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Perceptual Speech Characteristics of Cerebellar Dysarthria Associated with Lesions in Different Cerebellar Loci

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Abstract

The perceptual method of classifying dysarthria is considered the "gold standard" for clinically differentiating the types of dysarthria. Darley et al., [1] pioneered the use of perceptual classification system to identify clusters of salient perceptual characteristics in speech that are associated with lesions in the central and peripheral nervous system. This system is also popularly referred to as the "Mayo Clinic Dysarthria Research" [1]. Many researchers who investigate the acoustic and physiologic bases of dysarthrias also use the perceptual classification system. The present study attempts to analyse the perceptual speech characteristics in dysarthria associated with lesions in different cerebellar loci.

Key words: Cerebellum, dysarthria, perceptual analysis

Introduction

Normal speech production requires good coordination between the various structures and its response to various intrinsic and extrinsic influences. It is produced by the smooth coordination of five components of speech mechanism including respiration, phonation, resonance, articulation and prosody. When one or any combination of the five components is affected by a neuromotor disturbance, it leads to motor speech disorders such as dysarthria and apraxia. Ataxic dysarthria is caused due damage to the cerebellum or associated structures.Three deviant clusters of abnormal speech characteristics were reported by Darley et al., [1] in ataxic dysarthria. They include (a) articulatory inaccuracy (b) prosodic excess (c) phonatory - prosodic insufficiency.

There are very few studies, which have aimed to determine the characteristics of ataxic dysarthria, based on the different lesion sites in the cerebellum [2, 3]. There is need for a study that includes perceptual measures to evaluate the performance of subjects with lesions restricted to different cerebellar loci, in order to see if there is region specific speech motor control in ataxic dysarthria. There is a need for a detailed study probing into the differential speech subsystem involvement including perceptual tasks to identify speech motor control by specific region in the cerebellum. The study is planned to fulfill this objective. Malayalam language was chosen for the study as the investigator was a native speaker of Malayalam and also because of the accessibility and availability of subjects with lesions in different cerebellar loci from different hospitals in Kerala state of India where Malayalam is spoken by majority of people.

Aim of the Study

To analyse and differentiate some aspects of voice and speech in selected speech tasks in subjects with ataxic dysarthria due to lesions in various sites of the cerebellum using perceptual analysis

Method

The experimental group included seventeen subjects with ataxic dysarthria. This group included subjects with lesions in left superior paravermal (LSP), left anteroinferior (LAI), superior vermis (SV), right superior paravermal (RSP), right posterosuperior (RPS) and right anterosuperior (RAS) regions of the cerebellum. The control group included thirty number of subjects matched for age and sex of the experimental subjects.

Material and Recording

A 524 syllable passage incorporating all the most frequently occurring phonemes, consonant clusters, inflectional morphemes, words, word boundaries fused by morphophonemic alternations and words with different suffixes in Malayalam as given in Ghatage[4] was developed by the investigator in consultation with a qualified linguist. Face validity of the passage was checked by three experienced Speech - Language pathologists. They were asked to rate the passage based on a binary scale (0 = agree that the passage is suitable to test, 1= not agree that the passage is suitable to test).

The voice and speech samples of the subjects were audio recorded using a digital tape recorder Sony MZ-55. The subjects were tested in individual setup. Perceptual analysis was carried out for 38 dimensions of speech based on the method proposed by Darley et al.,[1]. The speech samples were rated on a seven point rating scale by three judges. Inter and intra judge reliability was computed.

Perceptual Analysis

One minute sample was identified from the corpus of narrative speech from the sample of the subjects. The selected speech samples were randomized using a random table and transferred to a different tape. A total number of 47 samples were recorded. A 50 s silent interval was inserted between each of the samples. Three native female speakers of Malayalam (investigator and 2 Post graduate students in Speech – language pathology) served as the judges for perceptual analysis of speech. All three judges had prior experience / exposure in perceptual rating of dysarthric speech. A seven point severity rating scale was adopted for perceptual judgment. The scale was as follows: 1 = normal speech, 2 = mild, 3 = mild to moderate, 4 = moderate, 5 = moderate to severe, 6 = severe, 7 = very severe. Percent agreement was calculated for the perceptual analysis of word repetition task by the three judges. Item by item reliability was calculated for the perceptual evaluation of the narration sample for all the thirty eight dimensions given by Darley et al.[1]. Reliability coefficient alpha (∝) was obtained separately for the ratings between three judges. A contingency table for the reliability ratings between the three judges was prepared for all the thirty eight dimensions and a cut-off point was operationally defined.

Results and Discussion

The most deviant speech dimensions were rated as vocal quality, phonatory-prosodic dimensions, articulation and prosody. The deviant speech dimensions (a) for vocal quality included voice tremor, harsh voice and breathy voice, (b) for phonatory - prosodic dimensions included pitch level and monopitch, monoloudness and overall loudness, (c) for articulation included distorted vowels, prolonged phonemes, imprecise consonants and (d) for prosody included excess and equal stress, general rate, prolonged intervals and short phrases.

The results obtained for lesions restricted to different cerebellar areas, indicate that deficits are noticeable in speech dimensions related to vocal quality (laryngeal), articulation and prosody. Deviant dimensions related to respiratory feature are not seen as a characteristic feature of dysarthria associated with focal cerebellar lesions. This finding is in contrast to reports of reduced respiratory support for speech, forced inspiratory and expiratory sighs and audible inspiration in subjects with nonfocal cerebellar lesions[5]. Velopharyngeal involvement is not a common feature in ataxic dysarthria associated with nonfocal lesions[6]. The results indicate that vocal dimensions related to velopharyngeal aspects is not a characteristic feature of subjects with lesions in the left (left superior paravermal, left anteroinferior), superior vermis and right (right superior paravermal, right posterosuperior and right anterosuperior) cerebellar lesions, also. Duffy[6] reflected that characteristics of ataxic dysarthria due to nonfocal lesions are more apparent in articulation and prosody. The findings in this study for subjects with lesions in left (left superior paravermal, left anteroinferior), superior vermis and right (right superior paravermal, right posterosuperior and right anterosuperior) cerebellar lesions indicate that in addition to articulatory and prosodic dimensions, phonatory aspects are also deviant.

Table 1: Experimental groups in which the following perceptual dimensions of speech are absent.

Vocal quality			
	Right	Superior vermis	Left
Harsh voice	RPS	-	LAI
Breathy voice (continuous)	RSP, RPS,RAS	-	LAI
Voice tremor	RSP, RPS,RAS	-	LSP, LAI
Articulation			
Distorted vowels	RPS, RAS	-	LAI
Prolonged phonemes	RPS, RAS	-	LAI
Prosody			
Excess and equal stress	RSP, RPS,RAS	-	LAI
Rate	RPS	-	-
Prolonged intervals	RPS, RAS	-	LAI
Short phrases	RPS	-	LAI

Monoloudness	RPS, RAS	-	LAI
Overall loudness	RSP, RPS, RAS	-	LAI
Pitch level	RSP, RPS, RAS	-	LSP, LAI
Monopitch	RPS	-	LAI

It can be seen from Table 1 that most of the deviant perceptual dimensions are absent in subjects with right cerebellar (especially right posterosuperior lesion) and left cerebellar (especially left anteroinferior lesion) lesion. Majority of the perceptual dimensions are deviant in subjects with superior vermis lesions. The role of superior cerebellar vermis in speech motor control has been supported by several studies[7]. The role of superior vermis in speech motor control is also contradicted by several studies[8,9], who emphasized instead the role of the cerebellar hemispheres in speech motor control.

Differential localization is evident for the dimensions related to vocal quality. It is seen that harsh voice is seen in subjects with right superior paravermal, superior vermis and left superior paravermal lesions. Breathy voice is seen in subjects with superior vermis and left superior paravermal lesions. The finding of increased Jitter percentage, Shimmer percentage, NHR and SPI for the task of sustained phonation agrees with the findings of harshness and breathy voice in these groups. Voice tremor is seen only in subjects with superior vermis lesions also. Voice tremor associated with increased variation in fundamental frequency is reported in ataxic dysarthric subjects with diffuse lesions[10].

Neural correlates underlying dimensions related to articulation also revealed some differential localization in the cerebellum. Distorted vowels and prolonged phonemes are characteristic features of subjects with right superior paravermal, superior vermis and left superior paravermal regions of the cerebellum. In the task of diadochokinesis, prolonged total duration of syllable is seen only in subjects with lesion in right superior paravermal and right anterosuperior lesions in the AMR task. In SMR task, total duration of syllable is prolonged in all the experimental groups. Duration of short and long vowels is increased in all the experimental subjects. Thus task specific findings emerge with respect to dimension of prolonged phonemes in a narration sample versus that in DDK task and also based on duration of short and long vowels. Thus different patterns seem to emerge based on the speech task involved.

Prosodic dimensions are not equally affected in all the experimental groups. Excess and equal stress which is often quoted as a characteristic feature in ataxic dysarthria due to nonfocal lesions and is not a predominant feature in subjects with lesions in left (left superior paravermal, left anteroinferior), superior vermis and right (right superior paravermal, right posterosuperior, right anterosuperior) lesions. It is seen only in single subject with superior vermis and left superior paravermal lesion. Rate of speech is slow in subjects with left (left superior paravermal, left anteroinferior), superior vermis and right (right superior paravermal and right anterosuperior) lesions. It is comparable to normal controls in subjects with right posterosuperior lesion. This perceptual finding agrees with the findings of speech rate in narration and reading task.

It is noticeable that subjects with right superior paravermal, superior vermis and left superior paravermal lesions show deviations from normal ratings for most of the parameters. According to Darley et al.[1], there are ten perceptual dimensions that are predominant in subjects with ataxic dysarthria due to nonfocal lesions. These perceptual dimensions are imprecise consonants, excess and equal stress, irregular articulatory breakdown, distorted vowels, harsh voice, prolonged phonemes, prolonged intervals, monopitch, monoloudness and slow rate. Eight out of these ten dimensions are present in subjects with lesions in different cerebellar loci (imprecise consonants and irregular articulatory breakdown absent). The presence of these dimensions varied among different lesion groups with left (left superior paravermal, left anteroinferior), superior vermis and right (right superior paravermal, right posterosuperior and right anterosuperior) cerebellar lesions.

These perceptual findings in ataxic dysarthria due to lesions in different cerebellar areas may have a physiologic basis, as studies on ataxic dysarthria have documented slow movements, errors of direction and range of movements, impaired muscular forces in production of rapid movements, and reduced or exaggerated range of movements in respiratory, phonatory and articulatory systems [6, 11]. These abnormalities may be augmented by the motor symptoms characterizing cerebellar dysfunction, such as hypotonia, broad-based stance and gait, truncal instability; dysmetria, tremor and dysdiadochokinesis [6, 11].

Summary

Perceptual analysis of narrative sample revealed functional localization of neural correlates underlying dimensions related to vocal quality (breathy voice, harsh voice, voice tremor), loudness (monoloudness, overall loudness), articulation (distorted vowels and prolonged phonemes), prosody (stress and rate of speech, prolonged intervals and phrasing). The results have to be substantiated with more number of subjects with cerebellar lesions in specific areas distributed across the cerebellum and subjects with cerebellar tumours of different sizes.

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