TEMPORAL CHARACTERISTICS IN
SPEECH DIADOCHOKINESIS
OF SPASTIC CEREBRAL PALSIED AND NORMALS

MATHEW(ANDREWS)

(REGISTER NO. M 2K11)

A dissertation submitted in part fulfillment of the second year
M.Sc (Speech and Hearing), University of Mysore, Mysore.

MAY 2002

Dedicated to
Almighty God
&
All My Teachers

Certificate

This is to certify that the dissertation entitled *"Temporal Characteristics in Speech Diadochokinesis of Spastic Cerebral Palsied and Normals"* is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M 2K11).

Mysore
May 2002

Director
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Certificate

This is to certify that the dissertation entitled *"Temporal Characteristics in Speech Diadochokinesis of Spastic Cerebral Palsied and Normals"* has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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Declaration

I hereby declare that this dissertation entitled *"Temporal Characteristics in Speech Diadochokinesis of Spastic Cerebral Palsied and Normals"* is the result of my own study under the guidance of Dr. R. Manjula, Reader, Department of Speech Pathology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier in any other University for the award of any Diploma or Degree.

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INTRODUCTION

Speech is a highly integrated physiological motor act characterised by a series of complex motion executed by kinetic change (Fletcher, 1972). Dysarthria is a speech disorder resulting from the impairment of the neural mechanism that regulates the movement of speech. One of the etiology of dysarthria in children is cerebral palsy. (Brown, 1984).

Cerebral palsy (CP) is defined as a non progressive disorder of motor control caused by damage to the developing brain during prenatal, perinatal, or the early postnatal periods (Hardy, 1994; Love, 1992). Although the prevalence of dysarthria in cerebral palsy is unknown, it is a very common sequelae to the neurological disorder. Estimates of the incidence of dysarthria range from 31 to 88% (Yorkston, Beukelman and Bell, 1988).

One of the major constraint imposed upon speech is the motor aspect of speech in that, it is the muscle motility that governs the rate with which any set of utterance can be accomplished. The measurement of maximum speech output contains a greater amount of information about the physical and motoric system. It is also well understood that speech production characteristics pose a particular challenge to the fragile stability of perceptual judgement.

Diadochokinesis has been defined as the ability to perform rapid alternating and repetitive bodily movements such as opening and closing of the jaw or lips, raising or lowering of eye brows or tapping the fingers (Wood, 1971). Speech diadochokinesis has often been cited in literature as a sensitive task to measure the temporal deviation of speech. Speech diadochokinesis can be measured in terms of Alternating motion rates (AMR) and Sequential motion rate (SMR). AMR is very useful in determining the speed and regulation of reciprocal movement of the lips, anterior and posterior tongue and SMR is a measure of ability to move quickly from one articulatory position to another (Duffy, 1995; Hegde, 2001; Freed, 2000).

Need for the study

Over the years, majority of the Speech Language Pathologists have employed perceptual analysis as a major tool in gathering information regarding the speech characteristics of developmental dysarthrics. Studies using acoustic analysis have been extensively carried out on adult dysarthrics and it is comparatively limited in children, especially cerebral palsied. Most of the studies on acoustic characteristics of adult Spastic dysarthria have found evidence for prolongation of phonemes, slow transition from one phoneme to another, increased syllable and word duration, slow speech AMR's, centralisation of vowel formants and increased duration of non phonated intervals (Dworkin and Aronson, 1986; Hirose, 1986; Portnoy and Aronson, 1982; Ziegler and Von Cramon, 1986). Although it is not explicitly stated, often there is an assumption that the speech characteristics described for children with motor speech disorders are the same as that of the adult dysarthrias. This has been proved to be incorrect in the most commonly used Mayo Clinic classification system proposed by Darley, Aronson and Brown (1975). There is little evidence to support the notion that the characteristics of dysarthria in children are same as that of adults (Van Mourik, Catsman - Berrevoets, Paquier, Yousef, Van Dongen, 1997; Purnima, 2001; Kent, Duffy, Salma, Kent, Gift, 2001). Hence generalization of adult speech characteristics to children, including the acoustic speech dimension is not realistic. In other words, there is a need to study the speech characteristics of cerebral palsied separately.

Perceptual characteristics of Spastic dysarthria in Mayo Clinic classification point towards a significant temporal deviance in speech such as slow rate, short phrases, prolongation of phoneme, increased syllable and word duration, slow speech AMR's. The point to be noted is that these characteristics are true of adult dysarthria. The acoustic correlates of the temporal deviance in speech has been well addressed in adult dysarthria. (Dworkin and Aronson, 1986; Hirose, 1986; Portnoy and Aronson, 1982). However, there are no studies which describe the acoustic temporal deviance of speech in cerebral palsied.

Hixon and Hardy (1964) studied the severity of articulation defectiveness, rate of syllable diadochokinesis, and non speech diadochokinesis in Spastic and Atethoid children and determined that syllable diadochokinesis was a much better predictor of articulatory severity and is a sensitive tool to discriminate dysarthrics from normals. Heltmen and Peacher (1943) and Schliesser (1982) have used diadochokinesis to study severity of articulatory defects in cerebral palsied. None of these studies however, address the correlatory temporal acoustic features in Spastic cerebral palsied, thereby necessitating the need to study the acoustic temporal features of speech diadochokinesis in Spastic cerebral palsied.

Objectives

The objectives of the present study are:

1. To analyze the temporal parameters of burst duration, voice onset time, vowel duration and transition duration in speech diadochokinesis of Spastic cerebral palsied and age matched normals in the following tasks.
   (a) Alternative motion for voiceless syllables
   (b) Alternative motion for voiced syllables
   (c) Sequential motion for voiceless syllables
   (d) Sequential motion for voiced syllables

2. To study the temporal variation across the syllable train in Spastic cerebral palsied and normals.

Methodology

Twenty Kannada speaking male children with Spastic cerebral palsy and 20 Kannada speaking normal controls between the ages of 11-12 years and 12-13 years were included in the study. These age groups were selected because the review of literature indicates controversy in DDK performance in normal children.

Canning and Rose, (1975) suggested that adult like maximum repetition values are reached by 9-10 years, whereas Fletcher's (1972) data do not show convergence even at 15 years of age. There seems to be some consensus that DDK matures to adult rate by about 12-13 years (Blomquist, 1950; Irwin and Becklund, 1953). The speech diadochokinesis sample of both Spastic CP and normals were recorded using Sony minidisk digital tape recorder (MZ-R55) individually in a quiet room. Acoustic analysis was done using spectrography of the Computerized Speech Lab (CSL) 4400. The parameters considered for acoustic analysis were burst duration, voice onset time, transition duration and vowel duration. These parameters were analysed for both voiceless and voiced AMR and SMR tasks. Further, the middle, preceding and following syllable duration was measured in the AMR task to study the temporal variation across syllable train. The raw data obtained from the analysis was further subjected to statistical analysis.

Implications of the study

- Firstly the study will further the understanding of how the chosen acoustic parameters will be affected in AMR and SMR task.
- Secondly it will provide direction for future studies, which aim to deliberate on the acoustic classification of Spastic type of cerebral palsy.
- Thirdly it will facilitate any inferences that can be made regarding speech motor control and other factors like, motor equivalence and spaciotemporal index.

Limitations

- Due to time constraints, only Spastic cerebral palsy has been considered in this study.
- Only diadochokinetic task was considered for studying temporal characteristics of Spastic CP and hence it would be difficult to predict its implications on normal speech.

REVIEW

Speech is the externalised expression of language and sensorimotor control of speech can be defined as "the motor - afferent mechanism that direct and regulate speech movements" (Netsell, 1982). As a motor skill, speech is "goal directed" and "afferent guided" and it meets the general requirement of a fine motor skill, viz., it (1) is performed with accuracy and speed, (2) uses knowledge of results, (3) is improved by practice, (4) demonstrates motor flexibility in achieving goals and (5) regulates all of this to automatic control, where 'consciousness' is freed from the details of action plans (Netsell, 1982). Loss of sensorimotor control of speech leads to speech motor disorders in children and adults. One of the most common causes of the impairment of motor speech in children is cerebral palsy (Darby, 1985)

Cerebral palsy (CP) is be defined as a nonprogressive motor disorder that stems from an insult to the cerebral level of the prenatal or perinatal period (Yorkston, Beukelman and Bell 1988), where as dysarthria has been defined as a speech disorder resulting from impairment of the neural mechanism that regulates the movements of speech (Netsell, 1984). Dysarthria in adults and children tend to be associated with various pathological neuromuscular conditions. For example, Spasticity, Athetosis, Rigidity, Tremor, Hypokinesis, and Flaccidity are various types of cerebral palsy. Spastic type accounts for the vast majority of the cases (Erenberg, 1984). Although CP population is a heterogeneous one, a common characteristic is dysarthric speech. Dysarthria in children is less well studied than those found in adults (Stark, 1985).

Dysarthria in children may range in severity from complete anarthria, or lack of speech, to a disorder so mild that it may readily be confused with a resolving developmental articulation disorder. Developmental forms of dysarthria in children may show amelioration with age at least upto adolescence or in case of children with closed head trauma, over a period of at least two years post insult. In the case of degenerative disorders, it may increase in severity with age.

Assessment in developmental dysarthria will generally include assessment of oral motor abilities, including speech and nonspeech activities, primitive reflexes and assessment of sub systems of speech production. The speech and language problems may vary from mild to severe degree depending on the neuromuscular and neurosensory impairment. Traditionally few measurements are available to the Speech Pathologists for investigating the type and degree of speech problem in dysarthric's. Amongst them, are the perceptual rating systems such as that developed by Darley, Aronson and Brown (1969a, 1969b), which provides rating scales on different speech attributes such as intelligibility, bizarreness, breathiness, monopitch and imprecise consonants.

The speech apparatus is functionally divided into respiration, phonation, resonation, articulation and prosody. The execution of a precise control of these systems is a result of coordinated function of CNS (Boone, 1972 and Darby, 1985).

The acoustic speech signal is a very important source of information for objective description of aspects of speech movement control in dysarthria. Rapid changes in the manner of articulation are often reflected by clear boundaries in spectrographic records. Hence it is useful to obtain objective measure of speech sound segments in dysarthria (Kent, Netsell, and Abbs 1979; Yorkston, Beukelman and Bell, 1988; Weismer, 1984).

Prominent perceptual dimensions from the Mayo clinic studies (Darley et. al., 1969a, 1969b; 1975) like distorted vowels, imprecise consonants, hypernasality, monopitch, monoloudness, harsh voice, stress abnormalities can be studied using acoustic correlates. The acoustic correlates for studying distorted vowels are vowel durations, formant frequencies, and formant transition and the acoustic correlates for studying imprecise consonants are consonant durations, consonant spectra and formant transitions. (Forrest and Weismer, 1997).

Vowel articulation : Spectral and temporal aspects

a. Vowel duration

Measures of vowel durations are fairly straightforward; especially when the vowels are located between obstruent consonants. Vowel duration is quite variable during speech production, ranging anywhere from 40 to 300 milliseconds for normal speakers. The variation of vowel duration is due to factors such as stress, vowel identity, speaking rate, dialect and phonetic context (Crystal and House, 1988). In dysarthrics, the segment duration of vowels and consonants were found to be lengthened relative to their duration of normal speech (Caruso and Burton, 1987; Hertrich and Ackermann, 1997; Kent, Kent, Rosenbeck, Vorperian and Weismer 1997; Weismer, 1997).

b. Vowel formants and tansition

Vowel characteristics in dysarthria has been studied by various investigators. The most frequently reported abnormalities of vowels in dysarthria include: Centralization of formant frequencies (Ziegler and VonCramon, 1983a, 1983b, 1986b), reduction of the acoustic planar area for vowels (Turner, Tjaden, and Weismer, 1995) and abnormal formant frequencies for high and front vowels (Watanabe, Arosaki, Nagate and Shouji, 1994).

Consonant Articulation

As in the case of vowel durations, the temporal measures for consonants are quite straightforward and in most cases easily obtained from either waveform or spectrographic displays. Typically, stop closure durations, the time during which the vowel tract is completely occluded for the build-up of intraoral air pressure are measured from the final, full glottal pulse of the preceding vowel to the subsequent stop burst. Stop closure durations are usually in the order of 70-120 milliseconds and rarely exceed 150 milliseconds (Stathopoulos and Weismer, 1985). The other common measure of voice onset time (VOT) is measured from the burst to the first full glottal pulse of the following vowel.

Syllable Timing

Syllable and phrase repetition are primary vehicles for assessing dysarthric patients articulatory accuracy. The syllables and phrases are chosen to highlight the contribution of various articulatory structures to the overall speech product. Lip closure is evaluated by asking the patient to repeat bisyllabic consonant vowel combinations (pa-pa-pa, ba-ba-ba,). Tongue tip elevation is evaluated by asking the patient to repeat tongue tip alveolar ridge combinations (ta-ta-ta, da-da-da). Elevation of the back of the tongue is evaluated by asking the patient to repeat high back consonant combinations (ka-ka-ka, ga-ga-ga). Articulatory flexibility and co-ordination in longer segments of speech is estimated by asking the patient to repeat strings of syllables in which articulation point changes (pa-ta-ka, ba-da ga). At least for some aspect of syllable timing, acoustic methods may provide information that is not easily obtained from auditory evaluation.

Describing the characteristics of Spastic dysarthria, Darley et al., (1969a, 1969b) concluded that syllables were repeated at a slower than normal rate but with normal rhythm. In an acoustic study, Portnoy and Aronson (1982) observed an abnormal variability of syllable rhythm in a sample of 30 subjects with spastic dysarthria. Akermann, Hertrich and Hehr (1995) studied subjects with Parkinson's disease, using multivariate analysis. He found that subjects with Parkinson's disease generally produced lengthy repetition trains characterized by incomplete closure whereas subjects with Fredreichs ataxia produced trains with only a few syllables at a slow rate and with complete closure.

Syllable timing has been studied in ataxic dysarthria, whose speech is said to have a scanning and staccato rhythm. Abnormalities of rhythm are also frequently noted for the syllable repetition task. Acoustic studies done on ataxic dysarthrias have shown that the repetition is slow and the interval between syllables is irregular (Bousten, Bakker and Duffy, 1997; Cisneros and Braun, 1995; Gentil, 1990; Kent et. al., 1997; Portnoy and Aronson, 1982; Ziegler and Wessel, 1996). Duffy (1995) has recommended the syllable repetition task as being particularly sensitive to cerebellar dysfunction. Portnoy and Aronson (1982) examined the rates and irregularities of syllable repetitions in spastic and ataxic patients and found that acoustic measures of rate and variability in rate during experimental task performance demonstrated significant differences between the two groups of dysarthrics and normal.

Studies on Diadochokinetic rate in Dysarthria

Heltmen and Peacher (1943) constructed a test to discover the articulatory defects and diadochokinetic rate of spastics ranging from 4 to 23 years of age. They found that the diadochokinetic rates for spastic were lower than those of non

Spastics and it was found to increase with age in the Spastics. Hedges (1955) studied the relationship of three repetitive speech movements to speech understandability among 60 subjects with spastic and Athetoid type of CP. Rates of repetition of syllable /pa/, /ta/, /ka/ were used as measures of an individuals ability to open and close mouth, raise the tip of tongue and elevate the back of the tongue respectively. Hedges concluded that the ability to perform certain repetitive speech movements of the articulators was a valid measure of the ability to perform certain repetitive non-speech movements of the same structures.

In a study aimed at analysis of the severity of articulation defectiveness, rates of syllable diadochokinesis or non speech diadochokinesis in Spastic and Athetoid children, Hixon and Hardy (1964) determined that syllable diadochokinesis was a much better predictor of articulation severity than was non speech diadochokinesis.

Schliesser (1982) conducted a study on the alternative motion rate in diadochokinetic tasks in adult cerebral palsy. The results of their study suggested that in the cerebral palsied adults, certain non-speech alternative motion could predict the severity of dysartnria at least equally well as the speech alternative motion rates. The three non-speech alternative motion rate which demonstrated strong relationship to dysarmria in the study were opening and closing of jaw, retraction of the tongue to the alveolar ridge and retraction and rounding of the lips.

In a study on speech liming in Parkinson's (PD) and Huntington's disease (HD) Ludlow, Connor and Bassich, (1987) included twelve patients with Parkinson's and similar number with Huntington's disease and compared them with 12 age and sex matched controls. This study assessed reaction time task, syllable duration, sentence duration, and pause duration and syllable repetition rate. The purpose was to determine the effect of two different basal ganglia diseases on speech planning initiation and production. Speech reaction time was unimpaired, while changes in duration at different speech rates were affected differently in the two patient groups. In HD changes in the duration of syllables and pauses between phrases and sentences were all reduced, while in PD, only the control of sentence duration was impaired. The HD patients had reduced syllable repetition rates. The ratios of word to phrase time and of phrase to sentence time remained constant across group. The results suggest that PD and HD patients are not impaired in speech planning or initiation, but have poor control over the duration of speech events.

On similar lines Caruso and Burton (1987) studied temporal acoustic measures of dysarthria associated with Amyotrophic lateral sclerosis (ALS). Speech samples of eight subjects with ALS (5M and 3F in the age range of 47.4 to 67.5 years) and eight normal control subjects who were matched for age and sex were analyzed. The purpose of this study was to investigate stopgap, voice onset time (VOT) and vowel duration in intelligible speakers with Amyotrophic lateral sclerosis. Broadband sound spectrograms were used to measure speaker's intelligible speech productions of monosyllabic words containing word initial stop-plosive consonants (/p,t,k,b,d,g/). Significant differences were found between the two groups for both vowel duration and stop gap duration. Correlation analysis indicated that the ALS speakers as a group exhibited a direct relationship between stop gap and vowel durations associated with production of /t/ and /k/. No significant differences were found between the two groups for voice onset time.

Studies have also been conducted on VOT, one of the salient temporal dimension in speech. Morris (1989) studied voice onset time in dysarthria cases. The purpose of this study was to investigate whether voice onset time differences occurred among speakers exhibiting four different types of dysarthria. Twenty dysarthric speakers were used as subjects of whom five were Spastic, five were Flaccid, five were ataxic and five were Hypokinetic. Repeated utterance tasks using /pa/, /ta/, /ka/ were analyzed using spectrograph. All the speakers exhibited phonetic errors in their voice onset time productions. Voice onset times occurred in the ranges of values between voiced and voiceless stops. The Spastic dysarthria exhibited shortest voice onset times, while the Flaccid and Ataxia speakers exhibited significantly more voice onset time variability than the spastic and hypo kinetic speakers. The shortest voice onset times exhibited by these speakers were related to the physiologic demands of voiceless stop production. Similarly narrow range of variation exhibited by the speaker with Spastic and Hypokinetic dysarthria was consistent with reports of Hypokinetic speakers (Barclay, Murry, Caligiuri, and Seitz, 1987).

Studies were conducted on voice onset time in dysarthrics by Ozsancak, Auzou, Hanneguin (2001). The authors examined 10 repeated utterances involving the voiceless group consonants /p/, *I\J,* /k/ in 110 subjects (27 controls, 48 with Spastic dysarthria and 35 with hypo kinetic dysarthria). The mean age range of Spastic dysarthric were 70.5 yrs, that of Hypokinetic dysarthria was 67.8yrs and normal controls was 68 yrs. Findings indicated that the mean rate of measurable VOT was 95.1% for normal speech, 80 % for hypokinetic dysarthria and 84 % for Spastic dysarthria. Within each group, the rates of measurable VOT's for /p/, *Ixl,* */k/* were similar. Thus, the place of articulation did not seem to modify the rate. The main obstacle to successful measurement was lack of burst signifying the release of the plosive sound.

Very few studies have been reported in literature with regard to acoustical analysis of children with dysarthric speech. In a study by Farmer (1977) who studied stop cognate production in adult Athetoid cerebral palsied speakers, two females and one male (ages 24, 22 and 43 yrs) were studied and these subjects had dysarthria with prevocalisation (PV). PV's and voice onset time were compared for frequency of occurrence and durational relationship. Results indicated that for all subjects PV's occurred more frequently and were generally of longer duration before voiced than voiceless stop. In another study Farmer (1980) analysed voice onset time in cerebral palsied speakers. Ten cerebral palsied individuals, 5 predominately Athetoid and 5 predominately Spastic, were studied. The Spastic and Athetoid had a mean age of 20.4 yrs. Spontaneous production of words beginning with initial stop cognate were elicited. Results indicated that although both groups used the voiced, voiceless contrasts and demonstrated few substitution errors, their VOT's were generally longer than those reported for normal subjects. Athetoids demonstrated the longest and most variable VOT's which were significantly longer than those for Spastics for /p/, /t/, /k/.

Kent, Netsell and Abbs (1979) studied acoustic characteristics of dysarthria associated with Cerebellar disease. Five individuals with Ataxic dysarthria in the age range of 57-65 years (2 males, 3 females) were studied. Acoustic analysis of CVC words, words of varying syllabic structure simple sentences in the rainbow passage and conversation was carried out. Data from normal control speakers was obtained for six subjects, and were used for the overall speech sample. The most consistent and marked abnormalities observed were alterations of the normal timing pattern with prolongation of segments of speech and a tendency to equalized syllable duration. Vowel formant structures in the CVC words were found to be essentially normal except for transition segments. Moreover, the findings were that the greater the severity of dysarthria, greater the number of segments lengthened and the degree of lengthening of individual segments.

Disturbances of syllable timing were frequently accompanied by abnormal contours of fundamental frequency.

Gentil (1990) studied acoustic characteristics of speech in Friedreich's disease. The major objective of their study was to estimate speech characteristics by means of a quantitative analysis of the acoustic parameters of duration, fundamental frequency and intensity. This study focused on (1) the variability of segmental duration, fundamental frequency and intensity during various speech tasks and (2) the durational adjustment of the base word to the number of syllables in the word. Fourteen patients (10 females and 4 males) diagnosed as Friedreich's disease with mean age of 37 years and 3 normals with mean age of 27 years was studied. First task was production of CV syllable / pa,fa,ka,pu,fu / repeated seven times in normal conversational and fast rate. The second task involved production of a steady state vowel / a,i,u /. The third task was the production of words at normal rate. Findings indicated that within the same utterance and speaking rate, the coefficients of variability were larger for patients with Friedreich's disease than for control subjects. So it was concluded that inconsistency of segment duration is a deficiency of speech in Friedreich's disease. This study did not indicate inconsistent reductions of base word duration and instances of lengthening of the base word duration as the number of syllables increased.

Longitudinal measure of segmental durations in dysarthria of motor neuron disease was studied by Seikel, Wilcox, Davis (1991). Three males in the age range of 52 to72 years were included in the study. The speech samples chosen were to elicit six initial /p,t,k,b,d,g/ and two final /t,d/ stop consonants in two vowel /i,a/ contexts using a CVC syllable. Target vowel duration, duration of articulatory closure and voice onset time, was studied for a period of two years. All types of dysarthria studied i.e., Spastic, Flaccid, and Spastic-Flaccid type demonstrated some degree of neutralization of the prevocalic closure duration.

Hertrich and Ackermann (1994) studied speech timings in Huntington's disease using acoustic analysis. Fourteen subjects with Huntington's disease in the age range of 30 - 57 years and 12 control speakers were included in the study. Duration measurements of the acoustic speech signal such as the sentence durations, voice onset time, and vowel duration were analyzed. Findings indicated that in patients with Huntington's dysarthria, motor execution was irregular and slow, whereas the supra-segmental modulation in terms of syllabic pacing and stress contrasts were preserved.

In another study Ackerman and Hertrich (1994) studied syllable timing i.e., speech rate and rhythm in Cerebellar dysarthria. Fourteen subjects with Ataxic dysarthria in the age range of 36 to 63 years and 12 normal controls were included in the study. Comprehensive analysis of syllabic timing during sentence utterances was made. Findings indicated that firstly, the Ataxic patients presented with reduced speech tempo in terms of syllable structure and utterance durations secondly, a tendency for intrautterance syllabic isochrony, being an aspect of the symptomatic differences in decreased AMR's between individuals with Spastic and Ataxic dysarthria. The subjects were 6 individuals with Spastic dysarthria (49 to 75 yrs; mean 64.8 yrs) and six with Ataxic dysarthria (37 to 54 yrs; mean 48.3 yrs) and 6 normal speakers (37 to 74 yrs; mean 55 yrs). Monosyllables /pa/ and /ta/ were used to examine alternating motions of the lips and tongue respectively. In the decreased AMR's of the spastic group, the mean syllable duration was generally longer in individuals when the mean total syllable duration was longer. In the Ataxic group, the mean gap durations were longer in the individuals when the mean total syllable duration was longer. Findings in this study suggest that each syllable component could represent a separate function and contribute differently to the decreased AMR's in these dysarthric groups.

Majority of studies done on speech timing are with adult dysarthria. These studies indicate slow speech AMR's in all types of dysarthria, but temporal variability is suggested as the most characteristic feature of cerebellar and brainstem lesions associated with dysarthria. Temporal variability is not reported in adults with Spastic dysarthria. Similar studies have been carried out on speech diadochokinesis in children by various investigators. However, these measures were not acoustically measured, hence suggesting the need for the present study. Moreover temporal variability not being a characteristic of Spastic dysarthria needs to be verified and studied in children.

METHODOLOGY

Objectives

The main objectives of this study were

1. To analyze the temporal parameters of burst duration, voice onset time, vowel duration and transition duration in speech diadochokinesis of Spastic cerebral palsied and age matched normals in the following task.
   (a) Alternative motion for voiceless syllables
   (b) Alternative motion for voiced syllables
   (c) Sequential motion for voiceless syllables
   (d) Sequential motion for voiced syllables
2. To study the temporal variation across the syllable train in Spastic cerebral palsied and normals.

Hypotheses

1. There is no durational or temporal difference in speech diadochokinesis in Spastic cerebral palsied and normals.
2. There is no temporal variation across syllable train in speech of Spastic cerebral palsied and normals.

Method

A. Subjects

Two groups of subjects were taken. The first group consisted of 20 Kannada speaking male Spastic cerebral palsied children in the age range of 11-13 years. Second group consisted of 20 Kannada speaking normals in the age range of 11-13 years. The two groups of children were matched for age and gender of the group one subjects. This age range had been selected because many studies report that mature performance on diadochokinesis task emerges at around 12-13 years (Blomquist, 1950; Irwin and Becklund, 1953).

Group	Age	**Number**
Group 1	ll-12yrs	10
	12-13yrs	10
Group 2	ll-12yrs	10
	12-13yrs	10

The Spastic cerebral palsied subjects included in the study had a confirmed diagnosis as assessed by a Pediatrician, Neurologist and Speech Language Pathologist.

B. Criteria for selection of subjects

(i) Selection criteria for Spastic cerebral palsied subjects

(a) Only those Spastic cerebral palsied subjects who had a confirmed medical diagnosis by a Pediatrician, or Neurologist were chosen.

(b) It was ensured that the selected Spastic cerebral palsied children had adequate comprehension skills to follow test instruction, with an oral expression ability of minimum one word or phrase level utterances.

(c) It was ensured that subjects thus selected did not have misarticulation of/p/, /t/, /k/, */b/, /d/, /g/* sounds in Screening Kannada Articulation test (Bettagiri, Babu, and Ratna, 1972).

(d) Subjects who were chosen did not have any overlapping retardation, sensory or perceptual deficit as assessed by an Audiologist and Clinical Psychologist.

(ii) Selection criteria for normal subjects

(a) Subjects who were clinically free from neurological problems and who had no hearing, speech and language problems as assessed by Speech Language Pathologist were considered as normal subjects

(b) Normal subjects between the age range of 11-13 years, whose age and sex were matched with that of Spastic cerebral palsied were included in the study.

Test materials

Test materials consisted of syllables to test Alternating motion rate (AMR) and Sequential motion rate (SMR) for both voiceless and voiced cognates.

Syllables for Alternating motion rate (AMR) task were

Voiceless syllable

1. /p^/ /p^/……
2. */t^l lt^l*…….
3. /k^/ /k^/……..

Voiced syllable

1. /b^/ /b^/……
2. / d ^ / /d^/…….
3. /g^/ / g ^ /………

Syllables for Sequential motion rate (SMR) were

Voiceless syllable

/p^/ /t^/ /K^/ /p/ t^/ /k^/.

Voiced syllable

/b^/ /d^/ /b^/ /d^/ /g^/

Recording of the speech sample

Subjects were instructed to take a deep breath and produce these syllables as clearly and as fast as possible. The subjects were given two trials to ensure that he understood the instruction before the test recording. Recording was done individually using a Sony digital tape recorder MZ-R55 with a unidirectional dynamic microphone in a quiet room. Between each trial a rest period of 10 seconds was given. Microphone was placed at a distance of 8 to 10 inches from the mouth of the tester while recording. The samples were recorded in a random order within and between AMR and SMR task across subjects to overcome order effect.

Analysis

The obtained sample was subjected to acoustical analysis. To carry out acoustic analysis the recorded speech was digitized using the speech interface unit (SIU) using the line feed method. The signal from SIU was digitized at a sampling rate of 16000Hz using a 16 bit analogue to digital (A-D) and digital to analogue (D-A) converter housed within the computer. The digitized signals were stored on the hard disk of the computer with individual file homes for each subject. Using spectrographic analysis in Computerized Speech Lab (CSL) 4400, the samples were analyzed for the following parameters- Burst duration, voice onset time, transition duration of Fl (Formant one) and vowel duration. To obtain a stable speech sample the acoustic parameters were analyzed only for the middle sequence portion in a syllable sequence. This analysis was done for one syllable in the AMR task and one syllable sequence in SMR tasks.

Analysis of AMR

The AMR sample consisted of both voiceless and voiced cognates. In the AMR sample the middle portion of the syllable sequence was highlighted. For example if there are none iteration of repetition in AMR sample, the middle sequence syllable i.e., fourth, fifth and sixth syllable was highlighted. From this one syllable was subjected to further analysis. The burst duration, voice onset time, transition duration, and vowel duration was analysed for both voiceless and voiced syllable. Additionally, the total syllable duration of the middle syllable in a sample, the preceding syllable duration and following syllable duration were also analyzed in the AMR samples. This was done to study the inter-syllabic / temporal variation across syllable train in the AMR sample.

Analysis of SMR

The SMR sample also consisted of both voiceless and voiced cognates. In the SMR task the middle sequence of \ p,t,k \ and \ b,d,g \ was highlighted and these syllable were subjected to further analysis in which their burst duration, voice onset time, transition duration, and syllable duration were measured.

Description of the parameters

1. Burst Duration (BD)

Burst duration was defined as the time difference between the onset of irregular vertical striation depicting the articulatory release and the offset of the same. The acoustic evidence of this release is the burst or transient and the burst duration is measured using the cursor in milliseconds.

2. Voice Onset Time (VOT)

VOT was defined as the time equivalent space from the onsets of the stop release burst to the first vertical striation representing glottal pulsing (Liskar and Abramson, 1964). VOT was measured for both voiced and voiceless cognates in

AMR and SMR task. The cursor was moved to the first indication of energy associated with the stop oral release and later the cursor was moved to the beginning of the regularly appearing waveform of the vowel following that stop. The real time vowel (in millisecond) between the two markings provided the VOT for the particular consonants.

3. *Transition Duration (TD)*

The transition duration is the time difference between the onset and offset of the transition. The real time vowel between the onset and offset in transition (in milliseconds) was measured using the cursor and this provided the measurement of transition duration.

4. *Vowel Duration (VD)*

This was defined as the time in milliseconds between the onset and offset of the vowel. The vowels were identified based on the regularity of the waveform and vertical striations. The vowel duration was considered to extend from the beginning of one periodic signal to the end of the periodicity. The duration was highlighted using the cursor and this portion was played back through headphones, to confirm that it contained the vowel. Once this was confirmed, the duration of the highlighted portion was read from the display.

5. Syllable Duration

Syllable duration is the time taken between the initiation and termination of the longer syllable. This duration was highlighted through the use of cursor. The highlighted portion was played back through the headphones to confirm that it contained the syllable under study. Once this was confirmed, the duration of the highlighted portion was read from the display and this was considered as syllable duration.

Statistical analysis

A 2 way ANOVA was done to study if there is any significant difference between the two groups i.e., spastic cerebral palsied and control normals in the speech samples of AMR and SMR task for burst duration, voice onset time, transition duration and vowel duration. To study the temporal variation across syllable train the group mean, group standard deviation, intrasubject standard deviation and mean of intrasubject standard deviation was calculated.

RESULTS AND DISCUSSION

The aim of the study was to analyze the temporal acoustic features in the diadachokinesis speech samples of Spastic cerebral palsied and control normals.

The speech diadachokinesis sample of 20 male Spastic cerebral palsied (aged 11-13 yrs) and 20 age matched normals were subjected to acoustic analysis. The speech diadachokinesis task consisted of voiced and voiceless cognates for both AMR and SMR task.

Objectives of the study were:

1) To analyze the temporal parameters of burst duration, voice onset time, vowel duration and transition duration in diadachokinesis speech sample of Spastic cerebral palsied and age match normals in the following task :

    a. Alternative motion for voiceless syllable.
    b. Alternative motion for voiced syllable.
    c. Sequential motion for voiceless syllable.
    d. Alternative motion for voiced syllable.

2) To study the temporal variation across the syllable train in Spastic cerebral palsied and age matched normals.

The results are discussed under two main sections :

I. Acoustic analysis
    A. AMR samples
    B. SMR samples
II. Analysis for temporal variation across syllable train

I. Acoustic Analysis

Using Spectrographic programme of computerized speech lab (CSL) 4400 software the following parameters were analyzed and tabulated, for both AMR and SMR tasks.

- Burst duration
- Voice onset time
- Transition duration
- Vowel duration

In both AMR and SMR tasks, these parameters were measured for voice and voiceless cognates. The voiceless sounds were /P^/, /t^/, /k^/ and voice sounds were /b^/, /d^/,/g^/,

A repeated measures (2 x 2) analysis of variance (2 way ANOVA) was performed to find the statistically significant differences between the Spastic cerebral palsied and control normal group. The two factors considered for the analysis include :

1. Group type

Two groups studied are Spastic cerebral palsied and control normals.

2. Age type

The two groups are further divided in to two based on their ages, i.e., 11-12 years and 12-13 years.

The level of significance which was considered to decide whether the Spastic cerebral palsied group was significantly different from normals was 0.05 level.

A. Analysis of speech sample in Alternate motion rate task.

1. Burst duration

Burst duration is defined as the time interval between onset and offset of the burst.

The mean burst duration for Spastic cerebral palsied and normals for voiceless and voiced Alternating repetition task is depicted in Table 1(A).

Table 1(A)*: Mean burst duration (in milliseconds) for Spastic cerebral palsied and normals in Alternating motion task.*

Age	/pʌ/		/tʌ/		/kʌ/		/bʌ/		/dʌ/		/gʌ/	
	S	N	S	N	S	N	S	N	S	N	S	N
11-12 Yrs	4.71	4.10	5.40	4.71	11.50	7.92	5.03	3.79	8.03	5.57	10.04	7.18
12-13 Yrs	4.33	3.52	5.07	4.12	9.02	7.59	5.21	3.65	8.36	5.67	11.02	7.86

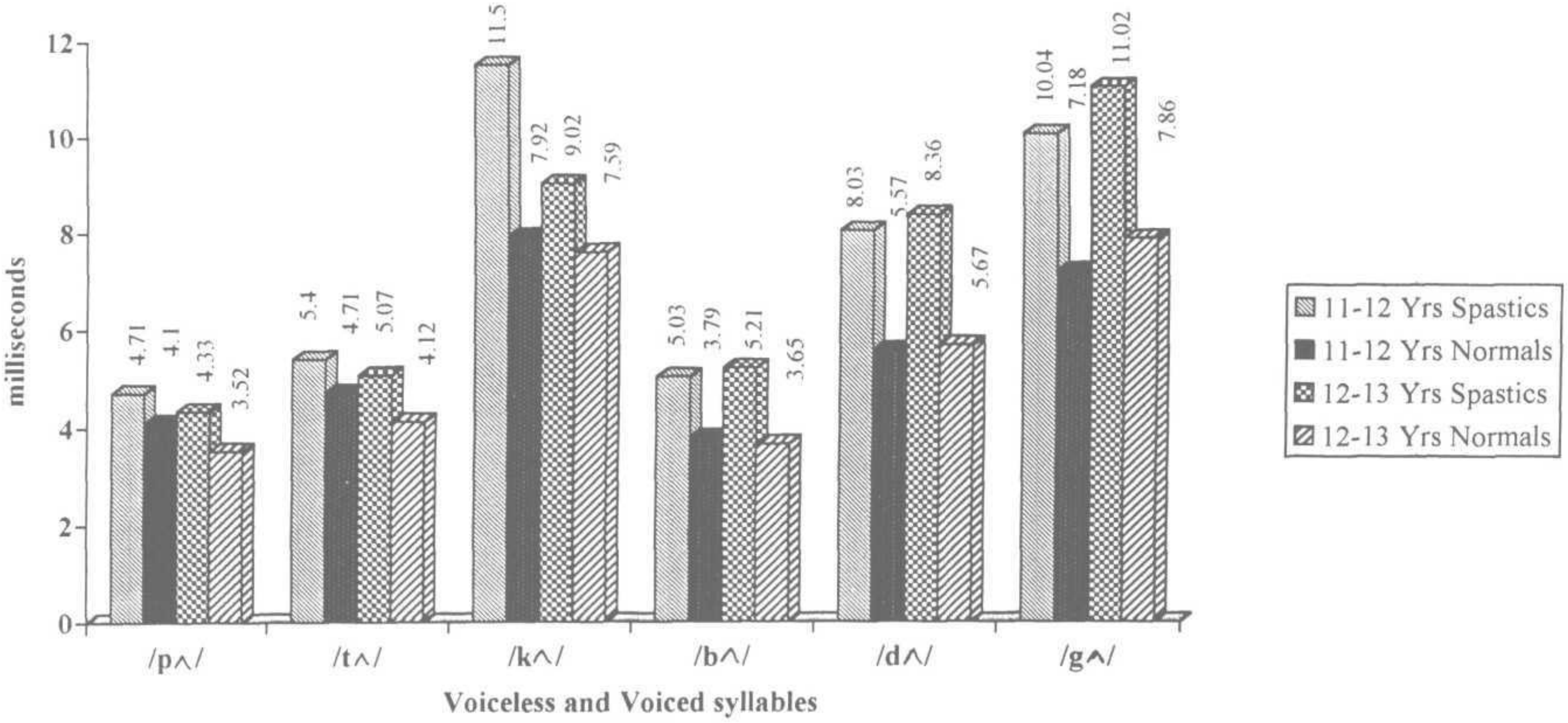
S : Spastic cerebral palsied N : Normal

From Table 1(A) and Graph 1 it can be seen that the burst duration is increased in Spastic cerebral palsied for both voiced and voiceless syllables, when compared with that of normals in both age groups. The significance for age and group factors was determined by 2 way ANOVA for each speech sound. The results are shown in Table 1(B)

Table 1(B): Levels of significance for various factors for burst duration in AMR task.

Factor	/pʌ/ Significance	/tʌ/ Significance	/kʌ/ Significance	/bʌ/ Significance	/dʌ/ Significance	/gʌ/ Significance
Group	0.012	0.028	0.000	0.001	0.000	0.000
Age	0.80	0.205	0.010	0.954	0.749	0.140

Graph 1: Mean Burst Duration fin milliseconds) for voiceless and voiced cognates in AMR tasks.



Results indicate that:

1. Burst duration is increased in Spastic cerebral palsied for all speech sounds, when compared to normals. The difference between the group is found to be significant at 0.05 level for all voiced and voiceless consonants. Qualitative judgment also showed that burst's were absent in few cases and this was due to incomplete closure and continuous transition from one sound segment to another.

2. There is no significant difference in the mean burst duration between 11-12 years and 12-13 years except for the voiceless syllable /k^/ where there is a significant difference at 0.05 level.

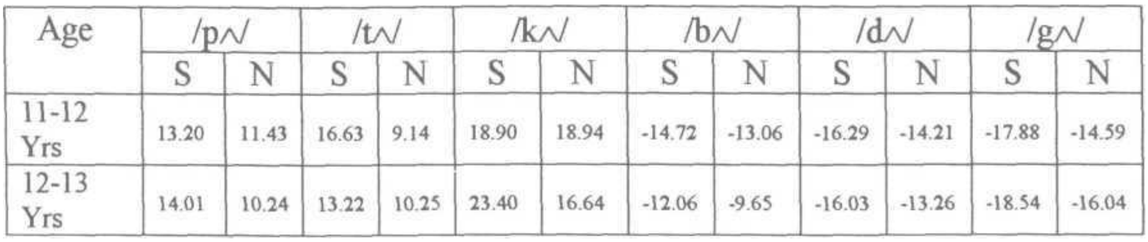
Though qualitative judgment shows that in majority of the Spastic cerebral palsied burst's are absent but when it is present in some subjects it is increased in duration compared to that of normals. This in turn contributes to the slow AMR seen in Spastic cerebral palsied. These findings are true to both voiced and voiceless syllable repetition in AMR task. It can thus be hypothesized that increased tone seen in Spastic cerebral palsied results in a forceful release of articulators in stop plosives resulting in increased burst duration.

2. Voice Onset Time (VOT)

VOT has been defined as a time interval between the release of the burst and onset of voicing. VOT for voiced stop is lead VOT as voicing onset is briefly preceeding the stop release (Kent and Read, 1995). For voiceless stops

VOT is lag VOT since during the production of voiceless stops, voicing starts when a trans-glottal pressure drop sufficient to voicing is developed after the release burst (Muller and Brown, 1980).

Table 2(A): Mean VOT (in milliseconds) of Spastic cerebral palsied and normals in Alternating motion task.

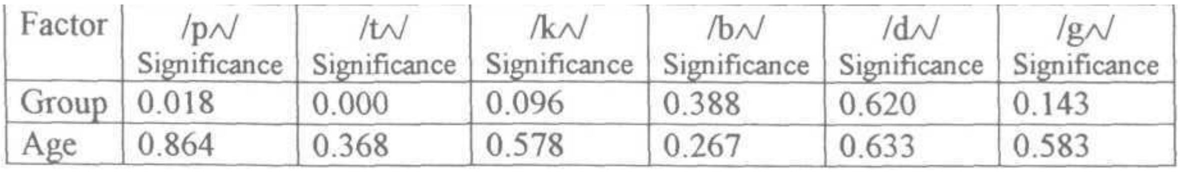


Age	/pʌ/		/tʌ/		/kʌ/		/bʌ/		/dʌ/		/gʌ/	
	S	N	S	N	S	N	S	N	S	N	S	N
11-12 Yrs	13.20	11.43	16.63	9.14	18.90	18.94	-14.72	-13.06	-16.29	-14.21	-17.88	-14.59
12-13 Yrs	14.01	10.24	13.22	10.25	23.40	16.64	-12.06	-9.65	-16.03	-13.26	-18.54	-16.04

S : Spastic cerebral palsied + : lag VOT
N : Normal - : lead VOT

The mean VOT for Spastic cerebral palsied and normals for Alternating motion task of both voiceless and voiced syllables can be seen from Table 2(A), 2(B) and Graph 2. It can be seen that the VOT values for both voiced and voiceless syllables are greater for Spastics as compared to normals. In other words, VOT is lengthened for Spastic cerebral palsied than for normals.

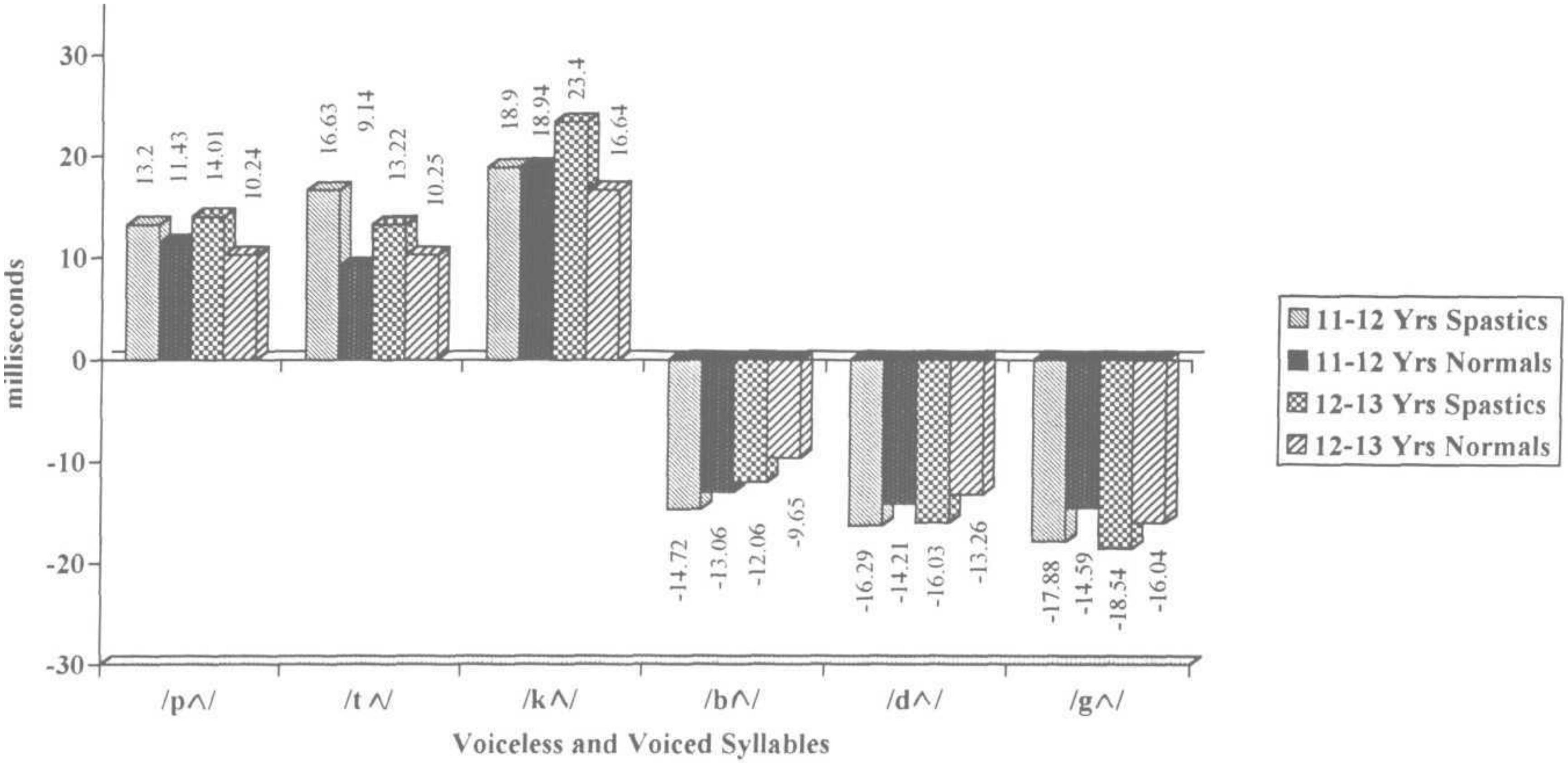
Table 2(B): Levels of significance for various factors for VOT in AMR task.



Factor	/pʌ/ Significance	/tʌ/ Significance	/kʌ/ Significance	/bʌ/ Significance	/dʌ/ Significance	/gʌ/ Significance
Group	0.018	0.000	0.096	0.388	0.620	0.143
Age	0.864	0.368	0.578	0.267	0.633	0.583

However, when significant difference for each factor was determined by a 2 way ANOVA, the difference is found to be statistically significant only for /p^/ and /t^/ sounds. There is no significant difference between mean VOT for 11 to 12 years and 12 to 13 years for both voiced and voiceless cognates.

Graph 2: Mean Voice Onset Time (in milliseconds) for voiceless and voiced cognates in AMR tasks.

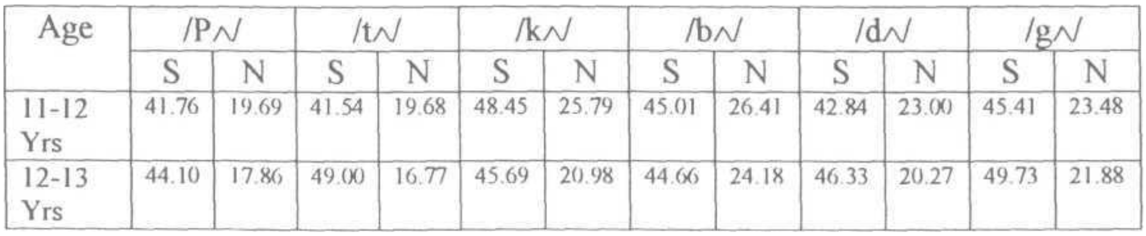


VOT being an index of subsystem co-ordination, it corresponds to the physiological interval between release of the consonantal constriction and onset of vocal fold vibration. VOT in Spastic cerebral palsied showed no increase in duration as compared to normals for most syllables except /p^/ and /t^/. This indicates that co-ordination between the laryngeal and articulatory system is comparatively difficult in Spastic cerebral palsies. Most studies on adult dysarthrics have shown differences between VOT in normals when compared with that of dysarthrics (Caruso and Burton, 1987; Morris, 1989). In the present study VOT is not significantly longer indicating that VOT does not contribute to slow speech AMR seen in Spastic cerebral palsied. Qualitative judgment of the sample revealed that the major limitation to measurement of VOT in AMR task is the absence of burst seen in same cases. Though VOT is increased it is variable. This finding is consistent with the observation made by Farmer, (1980) on Spastic cerebral palsied.

3. Transition Duration

It is defined as the time taken for formant one (Fl) following stop burst to reach the steady state of the adjacent vowel.

Table 3(A): Mean transition duration (in milliseconds) of Spastic cerebral palsied and normals in Alternating motion task.

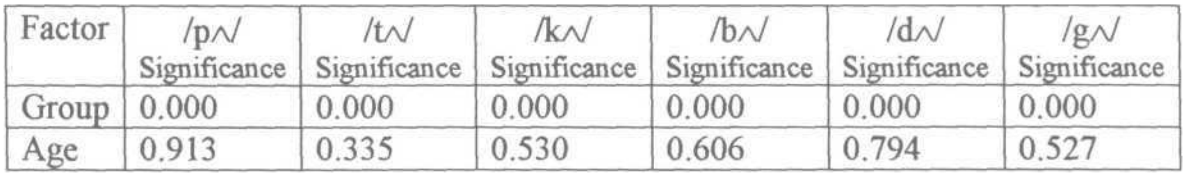


Age	/Pʌ/		/tʌ/		/kʌ/		/bʌ/		/dʌ/		/gʌ/	
	S	N	S	N	S	N	S	N	S	N	S	N
11-12 Yrs	41.76	19.69	41.54	19.68	48.45	25.79	45.01	26.41	42.84	23.00	45.41	23.48
12-13 Yrs	44.10	17.86	49.00	16.77	45.69	20.98	44.66	24.18	46.33	20.27	49.73	21.88

S : Spastic cerebral palsied N : Normal

Table 3(A) and Graph 3 shows the mean transition duration of Spastic cerebral palsied and normals for various voiceless and voiced cognates in AMR task.

Table 3(B): *Levels of significance for various factors for transition duration in AMR task.*



Factor	/pʌ/ Significance	/tʌ/ Significance	/kʌ/ Significance	/bʌ/ Significance	/dʌ/ Significance	/gʌ/ Significance
Group	0.000	0.000	0.000	0.000	0.000	0.000
Age	0.913	0.335	0.530	0.606	0.794	0.527

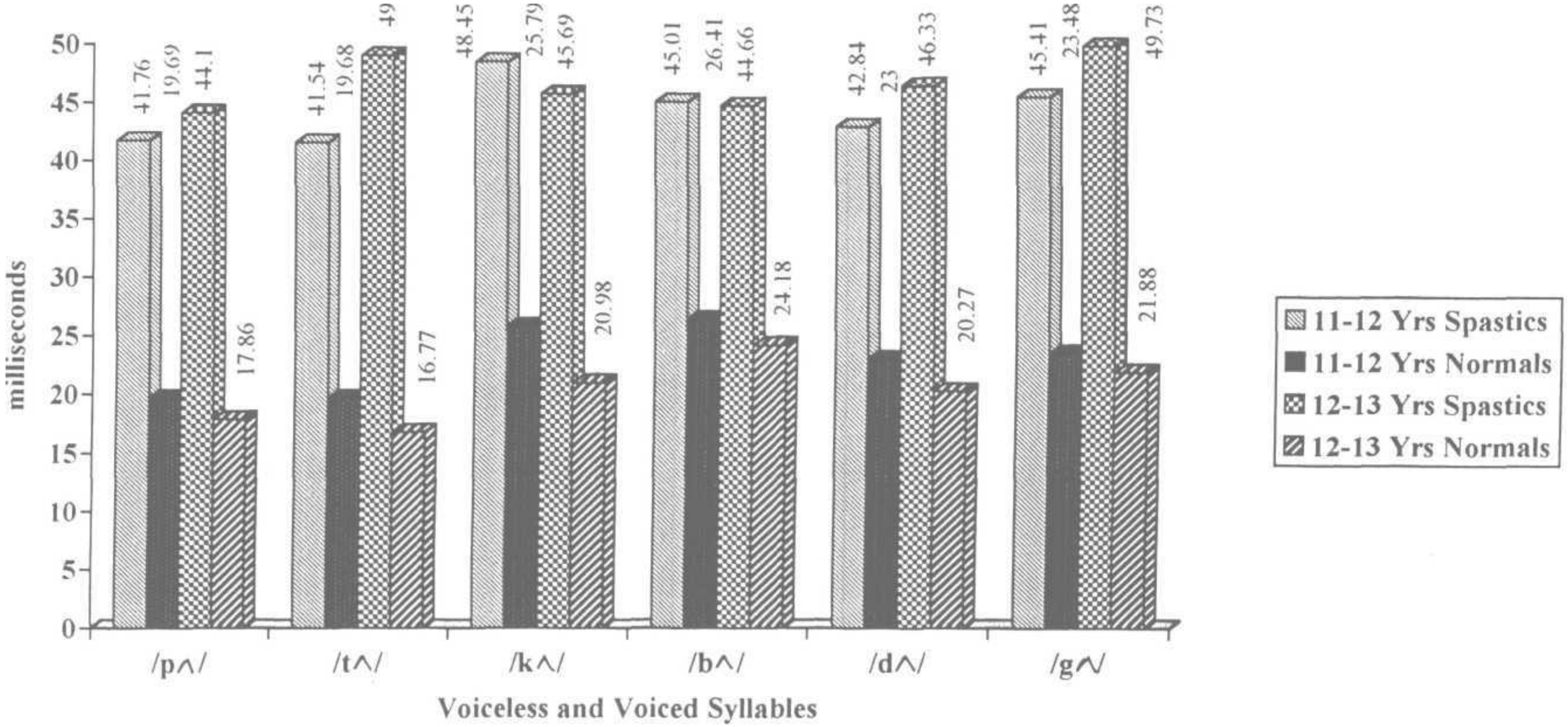
Using 2 way ANOVA the significance for Spastic cerebral palsied and normals is tabulated and this is presented in Table 3(B). From Table 3(A), 3(B) and Graph 3 the following features are observed.

1) Mean transition duration is increased for Spastic cerebral palsies when compared to normals and is found to be statistically significant at 0.05 level for all voiced and voiceless cognates. This increase in transition duration is attributed to the slow change in the articulatory gestures from one position to another.

2) There is no significant difference seen in mean transition duration between 11-12 years and 12-13 years in normals and Spastic cerebral palsied

The consistent increase in transition duration in Spastic cerebral palsied for both voiced and voiceless cognates in AMR task, is a major factor that results in the slow speech AMR seen in Spastic cerebral palsied. This can be evidenced from the fact that TD is highly significant even at 0.01 level, indicating a significant difference between normal and Spastic cerebral palsied.

Graph 3: Mean Transition Duration (in milliseconds) for voiceless and voiced cognates in AMR tasks.

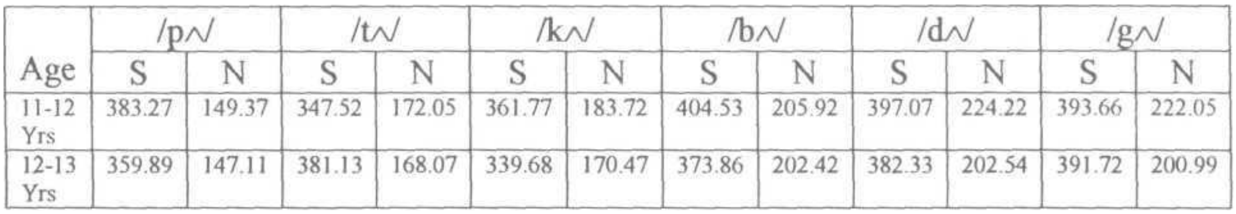


It is a well known fact that transition seen is an indication of the articulatory transfer from consonant to a vowel. Due to impairment of the motor ability in Spastic cerebral palsied, the physiological transition from a consonant to a vowel is slow, there by leading to an increase in transition duration. Similar findings of increased transition were also seen among Ataxic dysarthric in adults (Kent, Netsell and Abbs, 1979).

4.Vowel duration (VD)

Vowel duration (VD) is defined as the time between onset and offset of the vowel.

Table 4(A): Mean vowel duration (in milliseconds) for Spastic cerebral palsied and normals in Alternating motion task.

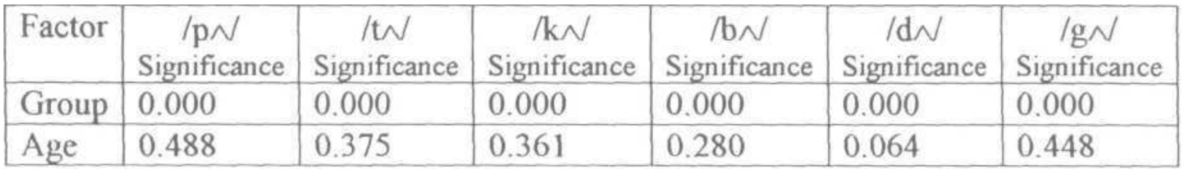


Age	/pʌ/		/tʌ/		/kʌ/		/bʌ/		/dʌ/		/gʌ/	
	S	N	S	N	S	N	S	N	S	N	S	N
11-12 Yrs	383.27	149.37	347.52	172.05	361.77	183.72	404.53	205.92	397.07	224.22	393.66	222.05
12-13 Yrs	359.89	147.11	381.13	168.07	339.68	170.47	373.86	202.42	382.33	202.54	391.72	200.99

S : Spastic cerebral palsied
N : Normal

The mean vowel duration for Spastic cerebral palsied and normals for voiceless and voiced syllables in Alternating repetition task is depicted in Table 4(A) and Graph 4.

Table 4(B): Levels of significance for various factors of vowel duration in AMR task



Factor	/pʌ/ Significance	/tʌ/ Significance	/kʌ/ Significance	/bʌ/ Significance	/dʌ/ Significance	/gʌ/ Significance
Group	0.000	0.000	0.000	0.000	0.000	0.000
Age	0.488	0.375	0.361	0.280	0.064	0.448

The significance for various factors was determined by 2 way ANOVA for each speech sound in voiceless and voiced Alternating motion tasks and is shown in Table 4(B).

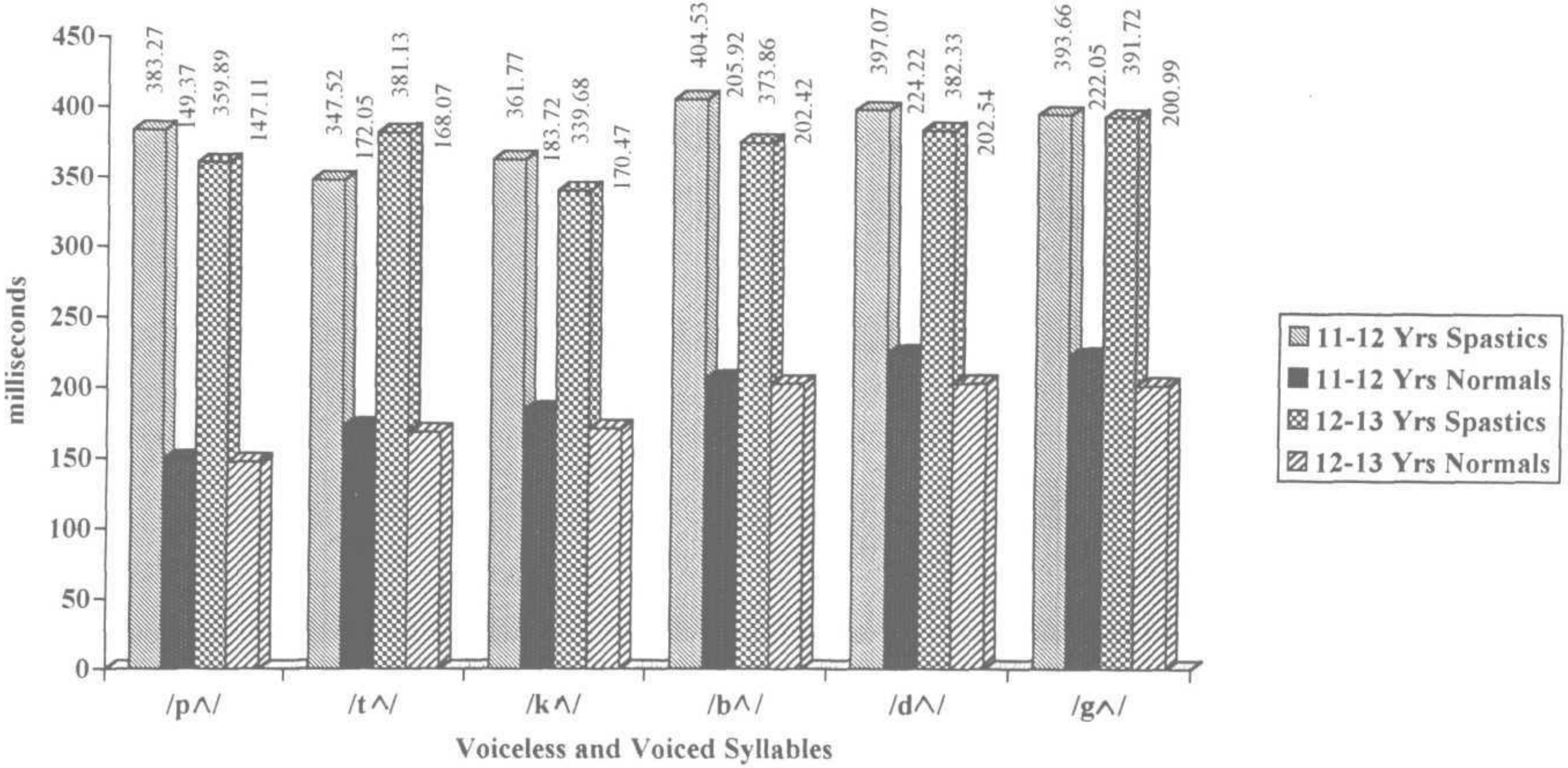
From Table 4(A), 4(B) and Graph 4 it is evident that:

1) Vowel duration is increased in Spastic cerebral palsies for all speech sounds; both voiceless and voiced as compared to normals. The difference is significant between the two groups in both age group.

2) There is no significant difference between the age groups for vowel duration, that is, between 11-12 years and 12-13 years in Spastic cerebral palsied and normals.

In the present study the difference in vowel duration between Spastics and normals is found to be highly significant even at 0.01 level, which indicates that prolonged vowel duration is another factor that contributes to slow speech AMR in Spastic cerebral palsied. In normal speech, the vowel duration is varied as a result of factors such as stress, vowel identity, speaking rate, and dialect (Crystal and House, 1988). But in the present study these variables were controlled and the task demanded only a rapid repetition of the syllables. Hence we can conclude that the vowel duration that is lengthened is only due to the severity of the neuro-motor involvement seen in Spastic cerebral palsied. Vowel duration is also reported to be increased in adult dysarthrics (Caruso and Burton, 1987; Seikel, Wilcox, Davis, 1991).

Graph 4: Mean Vowel Duration (in milliseconds) for voiceless and voiced cognates in AMR tasks

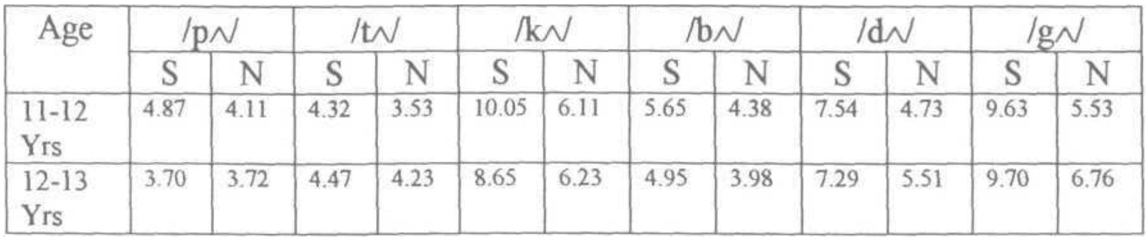


B. Analysis of Sequential motion sample

1. Burst duration

Burst duration as defined earlier is the time interval between onset and offset of the burst.

Table 5(A): Mean burst duration in (in milliseconds) for Spastic cerebral palsied and normals in Sequential motion task

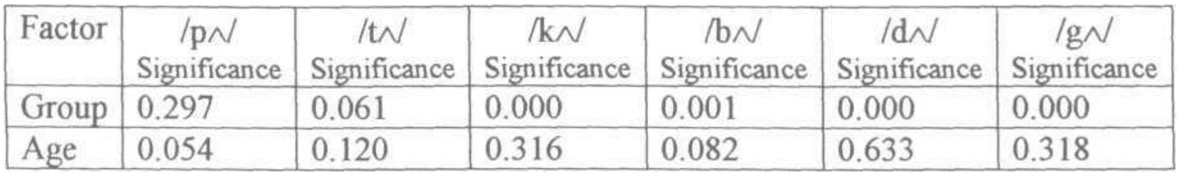


Age	/pʌ/		/tʌ/		/kʌ/		/bʌ/		/dʌ/		/gʌ/	
	S	N	S	N	S	N	S	N	S	N	S	N
11-12 Yrs	4.87	4.11	4.32	3.53	10.05	6.11	5.65	4.38	7.54	4.73	9.63	5.53
12-13 Yrs	3.70	3.72	4.47	4.23	8.65	6.23	4.95	3.98	7.29	5.51	9.70	6.76

S : Spastic cerebral palsied
N : Normal

The mean burst duration for Spastic cerebral palsied and normals for voiceless and voiced syllables in Sequential repetition task is depicted in Table 5(A)

Table 5(B): Levels of significance for various factors of burst duration in SMR task

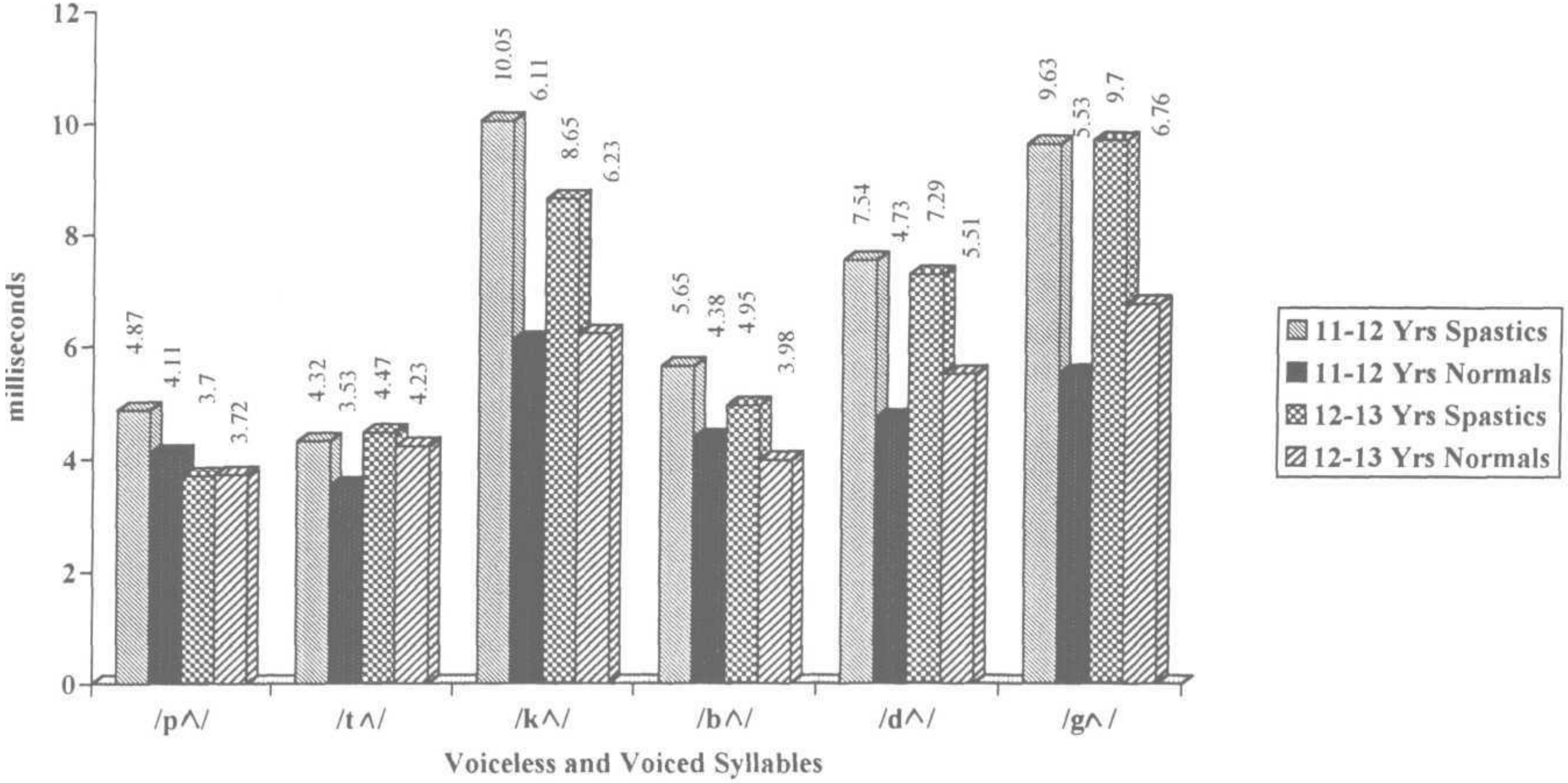


Factor	/pʌ/ Significance	/tʌ/ Significance	/kʌ/ Significance	/bʌ/ Significance	/dʌ/ Significance	/gʌ/ Significance
Group	0.297	0.061	0.000	0.001	0.000	0.000
Age	0.054	0.120	0.316	0.082	0.633	0.318

The significance ratio for various factors was determined by 2 way ANOVA for each syllable. These results are indicated in Table 5(B).

From Table 5(A), 5(B) and Graph 5 it is seen that:

1. Burst duration is significantly increased for /kʌ// in voiceless sequential motion task and /bʌ/, /dʌ/, /gʌ/ in voiced sequential motion task as



Graph 5: Mean Burst Duration (in milliseconds) for voiceless and voiced cognates in SMR tasks

compared to normals. Burst duration is not significant for /pʌ/ and Aʌ/ between Spastic CP and normals. This is inferred from the test of significance as shown in Table 5(B). Qualitative analysis also revealed that burst was not present in many samples in SMR task due to slow transition from one sound to another and due to incomplete closure

2. There is no significant difference in the mean BD between two age groups in both Spastic cerebral palsied and normals.

Burst duration is consistently increased in all voiced syllable in the SMR task and in /kʌ/ only in the voiceless SMR task. It can be said that the increase in BD contributes to slow SMR in voiced syllable repetition task The increase in BD seen in /kʌ/ for voiceless syllable could be due to multiple bursts seen in velar consonants.

2. Voice Onset Time (VOT)

VOT as defined earlier is a time interval between the release of the burst and the onset of voicing.

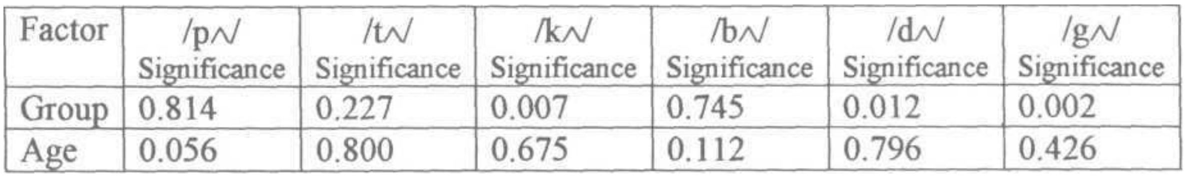
Table 6(A): Mean VOT (in milliseconds) for Spastic CP and normals in Sequential motion task

Age	/pʌ/		/tʌ/		/kʌ/		/bʌ/		/dʌ/		/gʌ/	
	S	N	S	N	S	N	S	N	S	N	S	N
11-12 Yrs	11.46	10.74	12.23	10.89	19.47	14.64	-14.78	-11.09	-18.18	-14.59	-19.63	-14.80
12-13 Yrs	12.52	12.87	12.55	11.14	19.20	13.34	-8.13	-10.69	-17.67	-14.82	-20.33	-16.22

S : Spastic cerebral palsied
N : Normal

Mean VOT for Spastic CP and normals for various syllables in SMR task is shown in Table 6(A).

Table 6(B): Levels of significance for various factors for VOT in SMR task.



Factor	/pʌ/ Significance	/tʌ/ Significance	/kʌ/ Significance	/bʌ/ Significance	/dʌ/ Significance	/gʌ/ Significance
Group	0.814	0.227	0.007	0.745	0.012	0.002
Age	0.056	0.800	0.675	0.112	0.796	0.426

The significance for various factors was determined by 2 way ANOVA for each syllable in SMR task and is shown in Table 6(B).

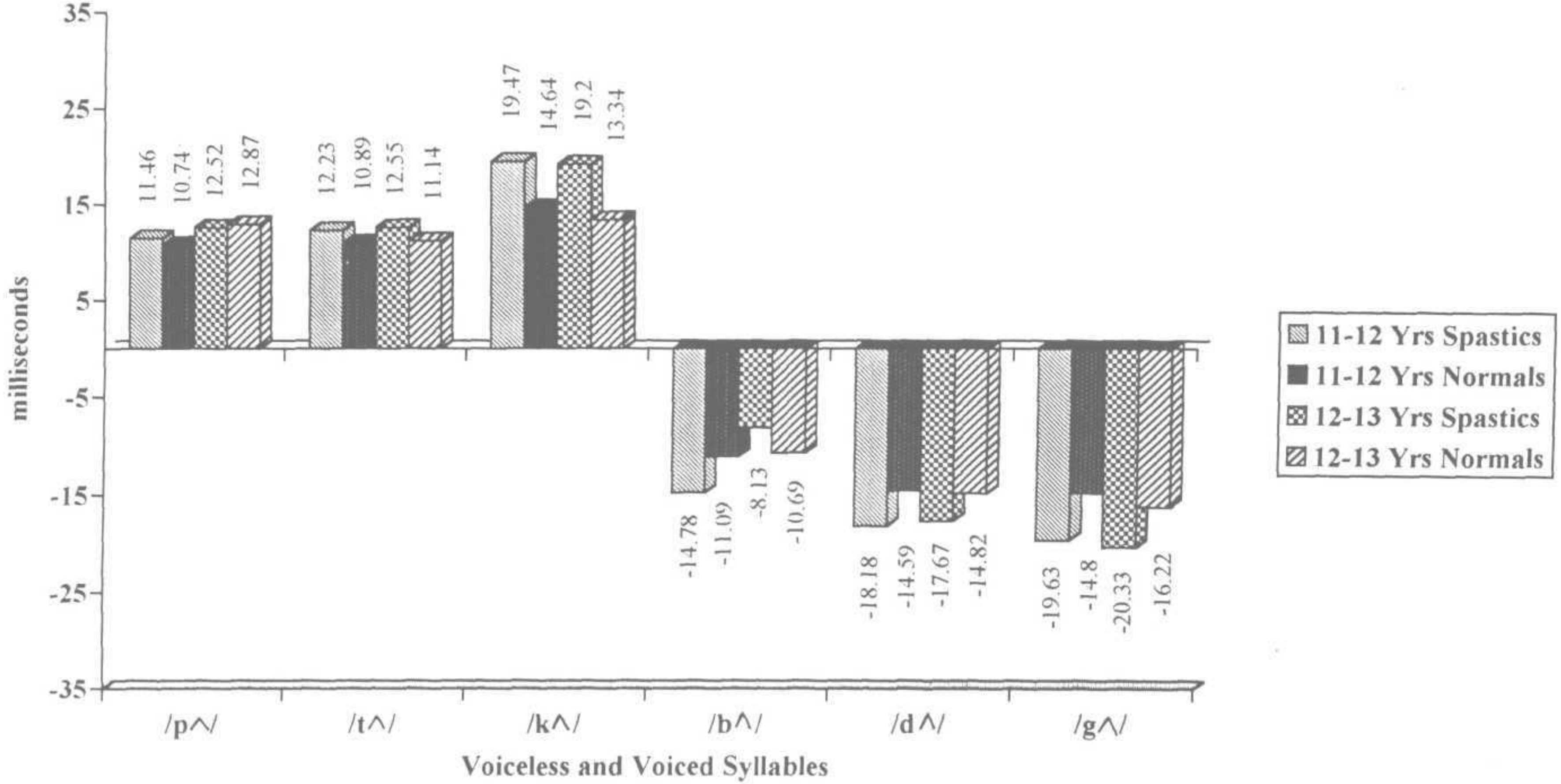
From Table 6(A), 6(B) and Graph 6 it can be seen :

1. VOT is found to be significantly increased in /Kʌ/ in voiceless sequential motion task and in AW, /gʌ/ in voiced sequential task in Spastic CP as compared to normals. The difference between Spastic CP and normals for /pʌ/ and /tV and /dʌ/was not significant as can be inferred from the test of significance.

2. There is no significant difference between two age groups in both Spastic cerebral palsied and normals.

As mentioned earlier, VOT is an index of subsystem coordination corresponding to the physiological interval between release of the consonantal constriction and onset of vocal fold vibration. Similar to SMR task VOT values are increased only for few syllables like /Kʌ//, /dʌ/ and /gʌ/. This indicates that the supra-laryngeal and laryngeal coordination is difficult only in some occasions in the production of SMR, suggesting inconsistency in this feature.

Graph 6: Mean Voice Onset Time (in milliseconds) for voiceless and voiced cognates in SMR tasks

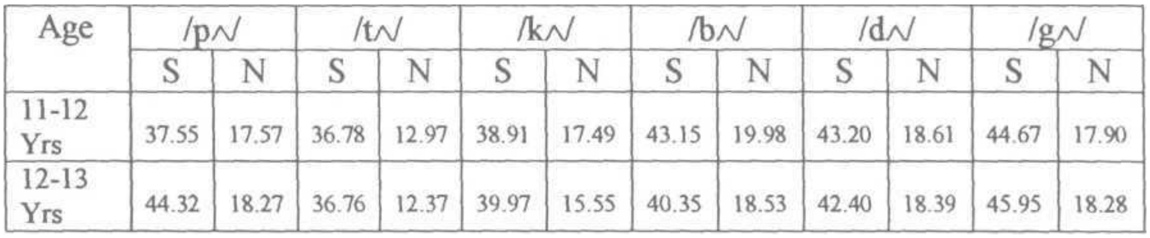


VOT of dysarthncs were found to be different from normals in most studies (Morris, 1989; Coruso and Burton, 1987). But in the present study VOT is increased only in few syllables. This indicates that VOT contributes to slow speech SMR, but not always. As mentioned for the AMR task, the major limitation in the measurement of VOT is the absence of burst in most subjects. VOT being increased in certain syllable and it being variable is consistent with the findings in Farmer's (1980) study on Spastic CP.

3. Transition Duration (TD)

As mentioned earlier, transition duration (TD) is defined as the time taken for Fl following the stop burst to reach the steady state of the adjacent vowel.

Table 7(A): Mean transition duration (in milliseconds) for Spastic CP and normals for Sequential motion task.



Age	/pʌ/		/tʌ/		/kʌ/		/bʌ/		/dʌ/		/gʌ/	
	S	N	S	N	S	N	S	N	S	N	S	N
11-12 Yrs	37.55	17.57	36.78	12.97	38.91	17.49	43.15	19.98	43.20	18.61	44.67	17.90
12-13 Yrs	44.32	18.27	36.76	12.37	39.97	15.55	40.35	18.53	42.40	18.39	45.95	18.28

S : Spastic cerebral palsied
N : Normal

Table 7(A) shows the Mean Transition Duration (TD) of Spastic CP and normals for the SMR task.

Table 7(B): Levels of significance for various factors for transition duration in SMR task.

Factor	/pʌ/ Significance	/tʌ/ Significance	/kʌ/ Significance	/bʌ/ Significance	/dʌ/ Significance	/gʌ/ Significance
Group	0.000	0.000	0.000	0.000	0.000	0.000
Age	0.133	0.895	0.854	0.166	0.633	0.686

The significance for each factor was determined by 2 way ANOVA for all voiceless and voiced cognates in Sequential motion task. The results are shown in Table 7(B).

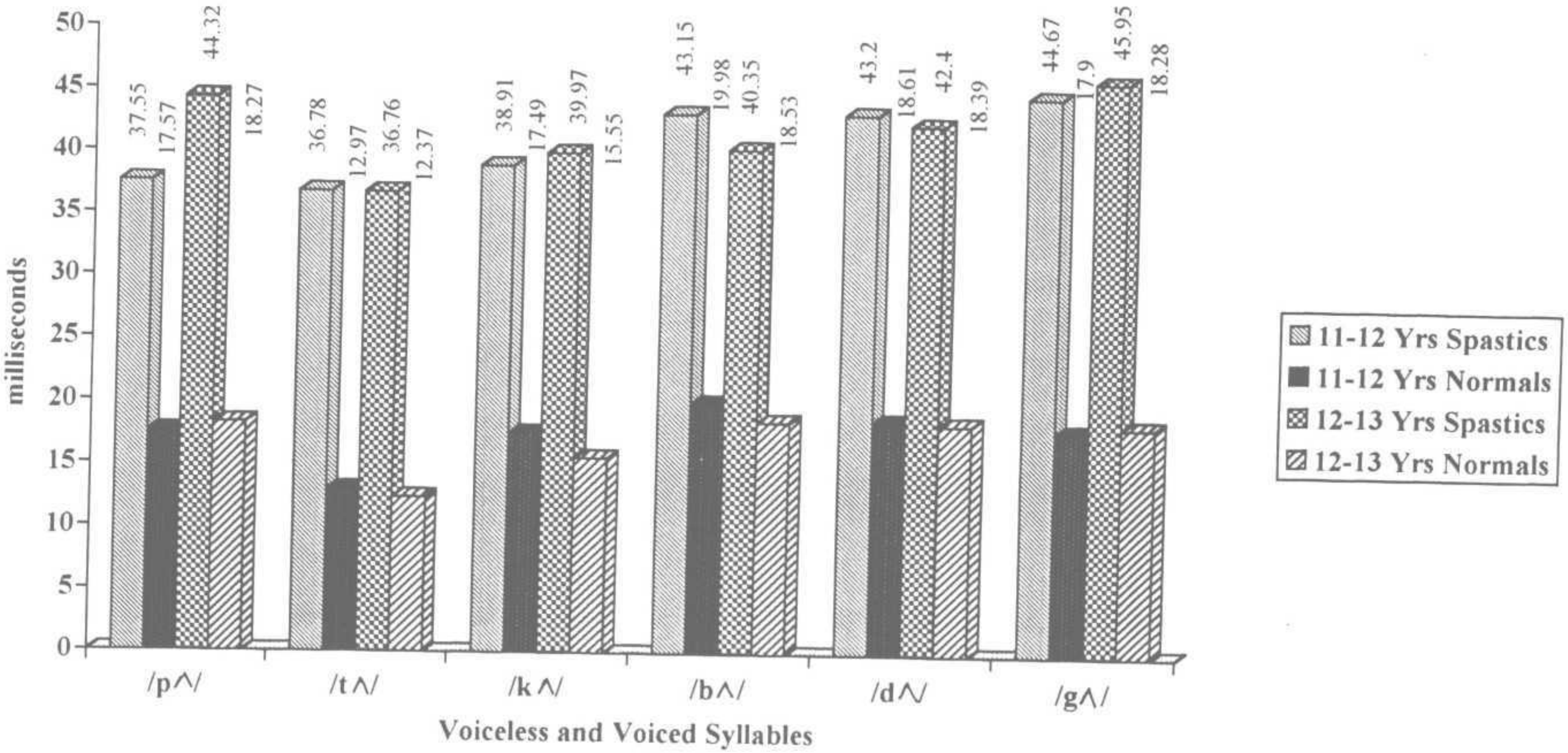
From Table 7(A), 7(B) and Graph 7 it is seen that:

1) Mean transition duration is increased in Spastic cerebral palsied when compared to normals. This difference is highly significant between the two groups for both voiceless and voiced syllables. The increase in transition duration is attributed to the slow articulatory movement change from one position to another.

2) There is no significant difference in the mean TD between the two age groups for both normals and Spastics.

As in the AMR task, the TD is consistently increased in Spastic CP for both voiceless and voiced cognates in the SMR task. Even in SMR task, the transition duration plays a major role as a feature contributing to slow speech SMR. The physiological structures i.e. tongue and lip needs to move sequentially for producing a SMR task. As sequential motion requires excessive control of the speech motor system, and due to impairment in the motor ability in the Spastic CP, the transition from one articulatory posture to

Graph 7: Mean Transit ion Duration (in milliseconds) for voiceless and voiced cognates in SMR tasks

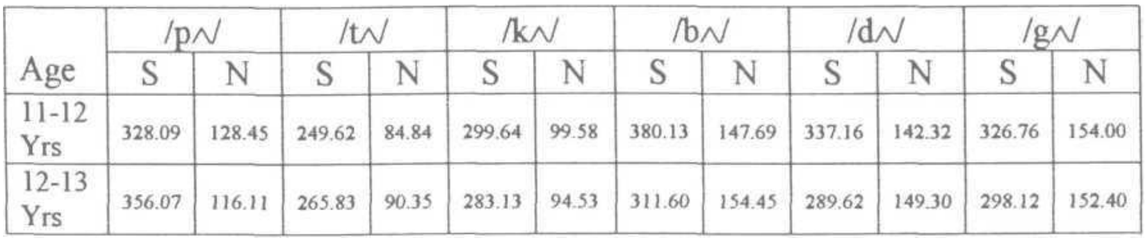


another is slow, resulting in increased transition duration. Similar findings of increased transition duration have been found among Ataxic dysarthric (Kent, Netsell and Abbs, 1989).

8. Vowel Duration (VD)

Vowel duration is defined as the time between onset and offset of the vowel.

Table 8(A): Mean vowel duration (in milliseconds) for Spastic CP and normals in Sequential motion task.

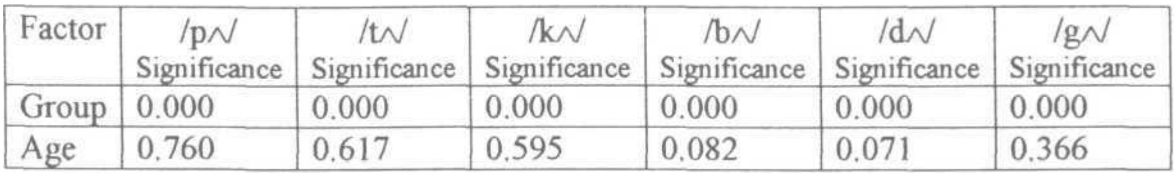


Age	/pʌ/		/tʌ/		/kʌ/		/bʌ/		/dʌ/		/gʌ/	
	S	N	S	N	S	N	S	N	S	N	S	N
11-12 Yrs	328.09	128.45	249.62	84.84	299.64	99.58	380.13	147.69	337.16	142.32	326.76	154.00
12-13 Yrs	356.07	116.11	265.83	90.35	283.13	94.53	311.60	154.45	289.62	149.30	298.12	152.40

S : Spastic cerebral palsied
N : Normal

The mean vowel duration for Spastic cerebral palsied and normals for voiceless and voiced syllables in SMR task is depicted in Table 8(A)

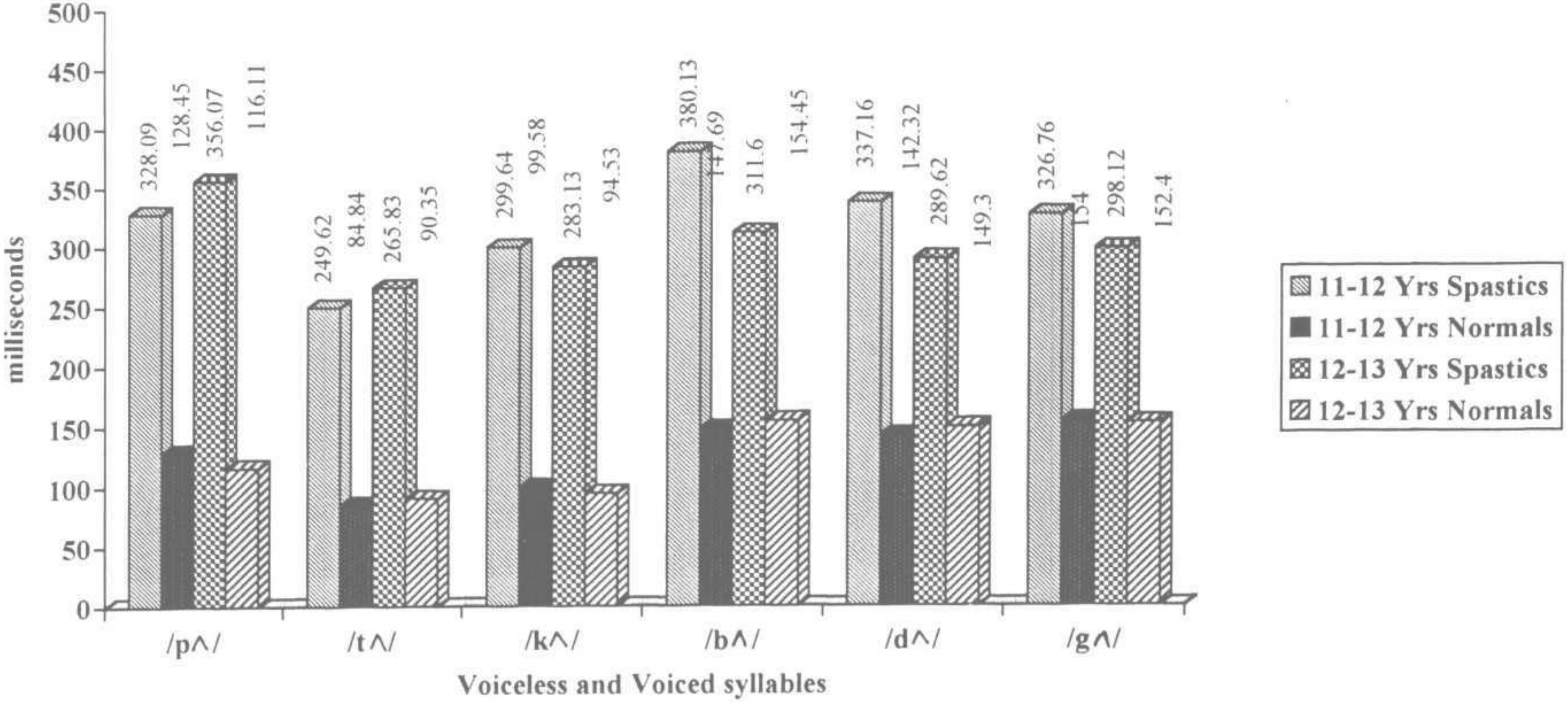
***Table** 8(B): Levels of significance for various factors of vowel duration in SMR task*



Factor	/pʌ/ Significance	/tʌ/ Significance	/kʌ/ Significance	/bʌ/ Significance	/dʌ/ Significance	/gʌ/ Significance
Group	0.000	0.000	0.000	0.000	0.000	0.000
Age	0.760	0.617	0.595	0.082	0.071	0.366

The significance for various factors was determined by 2 way ANOVA for each syllable in SMR task. The results are shown in Table 8(B).

Graph 8: Mean Vowel Duration (in milliseconds) for voiceless and voiced cognates in SMR tasks



From Table 8(A), 8(B) and Graph 8 it is seen that:

1) Vowel duration is increased in all syllables in SMR task as compared to normals and this difference is highly significant between the groups in both age ranges.

2) There is no significant difference between the age groups for vowel duration in both normals and Spastic cerebral palsied.

Similar to AMR task, the vowel duration is greatly increased, which indicates that prolonged vowel duration is a significant factor contributing to slow speech SMR in Spastic CP. This lengthening of vowel in Spastic CP in SMR task is due to the inability of the subjects to quickly move the following articulator for the production of the next syllable in the sequence. This could be due to the severity of the motor involvement seen in Spastic CP. Such an increase in vowel duration seen in speech SMR of Spastic CP have also been observed in adults dysarthrics (Caruso and Burton, 1987; Seikel, Wilcox, Davis, 1991).

II. Temporal variation across syllable train

Syllable duration for middle three syllables in syllable sequence train is measured from the Alternating motion task sample. This is analysed for both voiceless /pʌ/, /tʌ/, /kʌ/ and for voiced /bʌ/, /dʌ/, /gʌ/ in both Spastic CP and normals. The aim is to study for any temporal variation in syllable duration in the AMR task between spastic CP and normals.

Table 9: Syllable duration in milliseconds for Spastic CP and normals in the age range 11-12 years.

		Spastics			Normals		
Syllable		Preceding Syllable	Middle Syllable	Following Syllable	Preceding Syllable	Middle Syllable	Following Syllable
/pʌ/	GM	399.91	402.37	382.59	162.37	165.06	160.06
	GSD	77.97	59.87	59.08	28.50	34.98	31.12
/tʌ/	GM	372.96	365.27	361.91	181.15	185.32	180.21
	GSD	77.35	56.09	48.79	26.57	36.84	34.36
/kʌ/	GM	375.60	392.00	388.05	211.96	212.46	210.70
	GSD	82.27	73.39	86.01	25.59	32.48	20.91
/bʌ/	GM	381.62	413.22	407.65	213.81	211.62	210.41
	GSD	70.47	82.94	71.97	40.27	37.35	44.85
/dʌ/	GM	382.44	411.22	392.28	237.05	236.14	240.92
	GSD	65.17	55.88	56.02	37.20	29.96	34.34
/gʌ/	GM	411.93	418.92	412.48	238.63	241.92	244.04
	GSD	64.96	68.28	56.39	28.34	28.30	23.52

GM - Group Mean
GSD - Group Standard Deviation

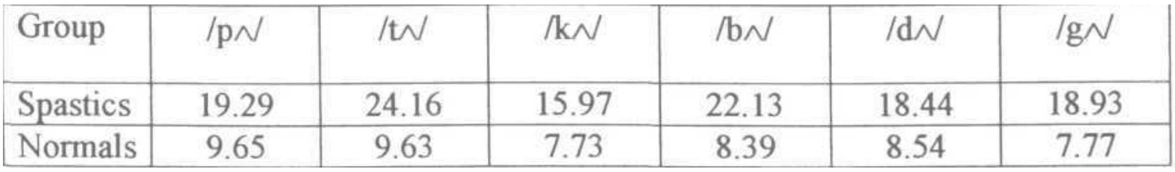
Table 10: Syllable duration in milliseconds for Spastic CP and normals in the age range 12-13 years.

		Spastics			Normals		
Syllable		Preceding Syllable	Middle Syllable	Following Syllable	Preceding Syllable	Middle Syllable	Following Syllable
/pʌ/	GM	344.03	371.99	354.35	159.66	160.38	158.67
	GSD	72.66	83.40	59.08	36.66	32.94	37.98
/tʌ/	GM	388.58	395.04	387.92	179.48	180.16	183.92
	GSD	83.96	79.94	80.61	24.10	14.07	21.07
/kʌ/	GM	353.67	369.21	367.96	193.95	193.72	192.69
	GSD	88.16	82.01	71.92	27.08	24.32	22.40
/bʌ/	GM	376.58	378.46	368.12	206.90	211.36	210.99
	GSD	47.05	53.96	59.93	19.61	14.85	13.73
/dʌ/	GM	365.00	386.77	379.82	215.29	217.73	220.27
	GSD	28.06	40.99	52.41	28.85	24.47	27.59
/gʌ/	GM	386.25	417.61	397.24	207.30	217.15	214.06
	GSD	67.09	60.32	47.51	29.78	30.99	31.77

GM - Group Mean
GSD - Group Standard Deviation

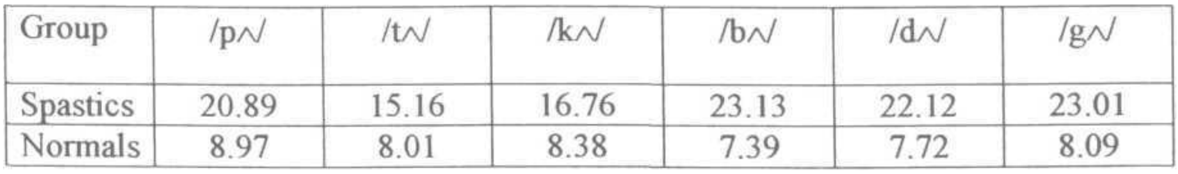
Table 9 and Table 10 shows the syllable duration in syllable sequences in the age range of 11 to 12 years and 12 to 13 years for both Spastic CP and normals. Syllable duration is measured for middle, preceding and following syllables for voiced and voiceless cognates in the Alternating motion task. Table 9 and 10 provides a cursory look at the group mean and group standard derivation for all syllables between Spastic and normals. These values only indicate the performance of the group as a whole. To determine if individual subjects are variable in Alternating motion task, intra subject standard deviation (IS SD) were calculated for each subject for each series of syllable repetitions. From these, the IS - SD mean (i.e., mean of the individual standard deviation) was calculated, which indicates the subject's variability in syllable duration across syllable train. This is shown in Table 11 and 12 for both age groups.

Table 11: Mean intra subject SD for 11-12 years in Alternating motion task.



Group	/pʌ/	/tʌ/	/kʌ/	/bʌ/	/dʌ/	/gʌ/
Spastics	19.29	24.16	15.97	22.13	18.44	18.93
Normals	9.65	9.63	7.73	8.39	8.54	7.77

Table 12: Mean intra subject SD for 12-13 years in Alternating motion task.



Group	/pʌ/	/tʌ/	/kʌ/	/bʌ/	/dʌ/	/gʌ/
Spastics	20.89	15.16	16.76	23.13	22.12	23.01
Normals	8.97	8.01	8.38	7.39	7.72	8.09

Table 11 and 12 shows the mean intra subject SD for 11 to 12 years and 12 to 13 years respectively. The mean values are higher than normals in both age groups. From Table 11 it can be seen that the range of variability for normals is less, and it varies from 7.77 milliseconds to 9.65 milliseconds in the voiceless and voiced syllable repetitions. Whereas in Spastic CP, the range of variability is from 15.97 milliseconds to 24.16 milliseconds which is larger when compared to normals in the age range 11 to 12 years.

Similarly in Table 12, the range of variability for normals for both voiceless and voiced repetition in AMR task is from 7.72 milliseconds to 8.97 milliseconds. Whereas in Spastic CP, the range of variability is from 15.16 milliseconds to 23.13 milliseconds indicating greater variability in Spastic CP in the age range of 12 to 13 years. Since the range of variability is greater than that normals for Spastic CP, it can be said that syllable duration is more temporally variable in the speech AMR of Spastic CP than for normals.

In the Mayo Clinic classification of adult Spastic dysarthrics, Darley et. al., (1969a, 1969b), report that syllables are repeated at a slower than normal rate but with normal rhythm. But in the present study, the temporal variability is seen within a sequence of utterance of repeated syllables. This finding is consistent with the study on adult Spastic dysarthric by Portnoy and Aronson (1982), who found abnormal variability in syllable rhythm.

Over the years, all studies on syllable timing have concentrated on Ataxic dysarthria and have shown that the interval between syllables is irregular (Boutsen, Bakker and Duffy, 1997; Cisneros and Braun, 1995; Gentil, 1990; Kent et. al., 1997). In the present study the interesting observation is that there is a temporal variability in the syllables in the AMR task. So the findings indicate that the temporal variability is a result of impaired speech motor control in Spastic CP. It could also be that the increased tone in Spastic CP results in poor co ordination that is required to produce regular timed syllables.

Summary

In summary a comparison of temporal measures like burst duration, VOT, transition duration and vowel duration in both AMR and SMR tasks in Spastic CP and normal children was made. Burst duration is found to be increased in Spastic CP for both voiced and voiceless syllables in the AMR task. In comparison, BD is increased only in voiced SMR tasks and /Kʌ// in voiceless SMR task in Spastic CP compared to normals.

VOT is increased only for /pʌ/ and /tʌ/ in AMR task, but not for other syllables in the same task. On the other hand, VOT is increased only for /kʌ/, /dʌ/ and /gʌ/ in SMR task indicating that there is a variability in the performance of Spastics in SMR task.

Transition duration is significantly increased in Spastic CP in both AMR and SMR tasks. Similarly vowel duration is also significantly increased in both these tasks, indicating that both TD and VD contribute significantly to slow speech AMR.

AMR sample tested for temporal variation showed greater variability in spastic CP as a group than normals. There is no difference between the age group 11 to 12 years and 12 to 13 years for any of the related temporal parameters. This could be reasoned as due to heterogeneity in both the groups taken for the study - Spastic CP and normals in terms of diadochokinesis and hence no significant change is seen between the age groups.

Spastic cerebral palsied included in the study was not controlled in terms of degree of motor involvement. The task required of them was to produce the AMR and SMR task as rapidly and as clearly as possible. Most of the Spastic CP children attempted to produce perceptually accurate repetition of these syllables. However, variance was seen in the temporal dimension of the acoustic output, which is evidenced from the spectrographic investigation although perceptually and qualitatively the speech output was considered appropriate with few distortion errors. Despite, the neuromotor defects present the Spastic cerebral palsied children produced syllable repetition that was perceptually invariant, acoustically however lengthening in duration was noticed.

Most of the temporal parameters are found to be increased in Spastics more so, with transition duration and vowel duration. To produce a perceptually invariant syllable repetition, it could be hypothesised that the Spastic CP children comprised or traded articulatory accuracy with temporal dimensions. To maintain perceptually invariant syllable repetition, dysarthics i.e., Spastic CP could be lengthening the syllable duration.

From the AMR study, we can understand the variable nature of speech production phenomena from repetition to repetition where in spatiotemporal relationship is affected. It can be reasoned that in order to be able to accommodate articulatory demands, the temporal dimension are surrendered although perceptually they are still within normal limits. Similar results were obtained in speech motor studies on adult normals with induced pertubated production of stop release. (Perkell et al., 1995). To help keep acoustic variability within perceptually acceptable limits, speech motor control mechanism may include a strategy by which different parts of the vocal tract area function are adjusted in a complimentary (motor equivalent) manner. This could also be due to a strategic compensation indirectly due to loss of capacity or a performance for accuracy in spastic children, which is similar to studies shown on geriatric population (Wohlart and Smith, 1998). So in conclusion it could be said that the temporal parameters lengthening is a result of involvement of the speech motor system, which is compensated by increase in syllable duration to produce a perceptually invariant syllable in the AMR and SMR task.

SUMMARY AND CONCLUSIONS

Dysarthria has been defined as a speech disorder resulting from impairment to the neural mechanisms that regulate the movements of speech (Netsell, 1984). Cerebral palsy is simply the name given to the motor manifestations of non progressive brain damage sustained during the phase of active brain growth (Brown, 1984). Developmental dysarthria is by far the most common of the motor speech disorders and is most frequently seen in children with cerebral palsy.

The most challenging task for a Speech Pathologist is to classify the type of dysarthria in children with cerebral palsy. There is some evidence to state that adult speech characteristics described by Darley, Aronson & Brown (1969) is not directly applicable to childhood dysarthric (Von Mourik et al., 1997 and Purnima, 2001). Many investigators like Portnoy and Aronson, (1982), Hixon and Hardy (1964) have reported that diadochokinesis is a sensitive tool to differentiate dysarthria from normals. Mayo Clinic classification in Spastic dysarthrics points towards a significant temporal deviance in speech such as short phrases, prolongation of phoneme increased syllable and word duration and slow speech AMR's. AMR studies by many investigators like Hixon and Hardy (1964), Heltmen and Peacher (1943), and Schliiesser, (1982) have reported slow speech AMR's in cerebral palsied children. However, these studies have not supplimented the perceptual data with acoustic data to verify their results. The present study analyzed the temporal characteristics of diadochokinesis speech samples of Spastic CP aged 11-12 & 12-13 years and normal age and sex matched controls.

The main objective was to analyse the temporal parameters of burst duration, voice onset time, vowel duration and transition duration in speech diadochokinesis of Spatic cerebral palsied and age matched normals in voiceless and voiced AMR's and SMR's. Acoustic spectrographic analysis was done using CSL 4400 to study the temporal parameters. Acoustic analysis was done on the middle sequence of AMR and SMR task. For example, if there are nine iterations of repetitions in AMR task, the middle syllable sequence i.e., fourth fifth and sixth syllable was highlighted similarly for example, if there are six syllable sequence of repetition of SMR task the middle syllable sequence was highlighted. From the highlighted middle syllable sequence one syllable in AMR task and middle syllable sequence in SMR task was analysed for the above mentioned parameters. Temporal variation across syllable train was also studied in the AMR task for both groups. Here the preceding, middle and following syllable duration was measured. The obtained raw data was subjected to a 2 way ANOVA in the statistical analysis. The findings of the study are presented below.

AMR task

1. Burst duration was consistently increased in Spastic CP as compared to normals, indicating that this increase probably is one of the factors contributing to slow speech AMR seen in Spastic CP.

2. Although VOT was found to be increased in some syllables, it was significant only for /pʌ/ and /tʌ/ suggesting that VOT is variable and hence may not be a significant factor contributing to the slow speech AMR's in Spastic CP.

3. Transition duration and vowel duration was significantly prolonged in AMR task in Spastic CP. Hence, it can be said that these factors contribute immensely for the slow speech AMR's.

SMR task

1. Burst duration was increased for all voiced SMR task, than for voiceless i.e., B.D plays a significant role in slow speech AMR's mostly for voiced syllable.

2. The increase in VOT was not consistent for few syllables suggesting that there is variability in performance of Spastic CP in the SMR task.

3. As in AMR task, transition duration, and vowel duration was significantly increased suggesting that these measures may be important was for slow speech AMR in Spastic CP.

On the whole, burst duration, transition duration, and vowel duration are significantly increased in slow speech AMR for both voiceless and voiced cognates in Spastic CP's. On the other hand, only burst duration in voiced cognates and transition duration and vowel duration in SMR task was found to be significantly increased in Spastic CP. There was no difference between the two age groups (11 to 12 and 12 to 13) for any of these parameters for both normals and Spastic CP, and this could be due to heterogenity in both these groups.

Temporal variance in AMR tasks

In the analysis of temporal variance across syllable train, it was noted that the Spastic CP, was more variable than the control normals. Due to deficient motor involvement in Spastic CP, there is lack of precision in their articulatory movements. Despite these imprecision in articulatory movements, the acoustic output is perceived as an invariant syllable. This finding indicates that there is a temporal trade off, for this acoustic invariance in order to compensate for the articulatory insufficiencies seen in Spastic CP.

Recommendations for future research

- A similar study could be carried out including all types of cerebral palsy on a large sample of subjects.

- A longitudinal study can be carried out to see if there is a development trend.

- A study comparing the acoustic characteristics of AMR and SMR task could be conducted with Spastic dysarthria in children and adult to study the similarities or variations in these findings.

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