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DISTURBANCE OF THE RHYTHMIC STRUCTURE OF SPEECH IN THE DYSARTHRIAS

Hajime Hirose and Masayuki Sawashima

Abstract Disturbance of rhythm in the speech flow process is one of the important factors in prosodic abnormalities. The rhythmic structure of Japanese is considered to depend, to a considerable extent, on regularity in syllable (mora) length, which is often affected in dysarthric cases of cerebellar dysfunction or Parkinsonism. In the present study, the dynamic patterns of the articulatory movements in the repetition of Japanese monosyllables were observed in dysarthric cases by means of pellet tracking technique using an x-ray microbeam system. It was found that in the case of ataxic dysarthria of cerebellar origin, the breakdown of speech rhythm is related to inconsistency in the velocity, range, and rate of repetitive articulatory movements. In parkinsonian dysarthria, so-called hastening phenomena were observed in terms of a gradual decrease in the velocity, range, and interval of repetitive movements. An analysis of the dynamic aspects of the dysarthrias will be a promising approach for elucidating the nature of central problems in the production of speech.

1. Introduction

Disturbance of rhythm or "abnormality in the pattern of a temporal sequence" in speech flow process is one of the important factors of prosodic abnormalities. Japanese is generally regarded as a "syllable timed" language, and rhythmic structure of Japanese is considered to be depending, to a considerable extent, on the regularity in syllable (mora) length, which is often affected in dysarthric cases of cerebellar dysfunction (ataxia) or Parkinsonism. In the present report, preliminary findings on the abnormal patterns of these types of dysarthria are presented based on the results obtained by means of pellet tracking technique using an x-ray microbeam system. Supplemental electromyographic (EMG) studies were made to investigate the coordinative patterns of articulatory muscles in the pathologic cases.

2. Procedures

2-1 Pellet tracking using an x-ray microbeam system

The strategy for the automatic tracking of the pellet on the moving articulators, such as the tongue, was essentially the same as reported previously (Hirose, Kiritani, Ushijima and Sawashima, 1978). The data output was read into the core of a PDP-9 computer through an x-ray detector and an A/D converter. For the purpose of off-line observations, a specially designed program was used in most cases to display the coordinate values for each pellet as functions of time (Kiritani, Itoh and Fujimura, 1975).

2-2 EMG analysis

For EMG analysis, the same system as reported in our previous paper (Hirose et al., ibid.) using hooked-wire electrodes was employed. The anterior digastric and the mentalis were selected as a representative pair for analysis.

2-2 Subjects and test words

The present study was made on the neurological cases, the final diagnosis of which was made at the Department of Neurology, Tokyo University Hospital prior to both x-ray and EMG studies.

In both recordings, the subjects were required to repeat Japanese monosyllables such as /pa/, /ta/, /ka/ and /teN/ separately at their fastest rate of speech.

3. Results

Figure 1 illustrates the patterns of movements of the lower lip in the normal subject and in the pathological cases for repetitions of the monosyllable /pa/. In the normal subject, both closing and opening movements of the lower lip are very regular in terms of the range and velocity of the movement. It is apparent in the ataxic subject that the range and velocity of the movement are markedly inconsistent and the alteration of the direction of movement is imprompt when compared to the normal subject. In Parkinsonian subjects, the range of movement is rather limited and the frequency of a repetitive production of the monosyllable tends to increase gradually (hastening phenomenon).

Figure 2 compares the velocity of lip displacement in the procustion of the sequence of /pa/ among the three subjects. The velocity was obtained by differentiating the displacement through use of a pertinent computer program. In the normal subject, the values are quite consistent and high in both direction of opening and closing. They are approximately 165 mm/sec (140-207 mm/sec in range) in lip opening and 222 mm/sec (188-254 mm/sec) in lip closing. The values are extremely inconsistnnt in the ataxic case and there is an occasional standstill where the velocity of the lip is zero and the apparent lip displacement must entirely depend on jaw movement. It should be noted however, that the maximum velocity of lip displacement is about 141 mm/sc, and the value is not much less than the normal value. In the Parkinsonian case, the velocity gradually decreases and becomes zero at the moment of the intermittent cessation of lip movement.

The patterns of lip and velum displacement of the Parkinsonian subject in the repetitive productions of the syllable /paN/ are illustrated in Fig. 3, in which two separate attempts made at a slow rate (3.4 Hz on the average) and a fast rate (6.9 Hz on the average) are compared. It can be seen that the velar movements are fairly consistent in both rate and displacement at the slower rate of repetition, while in the faster rate, the velar displacements become quite limited and irregular.

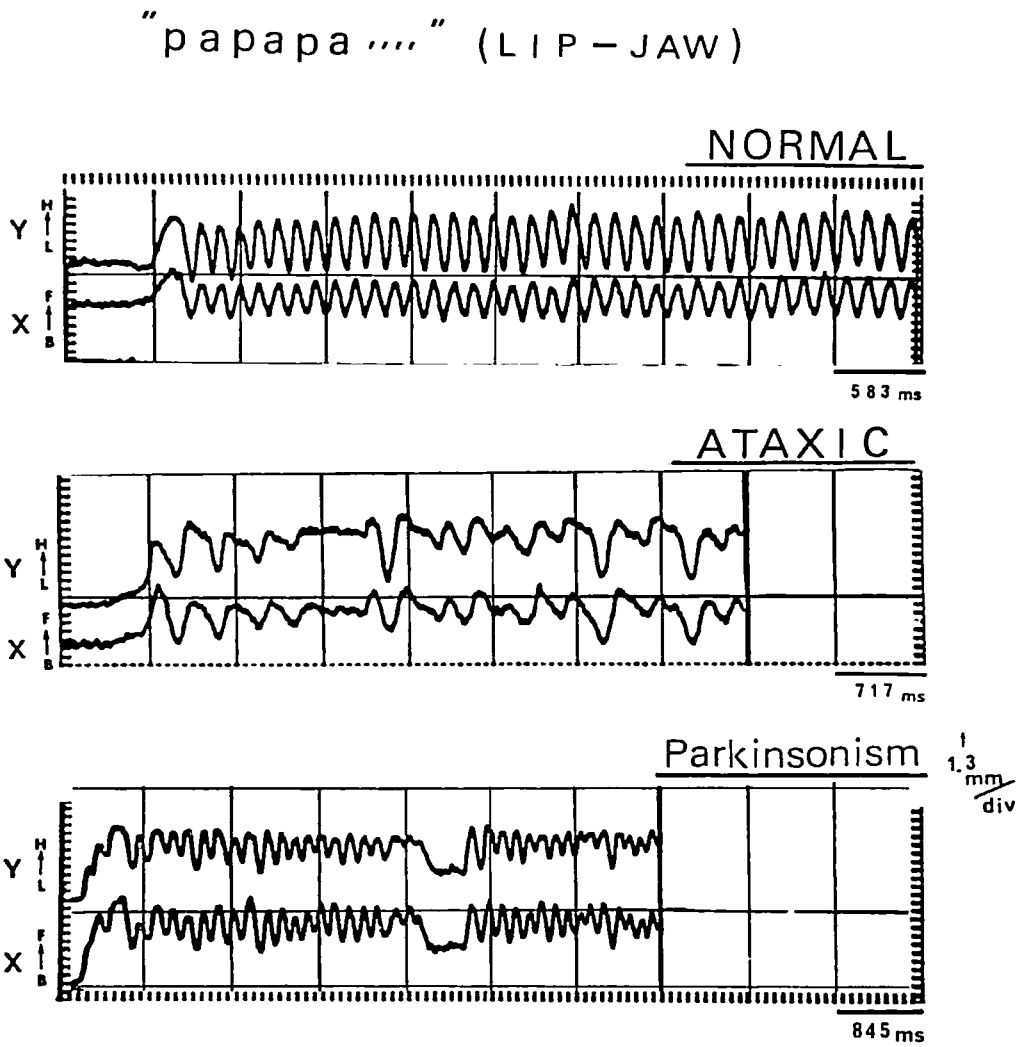

Fig. 1: Patterns of movements of the lower lip in the normal subject (upper), in the ataxic subject (middle) and in the Parkinsonian subject (lower) for repetitions of the monosyllable /pa/ displayed as time function of X (back [B] to front [F]) and Y (low [L] to high [H]) coordinates.
Here, the coordinate values for the jaw are subtracted from those of the lip so as to obtain the values for the lip itself.

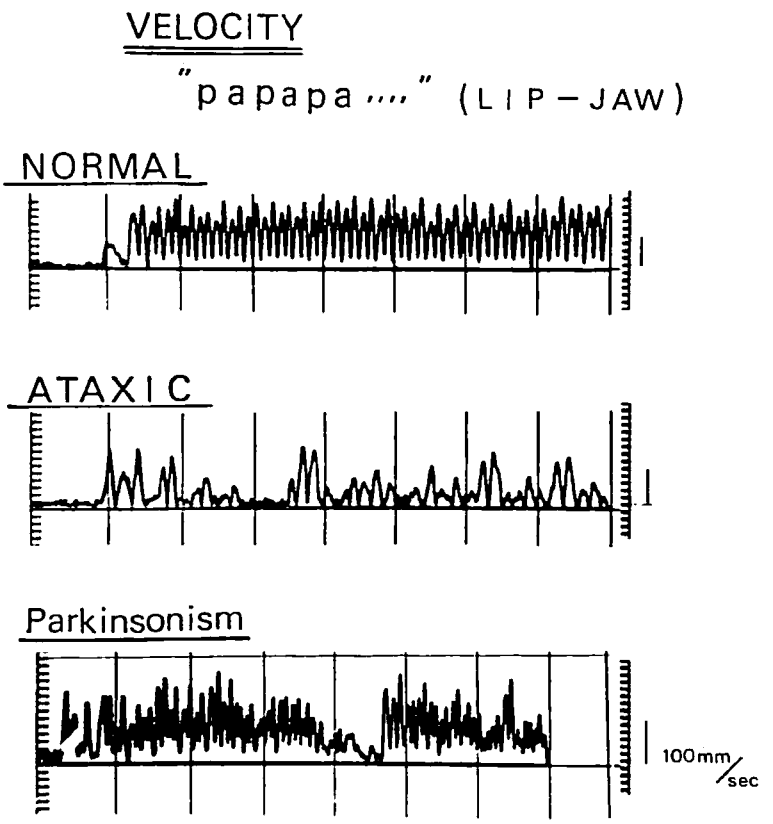

Fig. 2: Comparison of velocity of lip displacement in the normal subject (upper), in ataxic subject (middle) and in the Parkinsonian subject (lower) for repetition of /pa/.

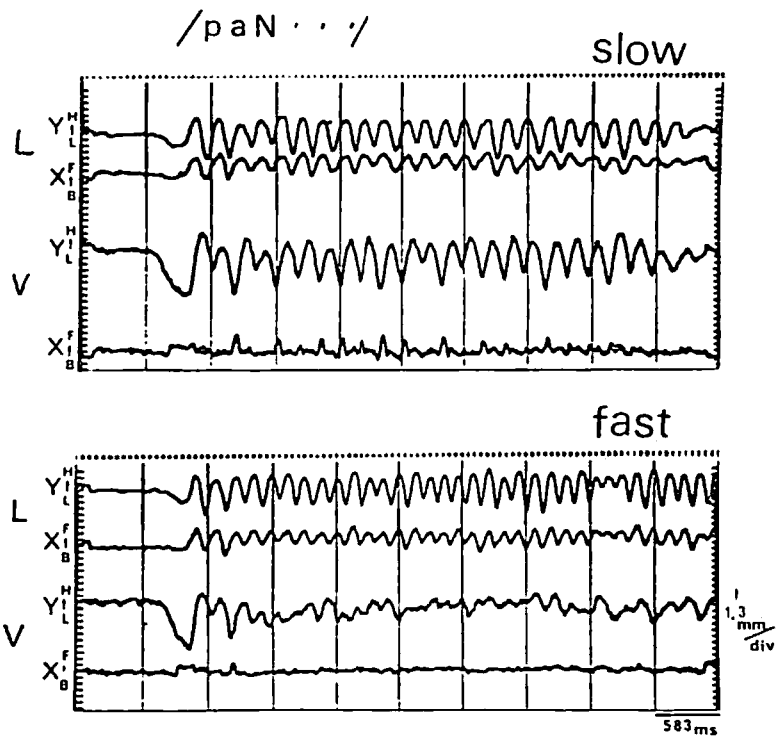

Fig. 3: The patterns of lip and velum movement of the Parkinsonian subject in the repetition of the syllable /paN/ are illustrated, where two separate attempts made at a slow rate (3.4 Hz on the average) and fast rate (6.9 Hz on the average) are compared.

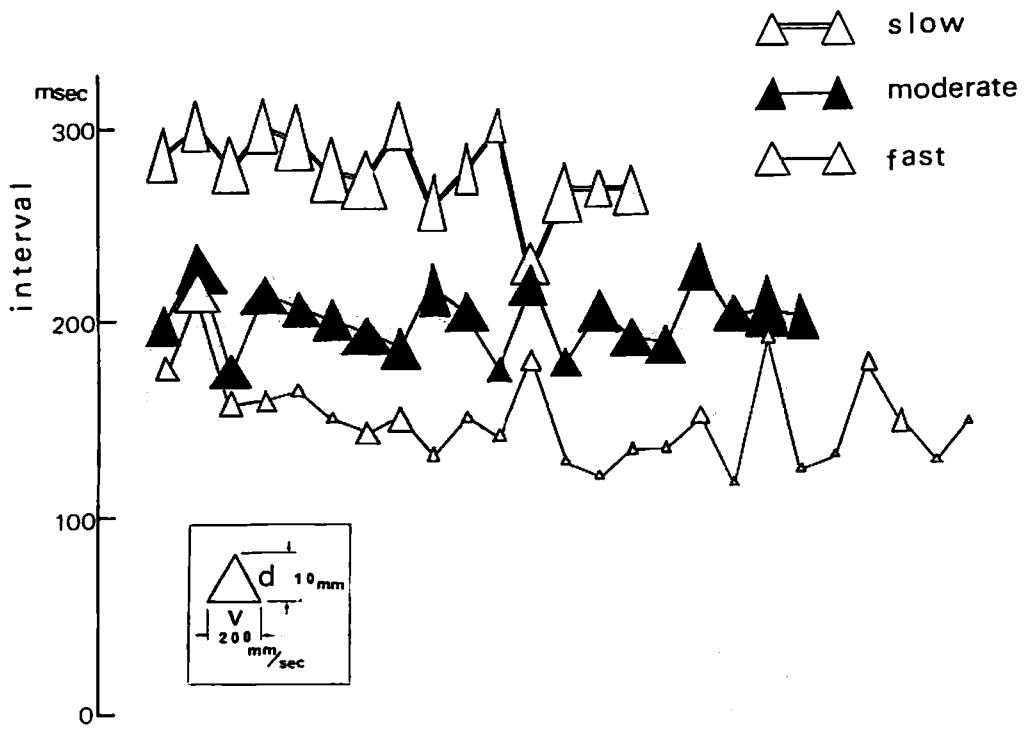

Fig. 4: Interval diagram of the velar elevation in the Parkinsonian subject in each attempt of repeating /paN/ in rhythmical fashion at three different rates of repetition. Each attempt is represented by a triangel where the height indicates the degree of vertical displacement and the base indicates the velocity of velar elevation.

Figure 4 compares the patterns of velar movement for the repetitive production of the syllable /paN/ at three different rates of utterance; fast (6.9 Hz on the average), moderate (5.3 Hz on the average) and slow 3.4 Hz on the average). In this figure, the interval between each utterance is represented by a triangle, the base of which indicates the velocity of velar elevation and the height of which indicates the degree of displacement. It can be seen in this diagram that, at the fastest rate of repetition, the interval becomes inconsistent and fluctuating, and velar displacement and its velocity are both markedly reduced.

Figure 5 illustrates samples of rectified and integrated EMG signals of the anterior digastric and the mentalis for the production of sequences of /pa/ in the normal subject, ataxic subject and Parkinsonian subject. A clean reciprocal pattern between the two muscles is found in the normal subject, while in the ataxic case, the EMG patterns of the two muscles are irregular both in shape and timing. In the Parkinsonian subject, the temporal reciprocity between the two muscles is no longer maintained.

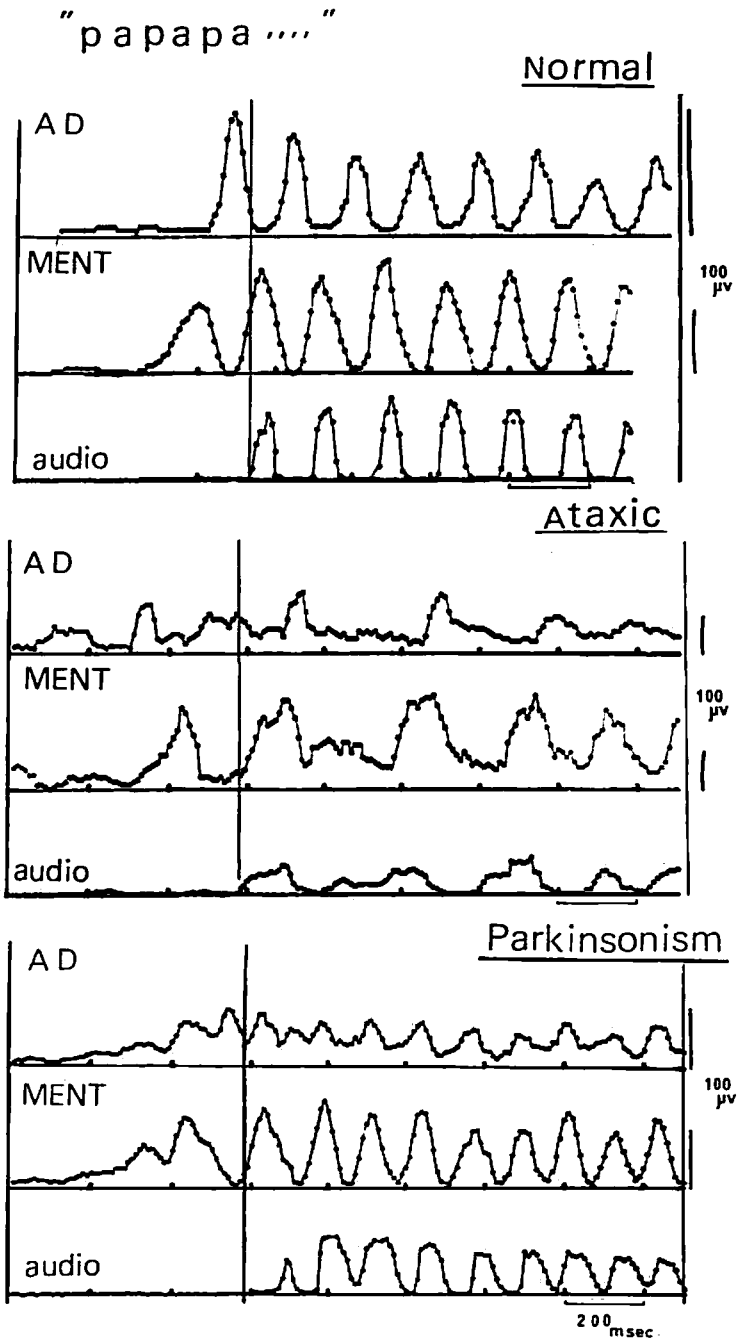

Fig. 5: Rectified and integrated EMG signals of the anterior digastric and the mentalis for the production of sequences of /pa/ in the normal subject, ataxic subject and Parkinsonian subject.

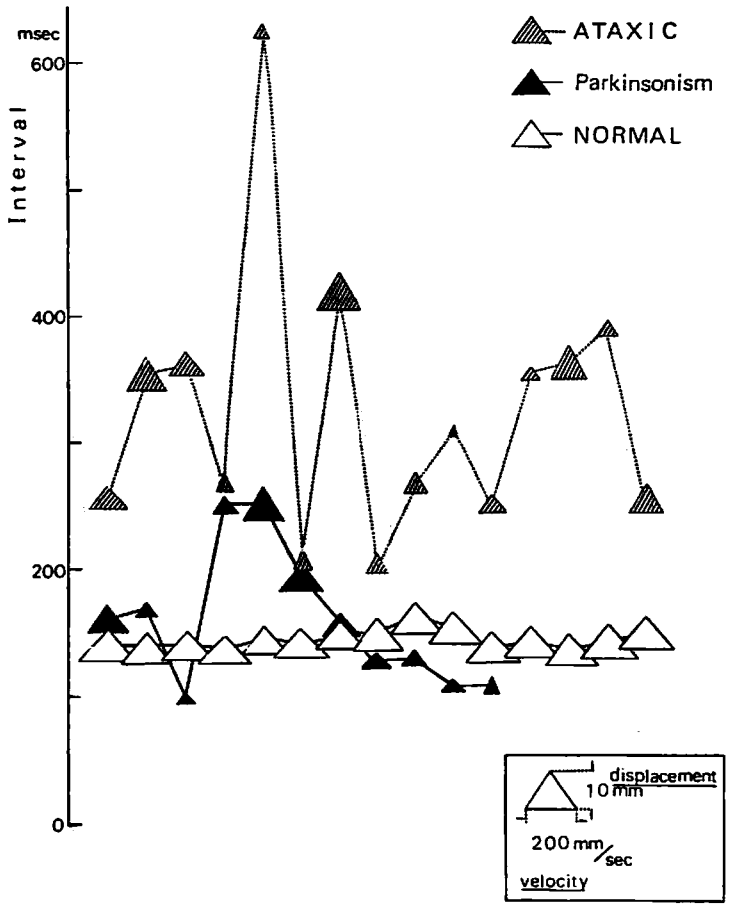

Fig. 6: Interval diagrams of repetitive closing movements of the lower lip for the sequences of /pa/ in the normal subject and dysarthric subjects.

In order to compare the representative pattern of articulatory movements among normal, ataxic and Parkinsonian subjects, interval diagrams are presented in Fig. 6, where the displacement and velocity of each attempt at lower lip elevation in the repetitive production of /pa/ are schematically shown in the form of a triangle as in Figure 4. In the normal subject, the rate, or the repetition interval, is quite consistent and there is almost no perturbation in the degree of displacement or in its velocity. In the Parkinsonian subject, there is a rapid reduction in the interval of repetition, and, as a result, the rate of repetition becomes higher than in the normal. At the same time, the values of displacement and velocity of lip elevation also rapidly decrease. In the ataxic subject, on the other hand, the interval of elevation movement of the lip is quite inconsistent and, in general, larger than normal. An inconsistency can also be noted in the degree of displacement and its velocity as well.

4. Comment

Abnormal patterns of articulatory movement in cerebellar ataxia must be explained as impairments of the programming and updating functions of the cerebellum. The so-called hastening phenomenon in Parkinsonism might be based on an abnormal release of the intrinsic oscillation mechanism in the central nervous system secondary to the dysfunction of the inhibitory system in the basal ganglia. Decrease in the range of movements must be related to the loss of reciprocity between the functionally antagonistic muscles.

It is hoped that neurophysiological approaches to the analysis of the articulatory movements in dysarthric subjects, particularly the analysis of rhythmic structure of speech will provide important information for a better understanding of the central control mechanism of speech production.

Acknowledgement

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