Estimation of Scanning Index in the Speech of Dysarthric Speakers

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Abstract

Dysarthric speech is characterized by prosodic subsystem errors which are considered unique to the different varieties of dysarthrias. These characteristics have been well established perceptually in the speech of dysarthrics. 'Scanning index' (SI) is an acoustic measure that has been used to study the speech of Ataxic variety of dysarthrics, which has yielded evidence for the perceptual characteristic of 'staccato speech'. An attempt was made to estimate SI and variability measures in the different varieties of dysarthrics where overlapping features of prosodic disturbances are evidenced. Also, tasks of varying linguistic complexities were selected, including a syllable repetition and sentence repetition, to throw a light on the possibilities of differential temporal control, over different tasks in dysarthrics. The results are discussed for the measures of intra-utterance and inter-utterance variabilities and scanning index.

Introduction

Oral communication requires the smooth sequencing and coordination of basic processes such as: Organization of concepts, Externalization of thought in speech and Programming of motor commands (Darley, Aronson & Brown, 1975). Dysarthria comprises of a group of speech disorders resulting from disturbances in neuromuscular control. Because there is damage to the central or peripheral nervous system some degree of weakness, slowness, in coordination or altered muscle tone is evident in the activity of speech mechanism (Darley, Aronson & Brown, 1975). Dysarthrias are classified on the basis of perceptual clusters of symptoms which are further dictated by the sites of lesion. Darley, Aronson & Brown (1975) classified dysarthias as:

- Spastic dysarthria due to lesions in upper motor neurons
- Flaccid dysarthria due to lesions in the lower motor neurons
- Hypokinetic dysarthria due to lesions in the basal ganglia and associated brainstem nuclei
- Hyperkinetic dysarthria due to lesions in the basal ganglia and associated brainstem nuclei
- Ataxic dysarthria due to lesions in the cerebellum and/or its connections
- Mixed dysarthria due to lesions involving any of the structures mentioned above

These types of dysarthria are characterized by specific clusters of speech subsystem errors of respiratory, phonatory, articulatory, resonatory and prosodic systems, involved in varying degrees. One area of emerging interest in the dysarthrias is that of the errors in the prosodic subsystem of speech. Prosody refers to the non-segmental components of spoken

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language, which are pitch, loudness and duration. These are served by three acoustic parameters of fundamental frequency, amplitude and duration (Lehiste, 1970).

Damage to these neural substrates sub serving the prosodic function can result in conditions of either aprosody or dysprosody in dysarthrics (Monard-Krohn, 1963). Dysprosodies are characterized by abnormalities in pitch patterns, intonation contours, stress patterns and temporal or rhythmic patterns of speech (Kent 2000), which also vary with the type of dysarthria. For example, Ataxic dysarthria is perceptually characterized by marked deviations in prosody than any of the other varieties. Impairments in the temporal control of speech is documented as most common prosodic errors in the dysarthrics, which include increased/decreased rate of speech, short phrases, excess and equal stress and so on. These errors have been attributed to deficits in motor programming for speech, where control of timing for speech is impaired. That is, although the overall speech gestures are preserved in dysarthrics, they lack precision in direction, range and timing which leads to the phenomenon called 'temporal dysregulation'.

Need for the study:

The phenomenon of temporal dysregulation has been established through perceptual evidences in different types of the dysarthrics. This has been studied extensively in Ataxic dysarthrics, where there are typical dysprosodic errors characterized as 'scanned' or 'staccato' speech which are characterized by clinical features of excess and equal stress, prolonged phonemes and slow rate of speech (Kent & Netsell, 1975)

Acoustic evidence for 'scanned' speech in Ataxic dysarthrias has been investigated using an index called as 'Scanning Index' a measure which looks into the variability of articulatory gestures on a time scale (Ackermann & Hertrich, 1994). The 'Scanning Index' involves the measurements of syllable durations, differences in intra-utterance syllable lengths (within the same sentence) and differences in inter-utterance syllable lengths (in repetition of the same sentence). This measure helps infer information on 'syllable isochrony' in Ataxic dysarthics, that is the phenomenon of equal durations of syllables which is the perceptual dimension of scanned speech.

The 'scanning index' (SI) proposed by Ackermann & Hertrich, (1994) is computed using the formula:

$$SI = \frac{S1 \times S2 \times S3 \times \ldots\ldots Sn}{[S1 \times S2 \times S3 \times \ldots. Sn/\, n]^{n}}$$

Where: S = syllable length or duration; n = number of syllables considered

Provided that all of the syllables have equal length, the index amounts to unity or '1'. If the speech is variable or not 'scanned', then the index should be less than unity or '1'.

Several investigations conducted on Ataxic dysarthrics using the measure of SI have concluded that clients with Ataxia present reduced speech tempo in terms of syllable and utterance durations and there is a tendency for syllabic isochrony for certain measures like intra-utterance variation and SI (Ackermann & Hertrich 1994; Hartelius, Runmarker, Anderson & Nord, 2000).

No study however has attempted to determine the effects of 'temporal dysregulation' on other types of dysarthrics, other than the Ataxic, using SI. It is observed that even the other varieties of dysarthria exhibit perceptual evidences of temporal disruption such as slow rate, short phrases, prolonged phonemes, excess and equal stress, (Darley, Aronson & Brown

1975). It would be interesting to observe if SI can be used as a measure to understand the temporal dysregulation in the speech of other types of dysarthria. Also in the previous studies, SI has been studied in limited linguistic contexts of consonant and vowel combinations (e.g. /p/, /t/, /k/ and /a/, /i/, /e/, /o/, /u/) embedded in nonsense words within a carrier phrase.

In this study, tasks of varying linguistic complexity is included in order to evaluate the effects of complexity of the stimuli on the measure of SI, which may throw light on the type of differential temporal control if any in other types of dysarthrics (Lindblom, 1990)

Aims of the study:

To compare the measures of 'Scanning Index', intra-utterance and inter-utterance variations in:

a. Subjects with different types of dysarthrias, namely Spastic, Flaccid, Ataxic, Hyperkinetic, Hypokinetic, and Mixed varieties and compare with age and sex matched normal control subjects.

b. Speech stimuli with varying linguistic complexity

   i. Syllable combinations of consonants and vowels
   ii. Sentences with increasing number of syllables
   iii. Varying consonant and vowel environments

Method

Subjects:

Two groups of subjects were considered:

A. *Experimental group*: Comprised of 6 adult male subjects with dysarthria (age range: 18-60 years). The subjects presented Spastic, Flaccid, Ataxic, Hyperkinetic, Hypokinetic and Mixed types of dysarthria (one subject per type) with severity ranging from mild to moderate degree.

- Inclusion criteria for selection of subjects in the experimental group were as follows:
  - aged above 18 years
  - mother tongue Kannada
  - confirmed diagnosis of the type of dysarthria from a neurologist
  - severity ranging from mild to moderate as assured on Frenchay Dysarthria Assessment (FDA) Scale
  - no therapeutic interventions including speech language therapy
- Exclusion criteria for selection of subjects in the experimental group were as follows:
  - neurological etiology of traumatic nature
  - associated sensory cognitive or linguistic impairments

Table 1 presents the demographic details of subjects in the experimental group.

Table 1: The demographic data of dysarthric subjects

Subject	Age	Sex	Duration of the disorder	Etiology	Type of dysarthria
1	19	M	5 months	Encephalitis	Spastic
2	25	M	3 years	Brainstem tumor	Flaccid
3	60	M	2 years	Aneurysm	Ataxic
4	19	M	1 year	Dystonia	Hyperkinetic
5	21	M	1 year	Parkinson's disease	Hypokinetic
6	20	M	6 months	Brain tumor	Mixed (Spastic-Ataxic)

B. *Control group*: Comprised of six age and sex matched normal subjects. They were screened for any neurological deficits, speech, language, memory and hearing problems.

Material: Two tasks were included which were as follows:

a) *Syllable repetition task:* Diadochokinetic (DDK) task, including sequential motion rate (SMR) and alternate motion rate (AMR). The voiceless stop consonants /p/, /t/ and /k/ were combined with five short vowels of Kannada language, **/a/, /i/, /e/, /o/ and /u/.** chosen in order to determine the possible influences of these on the measure of SI and variability, since inherent characteristics of consonant and vowels, such as tongue height or tongue advancement are assumed to influence segment durations of speech.

b) *Sentence repetition task*: Three natural sentences in Kannada which varied in syllable length, (increasing in the order of three, seven and eleven syllables) were included to observe for the effects of increasing complexity and length on the measure of SI. Care was taken to avoid the use of complex morpho-phonemic structures, geminates and clusters in the sentences in order to make the task simpler for the dysarthric subjects.

Procedure:

The test stimuli were spoken by an adult normal male speaker whose mother tongue was Kannada, in a natural context and these were audio recorded. The dysarthric and normal subjects were instructed to listen to the audio recorded model utterances and imitate the same. Three repetitions of each of the utterances were recorded and the best two of the three trials were selected by the investigator for analysis. Practice trials were also given for the subjects before the recording. The two tasks were recorded in a random order across subjects to rule out 'order effect'.

The audio recording was carried out in a sound treated room for each subject individually using a digital tape recorder (Sony MZ R55). The subjects were seated comfortably on a chair and presented with the model utterances in free field. The mike was held at a constant distance of approximately 10 cm away from the subjects' mouth.

Analysis:

The analysis was carried out in the following manner:

The recorded speech samples were digitized and fed to CSL 440 software for acoustic analysis. Only the best of the two trials of the three repetitions were included for the analysis.

The syllable durations (in milliseconds) within each utterance for both the DDK and sentence repetition tasks were analyzed. For the DDK task, the middle three syllables within

each utterance in the SMR task and the middle four syllables in the AMR task were considered for the analysis, in order to avoid speech onset and offset effects. This could not be followed for sentences due to the constraint of limited number of syllables that were considered in each sentence, to ensure an easy speech task for the dysarthric subjects. The syllables in Kannada language included 'consonant vowel' (CV) or a 'consonant-vowel-consonant' (CVC) sequences. The measure of syllable duration (in milliseconds) was defined as the distance from the initiation of burst for a stop consonant to the termination of voicing for a vowel in a CV sequence and initiation of burst for a stop consonant till the termination of the burst for the next consonant for a CVC sequence.

SI was calculated for both the syllable and the sentence repetition tasks. SI is a measure involving syllable durations using the following formula (Ackermann & Hertrich, 1994):

$$SI = \frac{S1 \times S2 \times S3 \times \ldots\ldots Sn}{[S1 \times S2 \times S3 \times \ldots. Sn/n]^{n}}$$

Where: S = syllable duration, n = number of syllables considered. SI was compared across trial repetitions of an utterance in both the tasks.

The acoustically computed syllable durations for the two repetitions of each utterance were compared across both trials, to check for inter-utterance variability. The acoustically computed syllable durations were compared within each utterance for both the trials, to check for intra-utterance variability. The inter-utterance and intra-utterance measures were computed for both the syllable repetition and sentence repetition tasks, for the experimental and control groups.

Results and Discussion

The results are presented and discussed under the following sections based on the tasks considered for the study:

- Syllable repetition task
- Sentence repetition task

A. Syllable Repetition Task:

The syllable duration measures were obtained for both SMR (Sequential motion rate) and AMR (Alternate motion rate) of DDK task.

SMR of DDK task:

The syllable durations (in milliseconds) within the five utterances with the combinations of three consonants and five vowels (/p/, /t/, /k/ and /a/, /i/, /e/, /o/, /u/) for each of the subjects were calculated for the two trials. Comparisons were made to observe for intra-utterance and inter-utterance variability measures and SI scores.

'Kruskal Wallis H Test' revealed no differences in the syllable durations for the different vowels, both within and across the two trials, for both the dysarthric and normal groups ($p > 0.05$). Since there was no difference in the syllable durations for the different vowels, all the syllable durations irrespective of the vowels were statistically combined together for comparison. 'Paired t Test', revealed no statistically significant difference across the three consonants considered, both within and between two trials, for both the groups ($p>0.05$). The mean syllable durations of different CV (consonant and vowel) in the SMR subtask are as shown in Table 2.

Table 2: Mean syllable durations (msec) of vowels and consonants in SMR subtask in both the groups

Subjects (n)	C (p, t, k) + V (a)		C (p, t, k) + V (i)		C (p, t, k) + V(e)		C (p, t, k) + V (o)		C (p, t, k) + V(u)	
	T1	T2	T1	T2	T1	T2	T2	T1	T2	T1
D1	0.281	0.273	0.238	0.228	0.225	0.225	0.233	0.234	0.232	0.245
N1	0.125	0.125	0.121	0.126	0.123	0.126	0.135	0.133	0.136	0.136
D2	0.222	0.223	0.233	0.225	0.225	0.225	0.239	0.235	0.225	0.233
N2	0.135	0.144	0.161	0.125	0.125	0.126	0.136	0.135	0.136	0.125
D3	0.233	0.225	0.238	0.228	0.228	0.226	0.234	0.238	0.236	0.223
N3	0.137	0.132	0.123	0.123	0.129	0.124	0.136	0.136	0.133	0.122
D4	0.233	0.233	0.237	0.226	0.226	0.222	0.236	0.237	0.237	0.236
N4	0.127	0.136	0.133	0.127	0.129	0.123	0.133	0.133	0.128	0.139
D5	0.240	0.235	0.222	0.228	0.223	0.222	0.235	0.236	0.225	0.238
N5	0.138	0.138	0.128	0.125	0.125	0.124	0.133	0.138	0.133	0.128
D6	0.233	0.245	0.213	0.224	0.223	0.228	0.238	0.226	0.228	0.234
N6	0.222	0.138	0.111	0.122	0.128	0.125	0.139	0.129	0.129	0.133

T1=Trial 1; T2 =Trial 2; D=Dysarthric subject; N=Normal subject; n =number of subjects, (DI=Spastic,D2=Flaccid,D3=Ataxic,D4=Hyperkinetic,D5=Hypokinetic,D6=Mixed)

As seen from Table 2 the mean syllable durations were nearly similar within the subjects of each group for the two trials. But marked differences were observed between the means of two groups of subjects. The raw scores of individual subjects in the dysarthric and normal groups were subjected to statistical analysis using 'Kruskal Wallis H Test' to examine if there is a difference in the syllable durations of dysarthric and normal subjects, both within and across the two trials. The results indicated that there was no statistically significant difference in the syllable durations within the dysarthric individuals and normals ($p > 0.05$). 'Independent Samples t Test' revealed that the intergroup difference between dysarthrics and normals in mean syllable duration was significant between the groups, for both intra-utterance and inter-utterance variability measures ($p < 0.05$). This is as shown in Table 3.

Table 3: The mean and SD for the intra-utterance & inter-utterance inter-group difference for SMR (msec)

Trials	Group	No. of syllables		Mean		SD		t value		P value	
		Intra utterance	Inter utterance	Intra utterance	Inter utterance	Intra utterance	Inter utterance	Intra utterance	Inter utterance	Intra utterance	Inter utterance
1.	Dysarthrics	90	180	0.129	0.123	0.008	0.007	8.854	12.49	0.000*	0.000
	Normals	90		0.005		0.001					
2.	Dysarthrics	90	180	0.119	0.008	0.009	0.001	9.047		0.000*	
	Normals	90		0.006		0.007					

'*'=significant difference at 0.05 level

B. Scanning index (SI) measure:

The SI scores for the utterances spoken by each dysarthric and normal subject were compared for within and between trials and, the groups using, 'Kruskal-Wallis H test.' The

results reveal that the differences between the individual scores for the various subject groups were not statistically significant (p> 0.05). 'Paired t Test' revealed significant differences in the means of SI scores of the two groups of subjects, and the same is shown in Table 4.

Table 4: The mean and standard deviation for SI intergroup difference for SMR (msec)

Groups	No. of syllables	Mean	SD	t value	P value
Dysarthric	60	0.987	0.002	3.458	0.001*
Normal	60	0.997	0.008		

''=significant difference at 0.01 level*

'Kruskal Wallis H Test' was used to examine if the difference in mean SI for different consonant and vowel combinations for both groups within and between the two trials was significant. The results indicated that there was no statistical difference in the SI scores for consonants and vowels (p> 0.05).

AMR of DDK task:

There were totally fifteen utterances (three consonant with five vowel conditions). For the AMR task the iterations of each consonant-vowel combination (e.g.: pa,pa,pa,pa) were analyzed. The syllable duration of the middle four iterations of each syllable of each subject was analyzed. The mean scores are shown in Table 5.

Table 5: The mean syllable durations (msec) of consonants and vowel combinations in AMR subtask in both groups

Subjects (n)	Vowels	Consonant p		Consonant t		Consonant k	
		T1	T2	T1	T2	T1	T2
D1	a	0.175	0.177	0.179	0.183	0.188	0.185
	i	0.177	0.175	0.176	0.177	0.178	0.184
	e	0.183	0.176	0.188	0.184	0.171	0.1800
	u	0.175	0.177	0.181	0.185	0.179	0.1777
	o	0.188	0.184	0.186	0.182	0.179	0.177
N1	a	0.008	0.114	0.005	0.008	0.006	0.102
	i	0.011	0.002	0.000	0.009	0.006	0.009
	e	0.121	0.001	0.001	0.001	0.008	0.001
	u	0.007	0.008	0.111	0.008	0.007	0.007
	o	0.001	0.005	0.005	0.001	0.001	0.001
D2	a	0.162	0.170	0.170	0.166	0.165	0.162
	i	0.166	0.175	0.172	0.170	0.164	0.166
	e	0.164	0.171	0.162	0.161	0.169	0.166
	u	0.166	0.164	0.165	0.175	0.177	0.172
	o	0.166	0.178	0.177	0.174	0.172	0.168
N2	a	0.007	0.006	0.009	0.009	0.008	0.008
	i	0.002	0.001	0.006	0.006	0.002	0.001
	e	0.112	0.123	0.121	0.008	0.008	0.006
	u	0.111	0.102	0.009	0.012	0.008	0.009
	o	0.008	0.007	0.007	0.005	0.007	0.008
D3	a	0.162	0.195	0.173	0.178	0.168	0.166
	i	0.166	0.165	0.187	0.177	0.171	0.164
	e	0.165	0.175	0.177	0.174	0.168	0.165
	u	0.177	0.166	0.0178	0.163	0.154	0.178
	o	0.175	0.168	0.169	0.166	0.164	0.162
N3	a	0.009	0.008	0.006	0.009	0.009	0.009

	i	0.012	0.121	0.112	0.132	0.114	0.102
	e	0.002	0.001	0.001	0.001	0.005	0.001
	u	0.111	0.112	0.009	0.008	0.113	0.114
	o	0.008	0.114	0.008	0.008	0.123	0.115
D4	a	0.176	0.177	0.189	0.199	0.175	0.166
	i	0.165	0.165	0.177	0.178	0.199	0.164
	e	0.174	0.175	0.166	0.164	0.166	0.174
	u	0.164	0.177	0.166	0.162	0.168	0.174
	o	0.177	0.168	0.198	0.166	0.168	0.167
N4	a	0.001	0.008	0.009	0.154	0.111	0.009
	i	0.005	0.006	0.007	0.007	0.007	0.007
	e	0.001	0.002	0.001	0.001	0.006	0.007
	u	0.145	0.002	0.002	0.005	0.001	0.001
	o	0.111	0.121	0.009	0.009	0.009	0.008
D5	a	0.177	0.158	0.177	0.163	0.162	0.174
	i	0.164	0.166	0.165	0.164	0.168	0.169
	e	0.175	0.177	0.178	0.184	0.164	0.168
	u	0.177	0.174	0.175	0.161	0.160	0.162
	o	0.165	0.171	0.177	0.174	0.174	0.178
N5	a	0.002	0.001	0.002	0.001	0.002	0.002
	i	0.001	0.003	0.005	0.006	0.005	0.005
	e	0.007	0.009	0.009	0.009	0.009	0.001
	u	0.004	0.001	0.001	0.112	0.112	0.009
	o	0.008	0.007	0.007	0.009	0.008	0.008
D6	a	0.178	0.178	0.179	0.176	0.177	0.175
	i	0.185	0.164	0.166	0.156	0.177	0.178
	e	0.174	0.177	0.168	0.166	0.165	0.166
	u	0.177	0.172	0.162	0.166	0.165	0.164
	o	0.162	0.166	0.165	0.156	0.166	0.166
N6	a	0.005	0.006	0.001	0.001	0.001	0.111
	i	0.008	0.004	0.007	0.007	0.006	0.006
	e	0.004	0.005	0.009	0.009	0.008	0.008
	u	0.009	0.009	0.008	0.007	0.007	0.007
	o	0.007	0.007	0.001	0.001	0.001	0.007

T1=Trial1; T2=Trial2; D=Dysarthric subject; N=Normal subject; n=number of subjects, (DI=Spastic,D2=Flaccid,D3=Ataxic,D4=Hyperkinetic,D5=Hypokinetic,D6=Mixed)

As can be seen from Table 5 the mean of the syllable durations were similar within the subjects of each group for the two trials, with few exceptions. But differences were evident between the two groups of subjects.

The raw scores were treated statistically using 'Kruskal Wallis H test' to examine if difference in the mean syllable durations between the dysarthric and normal subjects, across trials were insignificant. The result indicated that the difference in the mean syllable durations within the dysarthric and normals groups were not significant ($p > 0.05$). Since there was no significant difference between the mean syllable durations of dysarthric individuals and normal subjects, mean syllable duration of groups were compared using, 'Independent Samples t test' to observe if there is an intergroup difference between the groups within and between the two trials. The results indicated statistically significant differences between the groups for both the measures ($p < 0.05$). The results are shown in Table 6.

Table 6: The mean and SD for intra and inter-utterance inter-group difference for AMR

Trials	Groups	No. of syllables	Mean		SD		t value		P value	
			Intra utterance	Inter utterance	Intra utterance	Inter utterance	Intra utterance	Inter utterance	Intra Utterance	Inter utterance
1.	Dysathrics Normals	360	0.173 0.009	0.271	0.007 0.007	0.000	15.1 15.1	16.120	0.000* 0.000*	0.000*
2.	Dysarthrics Normals	360	0.173 0.008	0.111	0.006 0.005	0.006	18.9 18.9		0.000* 0.000*	

'*'=significant difference at 0.05 level

Intra-utterance and inter-utterance variability across different consonants and vowels:

The raw scores were statistically treated using 'Kruskal Wallis H test' to observe if the differences in the mean syllable durations for the different vowel, consonant combination, both within and between the two trials were significant. The result indicated that the difference was not statistically significant for the different consonant vowel combination for both the dysarthric and normal groups ($p > 0.05$). Since there was no difference in the mean syllable duration scores for the different vowels, the different consonant-vowel combinations were considered as a group and statistically compared using 'Paired t test' for differences across groups & within and between the two trials. The results indicated statistically no significant differences within the two groups ($p>0.05$). However, but for the intra-utterance variation measure, for both the groups, some variation in the mean syllable durations for the consonant /k/ in the second utterance of the first trial (in dysarthric group) were evident, but these differences were not found to be significant. Also, there were instances of variation in the mean durations of syllables for the consonant /t/ in the second trial (in normal group), but again these were not found to be statistically significant and were assigned to random chance factors ($p =0.05$). Differences were also not evident in the inter-utterance measure within both the groups, between the two trials.

a) Scanning Index measure in AMR task:

The SI scores for the utterances spoken by each of the dysarthric and normal subjects were compared for both within and across the two trials, using 'Kruskal-Wallis H test' and the results showed that the difference were not statistically significant when individual scores were compared ($p> 0.05$). The SI scores for the utterances of the dysarthric and normal subjects as a group were compared using 'Paired t test' to observe for evidences in the performance of the two groups. The results indicated statistically significant differences in the scores for the task between the groups ($p< 0.05$). The results are tabulated in Table 7.

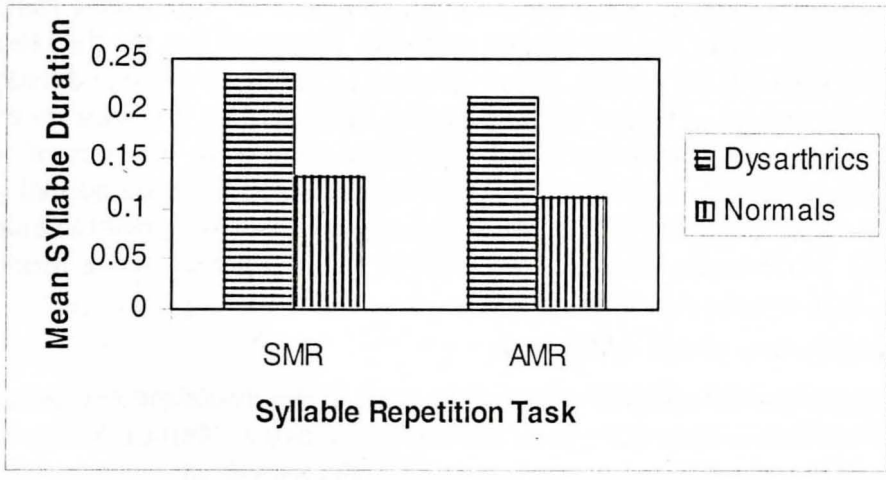
Table 7: The mean and standard deviation for SI intergroup difference for AMR

Consonant-Vowel	Groups	No. of syllables	Mean (msec)	SD	t value	P value
Pv	Dysarthric	60	0.920	0.002	2.016	0.001*
	Normal	60	0.997	0.001		
Tv	Dysarthric	60	0.896	0.007	3.981	0.000*
	Normal	60	0.998	0.000		
Kv	Dysarthric	60	0.893	0.001	3.520	0.001*
	Normal	60	0.998	0.000		

'*'=significant difference at 0.05 level

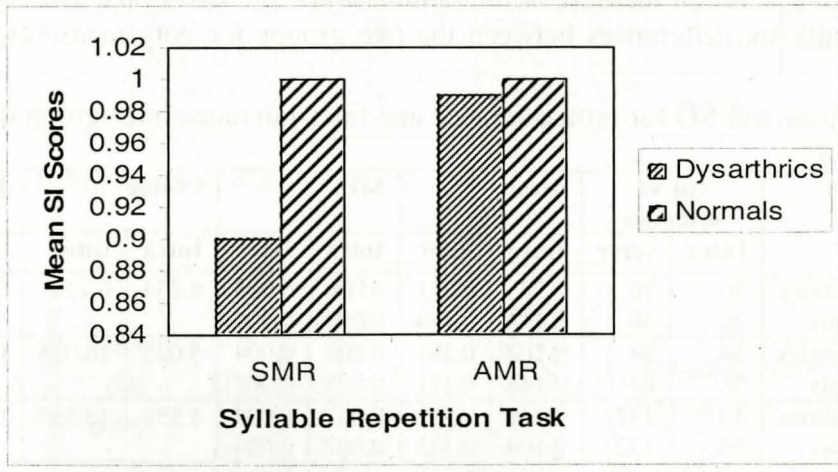
The mean SI scores for the groups were subjected to analysis using 'Kruskal Wallis H test' to examine if there is a difference in the values for the different consonants and vowels both within and across trials, for both subject groups. The results indicated that there was no statistical difference in the SI scores for both consonants and vowels.

The total mean syllable durations of dysarthrics and normals in the SMR and AMR subtasks are shown in Graph1. The mean depicted in Graph 1 is the combination of the means for all the syllable durations considered as one trial since there was no statistical difference seen in the duration measures across consonants and vowels and within the dysarthric and normal subjects.



Graph 1: The mean syllable durations (msec) of two groups for SMR and AMR subtasks

The mean of SI scores for the SMR and AMR subtasks for the two groups of subjects is shown in Graph 2.



Graph 2: Mean of SI scores of dysarthric and normal groups for SMR and AMR subtasks

b) Sentence Repetition Task:

The syllable durations (in milliseconds) for each syllable within the three sentences within each of the trials were calculated and compared. The comparisons were made to look for intra-utterance, inter-utterance variations and SI scores. The mean syllable durations for all the syllables within the subjects for the sentences is as shown in Table 8.

Table 8: The mean syllable durations (msec) across the three sentences for the two trials in both the groups

Subjects (n)	Sentence 1 (3 syllables)		Sentence 2 (7 syllables)		Sentence 3 (11 syllables)	
	T1	T2	T1	T2	T1	T2
D1	0.256	0.133	0.213	0.114	0.256	0.141
N1	0.161	0.145	0.120	0.118	0.214	0.112
D2	0.188	0.187	0.231	0.145	0.236	0.132
N2	0.185	0.188	0.245	0.136	0.223	0.131
D3	0.285	0.155	0.211	0.118	0.226	0.100
N3	0.137	0.149	0.212	0.113	0.123	0.115
D4	0.181	0.187	0.226	0.129	0.224	0.138
N4	0.185	0.121	0.220	0.122	0.227	0.134
D5	0.289	0.282	0.112	0.143	0.285	0.115
N5	0.182	0.189	0.224	0.158	0.279	0.121
D6	0.265	0.147	0.228	0.200	0.224	0.136
N6	0.151	0.128	0.224	0.112	0.239	0.122

T1=Trial1; T2=Trial2; D=Dysarthric subject; N=Normal subject; n=number of subjects, (DI=Spastic,D2=Flaccid,D3=Ataxic,D4=Hyperkinetic,D5=Hypokinetic,D6=Mixed)

As can be seen from Table 8, the mean syllable durations were similar within the subjects of each group for the two trials, except for few instances, but some differences were observed for the means between the two groups of subjects.

The mean scores were subjected to statistical analysis using 'Kruskal Wallis H test' to determine if there is a difference between groups and within and across the two trials. The results indicated no statistically significant difference among the subjects ($p > 0.05$). Since there was no statistical difference in the syllable durations within the subjects, all the syllables durations were considered as a single reading and the raw scores were subjected to

statistical analysis using, 'Independent Samples t test' to observe for differences between the groups for syllable duration measure within and between the two trials. The result indicated statistically significant differences between the two groups for both measures, as shown in Table 9.

Table 9: The mean and SD for intra-utterance and inter-utterance inter-group differences for sentences (msec)

Sentence	Group	No. of syllables		Mean		SD		t value		P value	
		Intra	Inter	Intra	Inter	Intra	Inter	Intra	Inter	Intra	Inter
S1	Dysarthrics	36	36	0.225	0.211	0.006	0.003	6.234	6.234	0.000*	0.000*
	Normals	36	36	0.111	0.114	0.006	0.006				
S2	Dysarthrics	36	84	0.202	0.251	0.005	0.004	5.025	10.025	0.000*	0.000*
	Normals	36	84	0.148	0.111	0.005	0.005				
S3	Dysarthrics	36	132	0.211	0.222	0.007	0.004	5.559	13.559	0.000*	0.000*
	Normals	36	132	0.109	0.145	0.007	0.004				

'*'=significant difference at 0.05 level

Since the differences between subjects within the groups were not significant, the data was subjected to analysis considering all the dysarthric and normal subjects as single groups, by combining the syllable durations for all the subjects. This was done in order to examine if there was a significant difference in the durations of the syllables within the sentences, using 'Friedman Test'. The results indicated statistically no significant differences across the syllable durations for both dysarthrics and normals, both within and between the two trials ($p > 0.05$).

The data however revealed that for intra-utterance measure, there were some differences observed in the means of the syllable duration for both the groups. For example, in the dysarthric group, in the second sentence of the first trial, few syllables differed in durations. A detailed analysis using 'Wilcoxon Signed Ranks Test' revealed that this irregularity was observed due to variations in durations of the second syllable, but this was not statistically significant reading and was attributed to random chance factors. Similarly for the control group, in the second trial of the second sentence and the first trial of the third sentence there were differences observed in the means but this was not considered statistically significant and was attributed to random chance factors ($p = 0.05$). Similar observations were made for the inter-utterance measure also. There were instances of differences in the means of syllable durations between the trials of few syllables in the second and the third sentences. Since these were only few in number, this was not considered as significant and it was attributed to random chance factors ($p = 0.05$).

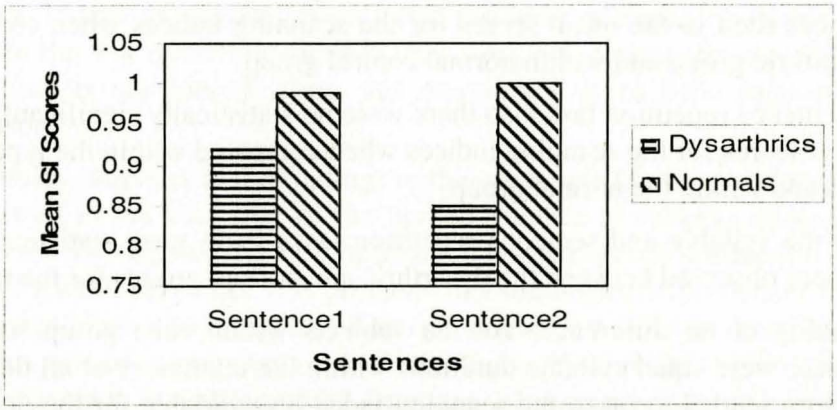
c) Scanning Index measure

The SI scores for the first two sentences (three and seven syllabic) were computed and the results were compared within and across the trials. The third sentence was not considered in the computation of SI, since the formula could not be applied for the calculation as the values approximated to zero when the SI formula was applied. The SI scores were subjected to statistical analysis using 'Kruskal Wallis H Test' to observe if there was a significant difference in the performance of each subject both within and across both trials of utterances. Results indicated that the differences were not statistically significant between the groups ($p > 0.05$). The SI values were analyzed statistically to observe for differences between the groups using 'Mann-Whitney Test'. The results are shown in Table 10, which indicated statistically significant differences between the two groups ($p < 0.05$)

Table 10: The mean and SD for inter-group difference in SI for sentence

Sentence No:	Groups	No. of syllables	Mean	SD	Z score	P value
1.	Dysarthric Normal	36 36	0.854 0.998	0.212 0.213	0.150	0.041*
2.	Dysarthric Normal	36 36	0.889 0.999	0.121 0.200	4.422	0.000*

'*'=significant difference at 0.05 level



Graph 3: Mean of SI scores of dysarthric and normal groups for sentence task

The performance of the two groups was not compared for the trials of the three sentences, because there were minimal differences in the mean syllable durations of the syllables in the sentences across the trials. These were considered statistically insignificant and attributed to random chance factors. But these were assumed to contaminate the comparison of means of the syllables for the three sentences taken together. The mean SI scores for the two groups is shown in Graph 3:

The results of the study are summarized under the following sections:

Intra-utterance and inter-utterance variability measures:

1. In the syllable repetition task (SMR and AMR), when the mean syllable durations were compared for the intra-utterance and inter-utterance variability, no significant differences were observed within the dysarthric and normal subjects, across the different consonant and vowel environments
2. In the sentence repetition task also there were no significant differences in the intra-utterance and inter-utterance measures of mean syllable durations within the dysarthric and normal subject groups.
3. In both the syllable repetition task and the sentence repetition task, there were statistically significant differences observed between the dysarthric and normal subjects.

This observation implies that there was 'syllable equalization' (syllable isochrony) rather than 'syllable variation' in terms of syllable durations when the results of dysarthric and normal subjects were compared as a whole. The tendency for syllable equalizations in the performance of all the dysarthric subjects supports the findings of the study by Ziegler, Hartman and Hoole (1993), who observed that dysarthric subjects showed a tendency towards syllable isochrony and this was not specific to the subgroup of Ataxic dysarthria, but was found to be a universal characteristic of all dysarthric types with different etiologies. The lack of difference in the performance for inter & and intra utterance duration within the

dysarthric subject group could be due to similar dysprosodic errors exhibited by the different types of dysarthrias. Though perceptual impression revealed excess and equal stress and slow rate of speech in Spastic dysarthria, prolonged phonemes, prolonged intervals are present in Hyperkinetic dysarthria etc. Thus, syllable isochrony cannot be unique to Ataxic dysarthria only.

Scanning Index measure:

1. In the syllable repetition task (SMR and AMR) there were no statistically significant differences seen in the mean scores for the scanning indices when compared within the dysarthric group and within normal control group.
2. In the sentence repetition task also there were no statistically significant differences in the mean scores for the scanning indices when compared within the type of dysarthric subjects and within the normal group.
3. In both the syllable and sentence repetition tasks there were statistically significant differences observed between the dysarthric and normal groups for the tasks.

The finding of no differences for the subjects within each group for the SI task, suggests that there were equal syllable durations within the utterances of all the subjects of a group. This in turn tended to make the scanning index less variable for the utterances (most of the subjects got a score of '1' both within the dysarthric and the normal groups). In other words, the differences seen in the syllable duration variability measures between the two groups were also reflected on the SI scores. Thus, it can be understood that the syllable durational variability measures mirror the scanning index measure.

There are few other studies which report that SI scores are similar for the groups of dysarthrics and normals (Ackermann & Hertrich, 1994). There is no supporting literature for the observation of similar SI values across the varieties of dysarthrics as seen in this study. Syllable repetition is a task in which temporal regularity is typically expected. This supports the findings of unit SI values for the AMR and SMR task.

The perceptual attributes of 'staccato speech' seen in Ataxic dysarthria has triggered the undertaking of a series of studies on 'syllable equalization' or 'syllable isochrony'. The phenomenon of syllable isochrony has been attributed to errors in the time control mechanism of the cerebellum. It is often assumed that syllable isochrony is seen in the speech of Ataxic Dysarthria since this disorder arises due to defects in the functioning of the cerebellum. However, this does not seem to be an exclusive feature of Ataxic dysarthria alone, as evidenced from the results of this study.

Further, the findings of syllable isochrony cannot be established as a phenomenon of temporal dysregulation in the dysarthrics, since the normal subjects have also performed similarly. The reasons for such a behavior can only be speculated. In the case of dysarthrics, the tendency towards syllable equalization could be a reflection of an inability to shorten syllables when appropriate, due to articulatory constraints. This would mean that syllable equalization is not primarily a dysprosodic characteristic but a feature secondary to the articulatory deficiencies (Ackermann and Hertrich, 1994). This would hold good for all varieties of dysarthria since articulatory disturbances are seen as a common characteristic in all dysarthrias. But the same cannot be said for the control normal subjects who have normal articulatory executions, unless one can speculate on the possible influence of the experimental condition which could have affected the performance of the normal subjects, which is however remote. Speech production is considered a dynamic process and variations in the duration of speech segments is expected in natural speech. But this phenomenon is not

being reflected in the performance of the normal subjects, in the SI scores, which amounts to unity, for almost all the subjects. Further, there are assumptions that the cerebellar cortex is an internal clock of a human being and is a pre-requisite for maintenance of the timing of movement sequences. Thus, a dysfunction of this assumed internal clock could give rise to variable inter and intra-utterance syllabic timing. This suggests that as a default, the cerebellum is responsible for utterances which are regularly timed sequences in a normal individual. That is, segment durations could be generally isochronous but a disruption in the same could result in variability. This can explain the finding of syllable equalizations in the case of normals. In case of dysarthrics only few instances of variable syllable durations were observed within the few dysarthric subjects that were not statistically significant, if this role of the cerebellum is considered. Thus, this assumption gains little support for the above mentioned reasons.

In summary, answers to the findings in this study need further exploration. The results have to be viewed in the backdrop of the limited number of subjects chosen for the study. These findings are also against the assumption that normal speech production is characterized by variations of speech segments. It is probable that the linguistic properties of the rhythm of Kannada language plays a role and that Kannada could be a syllable timed language, that is, all the syllables are of equal durations. But a study by Savithri (1995) in Kannada has suggested that Kannada is a stress-timed language. This contradictory finding only warrants the need for further studies in this direction.

Though the aim of the study included a comparison of variability measures and SI values across tasks of varying linguistic complexities, the results of the two tasks, the syllable repetition task and sentence repetition task could not be statistically compared and inferred due to differences in the data size of the tasks. On general observation it was seen that there were no differences in the SI values for the subjects within each task. Thus it may be hypothesized that there would be no differences across the two tasks. But more evidences are required to test this with the target stimuli selected for the experiment being controlled for equal number of syllables across the tasks.

Another observation that needs to be highlighted is the absence of differences seen in the duration measure for the different vowel and consonant environments in the syllable duration task. Such a result is highly unexpected again since the segment durations are bound to vary due to the inherent acoustic properties of the speech sounds due to coarticulatory effects, when speech sounds are uttered in combination (Lindblom, 1990).

Again, the task of sentence repetition with three sentences increasing in the number of syllables from three to eleven should have shown a different picture. That is, there should have been more variations in the scores for SI across the sentences as the length of the sentences increased. But this was not so. Another observation to be highlighted here is that there was limitation for calculation of SI values. Calculation of SI was more feasible for the first and second sentence (with three and seven syllables, respectively) and not for the third sentence with eleven syllables. The reason for this was attributed to the lesser values of syllable durations that were obtained in the raw scores for the sentence with eleven syllables. This finding questions the flexibility of calculation of SI, when larger utterances or lengthier utterances with a number of syllables within them are compared. In other words, calculation of SI is restricted to utterances with few numbers of syllables only and not useful in utterances which are lengthy.

But these questions would only be answered with further research carried out wherein SI is measured for longer sentences, conversation and spontaneous speech samples, where

there is scope for occurrence of increasing number of syllables. This also warrants the need for extensive research on the timing regulation functions of the cerebellum and its contributions for dysarthrics with different etiologies not restricted to the cerebellum. This is because even in the varieties of dysarthria like Spastic, Hyper-kinetic Spastic-ataxic (mixed) with non-cerebellar lesions, the dysprosodic features are perceptually and acoustically similar to that of Ataxic dysarthria. In these types the causes for temporal dysregulation have to be determined. The results of this study which was carried out on limited number of subjects, puts to question the existence of temporal dysregulation in dysarthria, due to the observations of lesser variations in the syllable durations and SI scores, within the dysarthric subjects.

Conclusions

The results of this study indicate that the phenomenon of syllable isochrony is not an exclusive feature of Ataxic variety of dysarthria since all the subjects with different types of dysarthrias (including Ataxic dysarthria) performed in a similar manner. The assumption that SI is a sensitive measure for assessing the feature of dysprosody seen in dysarthrias is also questioned, since the normal subjects also showed tendencies of syllable equalizations. Hence, it is postulated that cerebellar structures alone may not contribute to the timing control of speech. But these are assumed in the light of the limited number of subjects considered in this study.

This study also questions the computation of scanning index as a measure of temporal dysregulation. This is because of the observation that although variations were seen in the means of the syllable durations in few of the trials for the syllable repetition task (especially in dysarthric group), this was not reflected in the SI score. The SI scores of most of the subjects was '1' for both the groups. Another point highlighted was that SI was more appropriate to the DDK task and sentences with limited number of syllables. This again questions the sensitivity of this index in reflecting the temporal characteristics of speech. Also, there were no differences seen in these measures within the individual subjects of both the groups for the tasks varying in linguistic complexity, which is another finding of interest since variation across tasks are assumed to be seen in any speech measure.

These conclusions are however drawn with caution since the experiment was done with the limitations of:

a) number of dysarthric subjects

b) limited tasks of varying linguistic complexity (syllable and sentence repetitions)

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