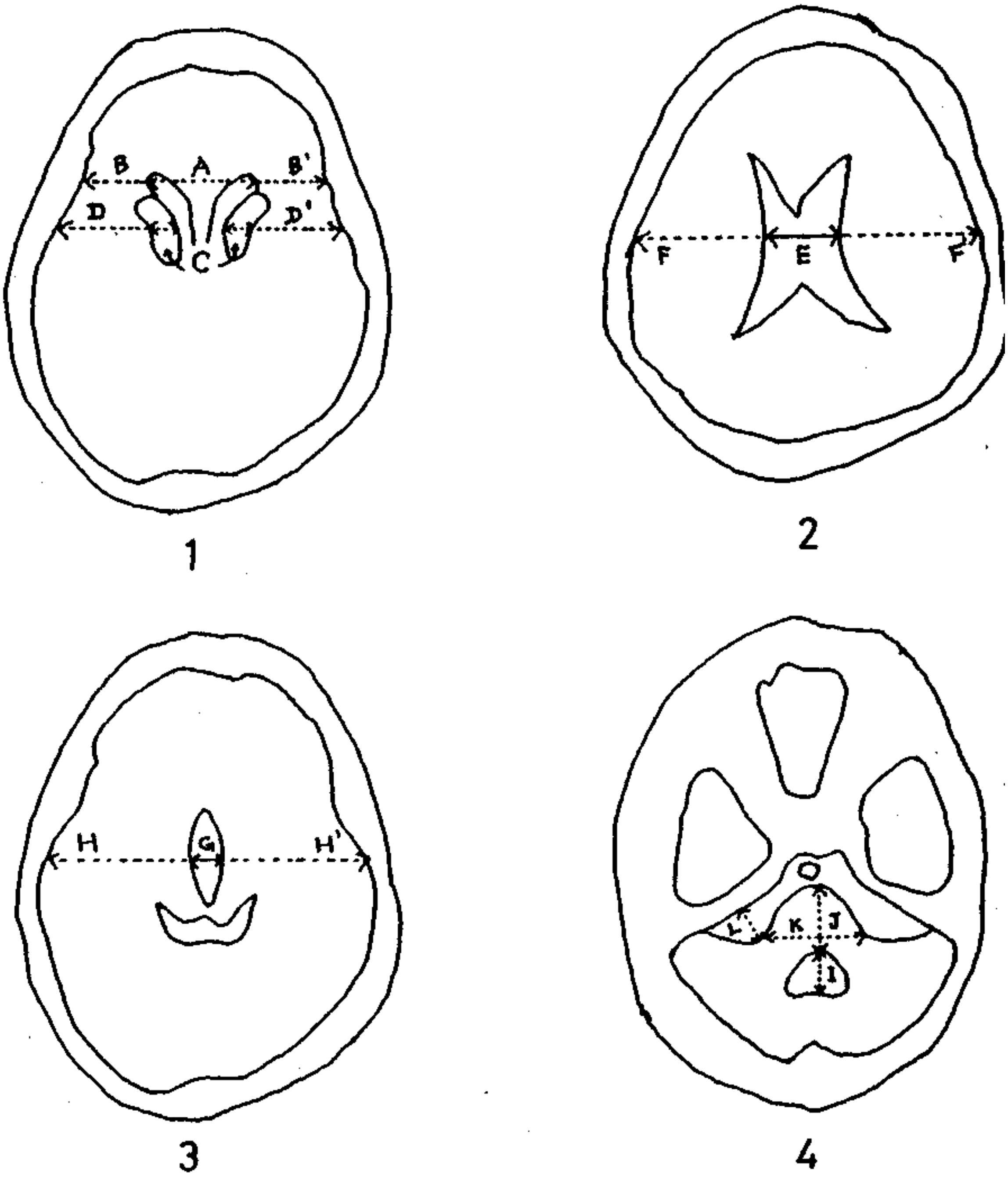
I : APD of the fourth ventricle (Figure 4).

J : APD of pons (Figure 4).

K : TD of Pons (Figure 4).

L : Cerebello pontine angle cistern (Figure 4).

(APD = Anteroposterior diameter: TD = Transverse diameter)



Schematic diagram showing CT Scan measurements

Appendix 5

Description of the Patients of this Study

Subject 1

Mr. **KRI,** 58 year old, agriculturist by profession, reported with the complaints of shaking of right hand and both the legs, and difficulty in walking of 2 years duration. On examination, a slow shuffling and stooped gait was prominent. Plantars were flexor with mild weakness of the left half of the body. Deep tendon reflexes of the left side were brisk, but hypertonicity was observed bilaterally. Mild slurring of speech was noticed.

The patient had resting tremors of right hand and both the lower limbs, with rigidity in left extremities, and dystonia of left foot. Features of bradykinesia and mask-like face were observed. Computerized tomography (CT scan) revealed minor atrophic changes in vermis and cerebellar hemispheres. Voice and speech disturbances included a low pitched, soft but hoarse voice on phonation of vowel /a/; articulation impaired for nearly 1/5 of the words spoken with errors involving consonants like /ch/, /h/, /\7, and /s/ sounds; speaking rate was fast. He had mild to moderate dysarthria, but had intelligible speech except for occasional words.

Impression : **Parkinson's syndrome with dystonic foot**

Subject 2

Mr. GON, a 40 year old person, reported with complaints of shaking of all four limbs, and a consequent difficulty in combing hair and holding objects 2 years duration.

Mental functions were normal. Deep tendon reflexes were brisk in all four limbs, with flexor plantars. Mild slurring of speech was noted. Extrapyramidal features included: resting tremors of all the four limbs, cogwheel type of rigidity and slowness of gait (bradykinesia). Masklike facial expression and mild dysarthria were noted. CT scan of head revealed a normal study.

The following voice and speech characteristics were noted : high pitched, soft but hoarse voice; impairment of articulation involving consonants like /d/, /k/ and /sh/ sounds; and a fast rate of speaking. Speech was intelligible except for occasional words and the severity of dysarthria was rated to be mild to moderate.

Impression : Juvenile Parkinsonism with mild to moderate dysarthria.

Subject 3

Mr. GID, a 60 year old farmer, came with complaints of difficulty in speaking, weakness of left upper limb, tremors of both hands and drooling of saliva of one year duration.

His higher mental functions were normal. Drooling, expressionless face (masked face), slowness in speaking, difficulty in chewing and swallowing and dysarthria were evident. He had tremors at rest of both hands and cogwheel type of rigidity. Deep tendon reflexes were brisk, plantars were flexor and abdominal reflexes were present. CT scan was normal except for mild atrophic changes in the vermian and cerebellar hemispheres.

Voice and speech impairments consisted of low pitched, monotonous (monopitch and monoloudness) harsh voice. Speech articulation was impaired for nearly 50% of the words spoken. Articulatory errors encompasses almost all consonants and vowels. Other speech deviations included audible inspiration and expiration, and slow rate of speaking with dysprosodia. Speech intelligibility was poor. Overall, the patient had moderate degree of dysarthria.

Impression : Parkinsonism with moderate dysarthria.

Subject 4

Mr. **CHA**, a 49 year old weaver reported with symptoms of tremors of both hands, progressive weakness of the right leg and difficulty in speaking. Tremors and weakness was of 6 years duration while the difficulty in speaking was of more recent onset (1 year).

Patient was alert, conscious and oriented at the time of reporting. Occasional slurring of speech was noticed. Deep tendon reflexes were brisk with flexor plantars. Extrapyramidal features included resting tremors of all four limbs, coarse static tremors of the right hand with pill-rolling movements, cogwheel type of rigidity, and masklike face. CT scan did not reveal anything significant, it was essentially a normal study.

The patient had a low pitched, soft voice with pitch breaks in running speech. Mild hypernasality was evident. Speaking rate was normal. Articulation errors were occasional (only 3-4 percent of the words were affected) and the sounds affected were /ch/ and
Ixl. Patient's speech was completely intelligible. Dysarthria severity was classified as very mild.

Impression : Parkinsonism with mild dysarthria.

Subject 5

Mr. CHI, 60 years old, businessman by profession, complained of difficulty in speaking, weakness of lower limbs, and tremors of the right hand of two years duration. The patient had noticed difficulty in raising his voice in the last 6 months. The patient was a known hypertensive and was under treatment.

The subject was alert, with normal language and cognitive functions His deep tendon reflexes were depressed, plantars flexors, with right sided motor weakness. Extrapyramidal signs included tremors at rest of the right hand, cogwheel type of rigidity of right hand (overall, mild rigidity) and hypokinesia. Cerebellar signs included mild inco-ordination (on finger-nose test) and broad-based gait. CT scan revealed . atrophic changes and lacunar infarcts.

The patient had a low pitched, strained, soft, mildly nasal voice. Rate of speaking was slow. Articulation was impaired for 30% of the words spoken with errors involving consonants such as /ch/, /n, / I / , /k/, /g/, /\/ and *hi* sounds. Most of the articulatory errors were of distortion type. His speech was, in general, difficult to understand. He was considered to be moderately dysarthric.

Impression . Hemiparkinson's syndrome with moderate dysarthria.

Subject 6

Mr. BAL, a 20 year old college student reported with difficulties in speaking and walking of four months duration. The onset of the symptoms was following an attack of tuberculous meningitis.

The patient had left upper motor neuron facial palsy, and mild wasting of tongue. Deep tendon reflexes were brisk (left > right), with flexor plantars. He had tremors at rest of the right hand, rigidity in left extremities, and dystonia of the right leg. Extrapyramidal symptoms included expressionless face and change in hand writing. Speech was slurred. CT scan revealed bilateral basal ganglionic infarcts.

Examination of the peripheral speech mechanism revealed deviation of the lips to the left side on retraction, mild difficulty in the elevation of tongue, and mild difficulty in chewing. Speech-voice deviations included monopitch, low pitch, with mild hypernasal voice. Speaking rate was fast. Articulation of speech sounds was impaired in almost 25% of the words spoken. Articulatory errors included distortion (consonants /b/, /ch/, /ja/, /th/, /la/, *It/;* vowels /a/ and */i/;* and diph-
— *
thong /y/), and substitution. Intelligibility of speech was almost normal, however. The patient was found to have mild to moderate degree of dysarthria.

Impression : Parkinson's syndrome with mild-moderate dysarthria.

Subject 7

Mrs. **RJM,** 60 years old, reported with the problem of shaking of the left hand since 1 year. Higher mental functions were normal. Speech was slurred. Deep tendon reflexes were normal, with flexor plantars. Extrapyramidal signs such as predominant tremors at rest, mild rigidity, mild bradykinesia (slow walking), and masklikc facial expression were noted. CT scan showed a normal study.

She had a harsh voice. Rate of speaking was normal. Articulation was impaired for nearly 20% of the words spoken with distortion and substitution type of errors. Speech was intelligible except for occasional words. Patient had moderate dysarthria.

Impression : Parkinsonism with mild-moderate dysarthria.

Subject 8

Mrs. **VIJ,** a 32 year old house wife, came with complaints of tremors of the right limbs since 6 months and defective speech. Defective speech was of 4 months duration.

The subject was alert, conscious and well-oriented with normal language, but had mild dysarthric speech. Deep tendon reflexes were brisk and plantars were flexors. Extrapyramidal signs included tremors at rest of all the 4 limbs, cogwheel type of rigidity (at wrist, elbow and shoulder); pill-rolling movements, bradykinesia, and staring look, that is, masklike face. Moderate degree of dysarthria was noted. Onset of the disease followed a bout of prolonged viral fever of 2 months duration. CT scan revealed a normal study.

Speech-voice deviations included low pitched, mildly nasal voice. Speaking rate was normal, phrases were short and articulation was impaired for nearly 35% of the words. Articulatory errors included substitution (s/sh, b/h, 1/1, n/n, d/t), omission (/k/), and addition (/i/) sound. Her speech was difficult to understand.

Impression : Parkinsonism with moderate dysarthria.

Subject 9

Mr. MKS, a 46 year old school teacher by profession was brought to the institute with problems of difficulty in walking, clumsiness of hands, loss of weight and forgetfulness. These symptoms were of 4 years duration and were progressive in nature. There was family history of similar problems with his father and younger brother suffering from similar disorders.

Neurological examination recent and old memory, impaired saccades, exaggerated deep tendon reflexes and plantar flexors. Extrapyramidal features included choreiform movements of head, tongue and all the 4 limbs, Inspite of the generalized wasting, he had hypertonia in lower limbs. CT scan revealed diffuse cerebral atrophy.

Speech-voice examination showed slow movements of tongue and lips, excess loudness of voice, variable rate of speaking, prolonged intervals, reduced stress, excess loudness, short rushes of speech, and short phrases. Articulation impaired to some extent with distortion and substitution of sounds being the type of articulatory errors evident. Sometimes sounds were omitted particularly the final sounds of words. Inspiration and expiration were forced and effortful. Loudness decay in speech was noted. Stuttering features like sound and syllable repetitions and audible inspirations were noted. Inspirations were frequent. However, his speech was generally intelligible. He was classified to have mild to moderate dysarthria.

Impression : Huntington's Chorea with mild to moderate dysarthria.

Subject 10

Mr. RKP, a 32 year old farmer, was brought with symptoms of jerky movements of all the four limbs and with the vague complaints of change in personality in the last 4 years. Symptoms were reported to be progressive in nature. The patients father was reported to have suffered from similar problems.

Neurological examination revealed cognitive impairment and impaired saccadic movement of eye (vertical > horizontal). Eye pursuits were normal; tone was decreased in all the 4 limbs, and plantars were flexors. Extrapyramidal signs such as choreiform movements of all the 4 limbs was noted. Tongue movements were slow. Speech was mildly slurred. CT Scan showed diffuse cortical atrophy.

Slow movements of the lips and tongue were observed during speech. Speech characteristics included excess loudness, mild hypernasal voice, explosive speech production with variable speaking rate, inappropriate silences, and excess and equal stress. Articulation was impaired with substitution errors dominating. Audible inspiration and forced expiration during running speech were noted. However, speech was intelligible, in general. Mild to moderate degree of severity of dysarthria was noted.

Impression : Huntington's chorea with mild-moderate dysarthria.

Subject 11

Mr. WAS, 60 years old, came with the complaints of involuntary movements of all the four limbs and neck, loss of memory and hearing problem. His father was reported to have suffered from a similar problem.

Neurological examination revealed cognitive impairment. Speech was affected. Audiometry revealed bilateral high frequency hearing loss. Deep tendon reflexes in upper limbs were brisk and plantars were flexors. Extrapyramidal signs such as choreac movements, resting tremors, mild rigidity in all the 4 limbs and myoclonic jerks were present. Neuropsychological testing was suggestive of frontal lobe involvement with deficits in visual learning and memory. CT scan revealed diffuse cerebral atrophy.

Voice-speech deviations included high pitched, mildly hypernasal voice with variations in loudness. Speech was dysfluent with syllable and word repetitions and use of interjections. Other speech deficits noted were variable speaking rate (speaking rate tending to become fast), explosive speech production, reduced stress, and forced expirations. Articulation of speech sound was mildly impaired. Overall, speech was completely intelligible with mild dysarthria.

Impression : Huntington's chorea with mild dysarthria.

Subject 12

Mrs. RAJ, 39 year old lady, teacher by profession, reported that she developed involuntary movements of all limbs, forgetfulness and fatiguability 4 years back. Symptoms were progressive in the last four years. There was history of similar problem in her family with her mother suffering from similar difficulties.

Neurological examination revealed a cognitive impairment. Deep tendon reflexes were normal and plantars were flexor. Repetitive, non-purposive movements at the shoulder joint were observed. Extrapy-ramidal signs such as chorie-form movements of all the four limbs, and fasciculation and wasting of the tongue were prominent. CT scan showed diffuse cortical atrophy.

Neuropsychological testing showed involvement of the frontal and left temporal lobe, as also a severe impairment of the right temporal lobe.

Protrusion and lateral movements of the tongue were affected during speaking. Speech deviations included variable pitch and loud-ness with mild hypernasal voice. Speaking rate was variable. Her speech showed prolonged intervals, inappropriate silences, reduced stress, and audible inspiration and explosive production Speech articulation was only mildly impaired with the major deviation being the distortion of vowels. Overall speech intelligibility was normal. The patient was classified under mild dysarthria.

Impression : Huntington's chorea with mild dysarthria.

Subject 13

Mr. KRS, 60 years old, a professor at an University, reported with the complaint of tremors of hand of seven years duration. He first experienced difficulty in speaking as well as slowness in speaking 16 years back. The problem was insidious in onset and then progressed slowly. Subsequently, he developed tinnitus and gradual hearing loss in the left ear. Later, 9 years after the appearance of the first symptom of slowness of speech, he developed tremors of hands during volitional tasks, including writing, but was absent at rest. There was family history of similar problems with his 2 elder brothers, 2 elder sisters and maternal uncle suffering from a similar condition.

Neurological evaluation revealed normal higher mental functions and tremulous voice in speech. There was also involvement of the **VIII** cranial nerve on the left side resulting in profound sensorineural hearing loss in the left ear. Deep tendon reflexes were brisk and flexor plantars. Extrapyramidal symptoms of coarse action tremors of extremities, tremors of tongue and soft palate were observed. Cerebellar signs such as mild incoordination (on finger nose test) and mild tandem gait ataxia were observed. EM(i recordings confirmed coarse unipolar tremors, averaging 5-7 Hz. Tremors were absent at rest. There was no bradykinesia and no rigidity. CT scan revealed a normal study.

The voice was characterized by rhythmic and regular changes in pitch and loudness, on vowel prolongation, which the subject could not inhibit. Examination of the oropharyngeal region during sustained production of vowel /a/ revealed synchronous contractions of the posterior pharyngeal wall, base of the tongue and soft palate. Voice, besides being mildly hypernasal, was characterized by pitch breaks in running speech. Speech was slow and laborious, with short phrases and excess but equal stress. Forced expiration and inspiration were noticed during speech production. Oral diadochokinetic rate was slow. Articulation was impaired for nearly 40% of the words, with errors involving many consonants and vowels. Articulatory errors noticed were of the following type : prolonged phonemes, distorted vowels and imprecise consonants. Intelligibility of speech was reduced to such a level that sometimes, it was difficult to understand. The dysarthria severity was moderate.

Impression : Familial benign essential tremor with hyperkinetic dysarthria . essential voice tremor.

Subject 14

Mr. MAL, a 45 year old male, employed in a paper factory, came with the complaints of uncontrolled movements of hands, shaking of all the four limbs of 10 years duration. He had also noticed problems in his voice in the last three years. No family history of similar problem .

Neurological examination showed normal mental functions and intact memory. Speech was slurred and he was also unable to write. Deep tendon reflexes were normal and flexor plantars. Tremors of both ULs and left lower limb were present which increased during volition. Besides, titubation of the head was prominent.

Voice and speech deviations were in the form of rhythmic variation of pitch and loudness on prolongation of /a/ accompanied by tremors of the tongue, and mildly hypernasal voice. Speech was characterized by regular variation in pitch and loudness, and dysprosodia. Grunts were present at the end of expiration. Speaking and diadochokinetic rates were slow. Speech articulation was only mildly impaired, with only vowel distortions. Consonant production was normal. Speech was completely intelligible. Patient was classified under the category of mild dysarthria.

Impression : Essential tremor with hyperkinetic dysarthria : Essential voice tremor

Subject 15

Mrs. STB, a 60 year old widow, was brought with complaints of difficulty in speaking and swaying while walking for the past 5 years. She was hypertensive for the last 2 years and was on regular medication. There was no family history of similar problem.

The subject was conscious and well-oriented during examination. Deep tendon reflexes were normal and plantars were flexors. Tremors of jaw and titubation of head were prominent. Cerebellar signs included mild unsteadiness in tandem gait, swaying to both sides (Romberg's sign was positive). There was no limb ataxia. CT scan showed diffuse cortical and cerebellar atrophy.

The voice was characterized by alternating pitch and loudness variations on vowel prolongation. During sustained phonation tasks, jaw tremors were seen. Voice was tremorous. Speaking rate was slow. The patient showed equal and excess stress in speech. Oral diadochokinetic rate was slow and imprecise. Articulation was impaired for 30% of the words spoken and was characterized by distorted vowels, sound omissions at the end of words and/or at the end of phrase or sentences, and imprecise consonants. Forced expiration and inspiration were present in continuous speaking. Speech intelligibility was poor making her speech difficult to understand. Dysarthria severity was moderate.

Impression : Hypcrkinetic dysarthria : Essential voice tremor

Subject 16

Mrs. LAX, a 45 year old widow, reported with a difficulty in speaking and abnormal movements of hands of four years duration. The symptoms were progressive in nature. Subject was alert, conscious during examination. Tremulousness in speech was evident. Deep tendon reflexes were brisk and plantars were extensors Extrapy ramidal signs such as tremors of upper limbs at work and titubation of head were prominent. Cerebellar signs included mild unsteadiness on tandem gait and swaying to both sides. A positive Romberg "s sign was observed. CT scan revealed a normal study except *for* mild atrophic changes in the vermian region.

The voice was low pitched with regular variations in pitch and intensity on phonation of vowel. Speaking rate was low as also the diadochokinetic rate. Articulation was only mildly and included distortion of vowels and prolonged phonemes. Overall, speech intelligibility was mildly affected, but understandable speech except for occasional words. Dysarthric severity was put at mild to moderate degree.

Impression : Hyperkinetic dysarthria : Essential voice tremor

Subject 17

Mr. MAD. a 60 year old agriculturist, reported with difficulty in speaking of 2 years duration. The onset of the problem was insidious, but later progressed. Subject was alert and oriented during examination and used normal language. Speech was severely dysarthric. Cranial nerves normal. No tongue dystonia, wasting or fasciculation were observed. Motor symptoms included normal DTR's, flexor plantars, and brisk jaw jerk. Uvula was deviated to the right side. No cerebellar signs were evident. CT scan revealed a normal study.

Tongue movements were slow, lacked speed and force and were restricted in the range of movement The voice was low pitched with mild hypernasality. Speaking rate was slow and laborious, Compensatory efforts to make the speech intelligible were observed. Slower diadochokinetic rate was observed. Articulation was impaired for 50% of the words spoken. Distortion and substitution of sounds were the type of articulatory errors seen. Almost all the consonants were distorted. Speech was unintelligible, and was difficult to understand. Dysarthria severity was classified as moderately severe.

Impression : Oropharyngeal dystonia with slow hyperkinetic dysarthria

Subject 18

Mr. **ROM,** a 30 year old engineer, reported with a difficulty to speak of 6 years duration. His voice problem was insidious in onset and progressive. He reported of an initial block in the throat for five seconds when he attempted to speak. The block disappears as he continues his attempts to speak He found it difficult to produce voice after physical straining, and it used to take about 10 minutes for him to get his voice back.

Neurological examination showed normal higher mental functions. Deep tendon reflexes were normal, flexor plantars and with normal gag reflex. No other focal neurological deficits were evident. CT scan revealed a normal study. He was advised botoxilium injections to improve the voice, and was put on symptomatic treatment with pacitane tablets.

The main problems in his speech were the increased pitch and decreased loudness of voice which had a strangled quality. Voice production was highly effortful and this led, many a times to breathlessness. Pitch breaks were evident both in phonation and speech (transient aphonia). Rate of speaking was normal. Diadochokinetic rate was almost normal. Articulation was impaired for 75% of words with errors involving consonants and vowels. Speech was often unintelligible and difficult to understand. Dysarthria severity was considered to be severe.

Impression : Laryngeal dystonia with hyperkinetic dysarthria

Subject 19

Mrs. BAG, a 34 year old house wife, was brought with the problem of difficulty in speaking for four years, following encephalitis.

Neurological examination showed normal cognition and mental function in the subject. Deep tendon reflexes were normal and plantars were flexors. She had buccofacial weakness in the form of reduced force, strength and range of movements of lips and tongue. No cercbellar signs were evident. CT revealed a normal study.

Initial examination of speech revealed limited movements of the lips on protrusion and retraction. Similarly, tongue protrusion and elevation were reduced. Voice and resonance was normal. Speaking rate was slow. Speech production was effortful and the patient had to place excessive stress on speech sounds. Slower diadochokinetic motion rate was observed. Articulation was impaired for about 40% of the words with errors involving many consonants and vowels. Audible inspiration was evident during speech. Speech intelligibility was poor and it was difficult to understand her speech many a times. Dysarthric severity was put at moderate level.

Impression : Hyperkinetic dysarthria : Lingual dystonia

Subject 20

Mrs. DAK, a 22 year old young lady, was brought with the sole complaint of speech difficulty, of 5 years duration, which developed following encephalitis

The subject was alert, conscious and oriented during examination. Deep tendon reflexes were normal and flexor plantar. Extrapyramidal signs such as difficulty in writing (probably because of the weakness of the right thumb) and buccofacial weakness in the form of limited movements of lips and tongue were noted. No cercbcllar signs were evident. CT scan revealed a normal study.

Speech-voice deviations included a mildly hypernasal voice. Speaking rate was slow. Speech production was effortful and had excess and equal stress on syllables. Diadochokinetic rate was very slow. Articulation was impaired for almost 50% of the words spoken with errors involving mainly consonants. Speech was difficult to understand and the dysarthria severity was put at moderate category.

Impression : Hyperkinetic dysarthria : Lingual dystonia

Subject 21

Mr. **ABD,** a 60 year old male was on psychiatric treatment for severe depression for the past 3 years. After 2 years of medication, in a follow up visit, a change in speech was observed. At which time, he complained of drooling, mild swallowing difficulty, abnormal but inconsistent movements of the face (of one year's duration), and abnormal movements of the right leg

Neurological examination revealed abnormal involuntary, but inconsistent movements of face and tongue and face. Involuntary movements of the right leg were also evident. The movements were continuous and were absent during sleep. These movements could not be inhibited when called to the subject's attention. Higher mental functions like memory, reasoning and calculation were affected. Deep tendon reflexes were normal and plantars were flexors Extrapyramidal signs like lingual masticatory movements were present. CT scan showed a normal study.

The voice was low pitched and weak. His speech was marked by mild articulatory errors, particularly at the end of the words, Articulatory errors were predominantly of the distortion type and involved only a few consonants and vowels. Diadochokinetic rate was slow and imprecise. Speaking rate was slow. Reduced stress and short phrases were the other speech deviations noted. Audible inspirations were present. Subject had mild to moderate dysarthric speech. Speech was intelligible speech except for occasional words.

Impression : Drug induced tardive dyskinesia

Subject 22

Mr. VEN, a 27 year old male, was on regular psychiatric treatment for schizophrenia for a duration of 10 years. He was on various drugs like serenace, eskazine, largactil, THP, ATT, and so on. Since 1 year his mother and brothers noticed abnormal facial movements with change in speech pattern.

Neurological examination revealed abnormal involuntary movements of the tongue, mild tremors of the lips and tremors of the upper limbs. There was a history of left UMN facial palsy. Deep tendon reflexes were brisk (Lt > Rt), flexor plantars, gag reflex present and neck stiffness. Extrapyramidal signs such as lingual movements, tremors of the upper limbs, left sided hypotonia and weakness were no-

ly ticed. CT scan showed a normal study.

Voice-speech examination revealed an essentially normal loud voice interspersed, however, with pitch breaks. Prosodic abnormalities included variable speaking rate and inappropriate silences. Articulation was only mildly impaired and involved manly fricative sounds. Diadochokinetic rate was slower than normal. Speech was completely intelligible, with mild dysarthria.

Impression : Drug induced dyskinesia : Hyperkinetic dysarthria

Subject 23

Mr. **PBK,** a 50 year old sales man, was on regular psychiatric treatment for schizophrenia for the past 20 years. He developed uncontrolled tongue movements and tremors of the right upper limb in the last one year. Examination revealed abnormal movements of the orofacial structures including the tongue. Patient had only mild difficulty to speak. Deep tendon reflexes were normal and flexor plantars. No cerebellar signs were evident. CT scan revealed a normal study.

The voice was normal with mild hypernasality. Speaking rate, in general, was fast, but tended to be variable. Reduced stress on syllables while reading or speaking was observed. Oral diadochokinetic rate was normal. Articulation was impaired for 15% of the words, involving substitution and distortion errors. Audible inspiration was apparent in speaking. Overall intelligibility was normal. The patient was put under the mild to moderate dysarthria severity category.

Impression . Drug induced dyskinesia Hyperkinetic dysarthria.

Subject 24

Mr. TSS, a 35 year old, was a schizophrenic for 10 years and was on a regular regimen of antipsychotic drugs. After 3 years of medication, he developed drug induced chorie-form movements, focal to tongue, and tremors of upper limbs. Involuntary protrusion of the tongue (akin to the extended tongue of a frog during the act of catching it's prey) was the major choreiform movement noted. These choreatic movements of the tongue had an halting effect on his speech as a result of which his speech sounded abnormal. Neurological examination revealed, brisk deep tendon reflexes and flexor plantars. No cerebellar signs were evident. CT revealed a normal study.

Voice and speech examination revealed normal pitch and loudness with mildly hypernasal voice. Speaking rate was normal. There was excess and equal stress on all the syllables during speech production. Diadochokinetic rate was essentially normal, with interruption in between due to the choreic movements of the tongue. Articulation was impaired for nearly 20% of the words spoken, but involved only a small number of consonants. Substitution and distortion errors were seen. Speech was definitely dysarthric, of mild - moderate degree, but overall, speech was intelligible.

Impression Drug induced tardivc dyskinesia

DEVIANT SPEECH-VOICE DIMENSIONS IN DYSKINETIC DYSARTHRIAS AND THEIR NEUROMUSCULAR BASIS

Thesis submitted for the award of the degree of
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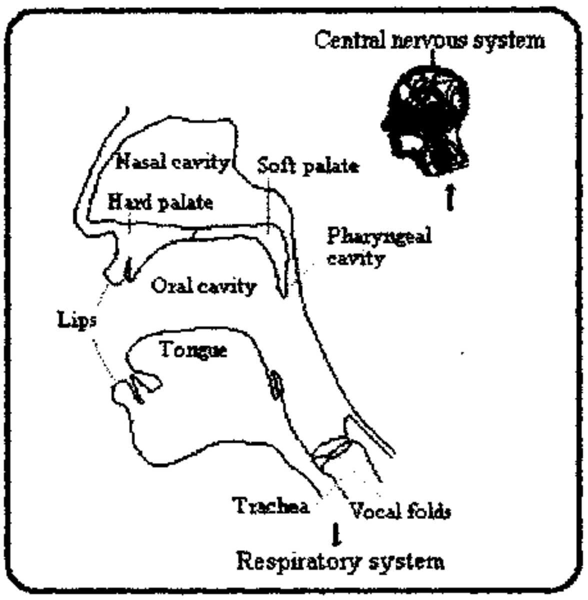
Dedicated to



' Speech is movement made audible' - Raymond H. Stetson (1928)