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ON THE NATURE OF BRADYLALIA – A PRELIMINARY STUDY OF THE ACOUSTIC CHARACTERISTICS OF DYSARTHRIC SPEECH –

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Introduction

There have been two separate approaches to the nature of dysarthric speech. One is the acoustic approach in which the characteristics of dysarthric speech sounds are studied, while the other is to analyze the dynamics of the articulatory organs of dysarthric subjects. During the past several years, we have investigated the nature of dysarthric speech mainly based on findings obtained through the latter approach using an X-ray microbeam system.

As for the acoustic approach, most studies in the past were made on a perceptual basis. For example, Darley and his colleagues (1969, a, b) reported the results of their extensive studies of various types of dysarthrias based on a systematic perceptual analysis of the speech sounds of selected cases. They attempted to establish a concept of clusters of deviant speech dimensions being characteristic for different categories of neuromuscular abnormality. Similar studies have been made in Japan, and the results suggest that perceptual study is applicable to the differential diagnosis of different types of dysarthrias (Hirose, 1973; Fujibayashi et al., 1977). Although these studies confirmed that perceptual judgment by well-trained human ears is reliable and clinically useful, it has often been claimed that the acoustic analysis of speech sounds should be used as well. In particular, it is often pointed out that the analysis of the acoustic features of each dimension of perceptual judgment is necessary for a better understanding of the relationship between perceptual terminology and its acoustic characteristics.

The aim of the present study was to investigate the nature of bradylalia based on acoustic and perceptual analyses. Bradylalia is usually referred to as slowness of speech. Slowness of speech, or a slow speaking rate, is one of the important perceptual dimensions of the abnormal speech often noted as a characteristic feature of some types of dysarthrias. such as paralytic or ataxic dysarthrias. In the present study, measurement of the duration of speech segments was made on the speech samples obtained from pertinent pathological cases for evaluating the speaking rate. The results were then compared to those of a perceptual analysis of the same speech samples. Further, perceptual judgment of slowness was tested using synthesized speech.

Procedures

Speech samples were obtained from 10 selected cases of cerebellar degeneration. The patients were requested to read a specially prepared list consisting of 9 Japanese test sentences at their natural rate of speech, and the speech samples were recorded on a tape recorder. The same list was also read by 10 normal subjects and 2 cases

with amyotrophic lateral sclerosis, and their speech was also recorded as control samples.

The recorded samples of the 12 pathological cases were first subjected to a perceptual rating by a group of 8 judges on a series of dimensions which was proposed and has been in use by the authors' group (Fukusako et al., 1982). The rating was made through the use of a four-point (0–3) scale of severity, where "0" represents normal speech and "3" represents a severe deviation from normal. Since special attention was given to the dimension of "speaking rate" in the present study, the results on the other dimensions will not be treated in this report. The mean of the scale values assigned by the 8 judges to each case for the dimension of speaking rate was obtained and the subject was categorized as having a slow rate of speech when the mean was above 1.0.

For each subject, the following 2 sentences out of the 9 were chosen for acoustical analysis using a sound spectrograph, and the duration of the underlined segments (5 syllables a "morae" per sentence) was measured on the sound spectrograms.

1) /kono tatami no heya wa otooto to tomodachi tode tateta mono desu/
   (This room with tatami-mattresses was built by my brother and his friend)
2) /karada ga darukute darukute shikata ga nai/
   (I feel awfully dull)

The consonant and vowel durations of each of the 10 syllables were then measured on the same spectrograms and the mean vowel/consonant ratio was obtained for each subject.

As an additional experiment, an attempt was made to test the perceptual criteria of the judges for slowness of speech using synthesized speech. Recorded samples of the above-mentioned 2 test sentences by one of the normal subjects were used as the original, and the same sentences were synthesized by means of an analysis-by-synthesis method in which the pitch pattern of each original sentence was kept unchanged, while the duration of individual segments was increased linearly by a 20% step from 0 to 100% of the original. Six synthesized sentences with different length, i.e. different speaking rate, were thus obtained from each of the 2 original test sentences. Four examples at the same rate of expansion were prepared and 24 examples were eventually obtained for each sentence. These were recorded in random orders and subjected to the additional perceptual test. Five out of the 8 judges participated in the test and gave their rating on the dimension of speaking rate.

Result

Fig. 1 illustrates the distribution of the segment durations for the 2 test sentences measured in the 12 pathological cases. In this graph, the mean duration and the rejection threshold obtained from the values of the normal subjects are also indicated by an arrow and a vertical dotted line, respectively. A chain line indicates the duration of 140% (40% elongation) of the normal mean. An asterisk (*) attached to the subject number indicates that the mean rating of the 8 judges for the speaking rate was above 1.0 for that subject.

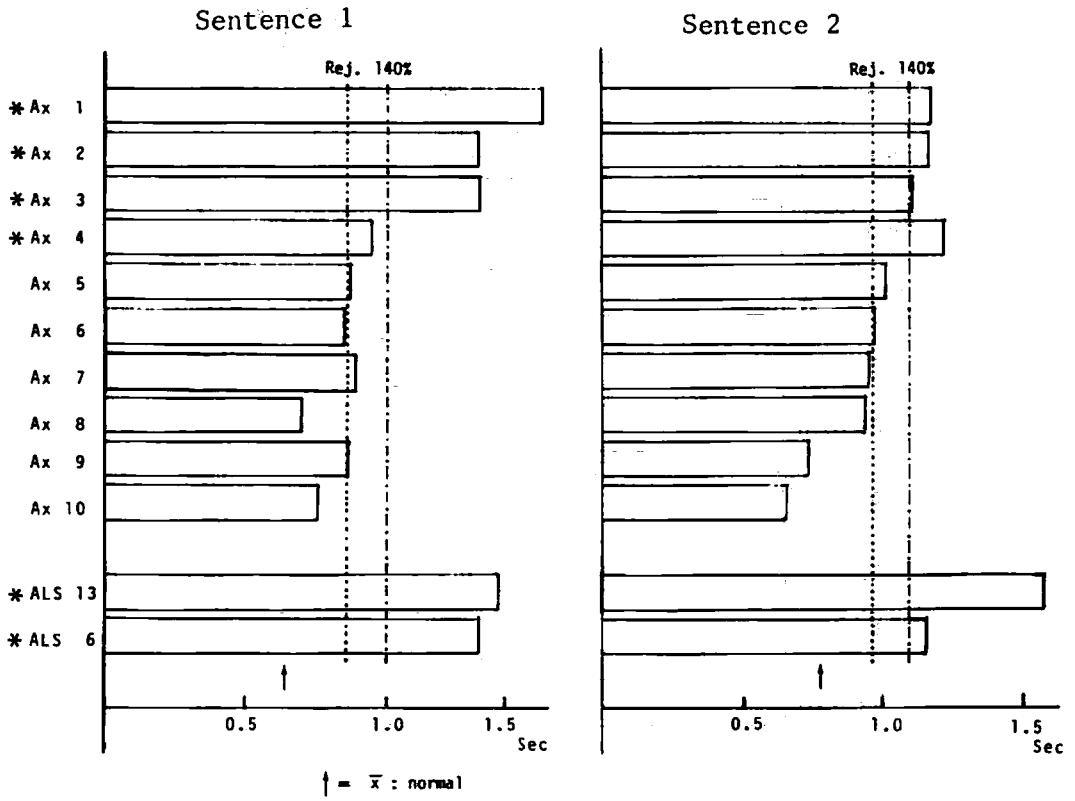

Fig. 1 *Distributions of segment duration in 2 test sentences measured in 12 pathological cases. An asterisk (*) indicates that the subject was perceptually judged to have an abnormally slow speaking rate.*
(Ax: cerebellar ataxia, ALS: amyotrophic lateral sclerosis)

Except for case 10, the segment duration is always longer than the normal mean, and rather close to the rejection threshold in most cases. However, the mean perceptual rating score was above 1.0 in only 6 cases in whom the segment duration appears to exceed 140% of the normal mean. In other words, a subjective judgment of slowness of speech is made only when the segment duration increases by more than 40% of the normal mean.

The results of the ratings of the 5 judges for the synthesized speech samples with different degrees of elongation showed that all of the judges also scored slowness of speech only for those samples with elongation of more than 140% of the original.

Fig. 2 shows the mean vowel/consonant ratio for the 12 pathological cases. There was a tendency for the value to be generally smaller than the normal mean. In particular, the value is significantly smaller ($p < 0.01$) than the normal mean in 5 out of the 6 subjects who were judged to have a slow speaking rate (the mean rating score was above 1.0) in the preceding perceptual test.

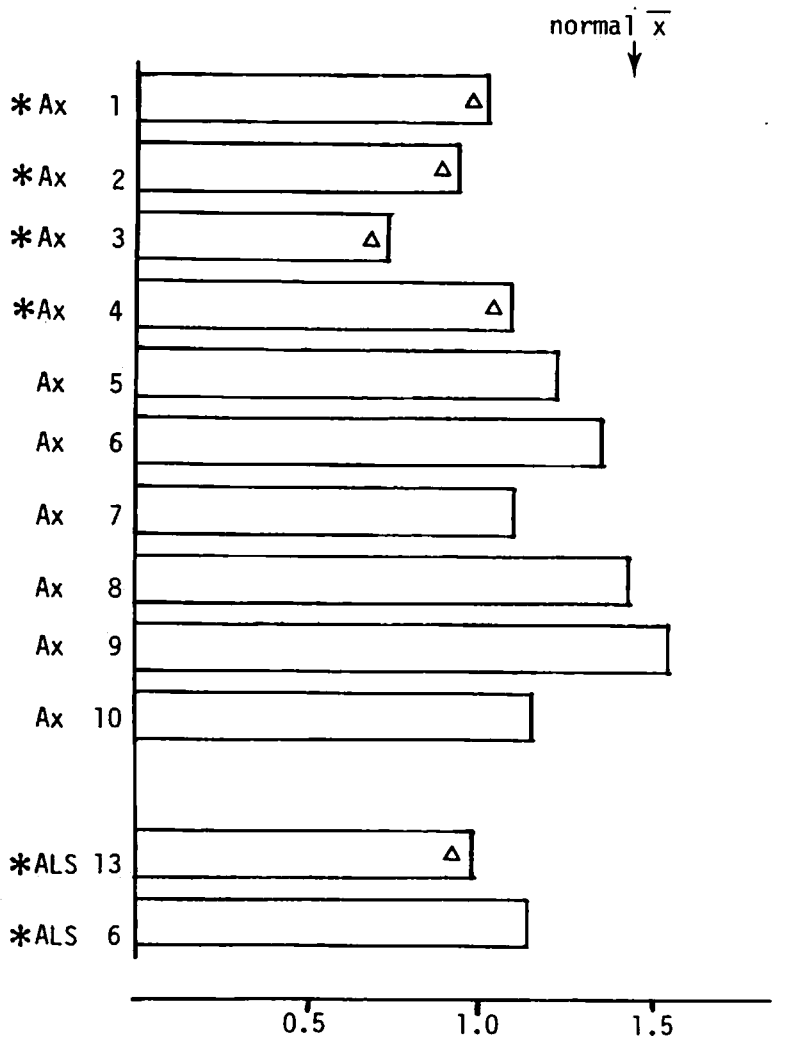

Fig. 2 *The mean vowel/consonant ratio for the 12 pathological cases. An asterisk (*) indicates that the subject was perceptually judged to have an abnormally slow speaking rate, while a triangle indicates that the vowel/consonant ratio of that subject was significantly lower than the normal.*

Comments

Speaking rate is one of the important components of prosody of speech. During continuous utterance, speech may flow quickly or slowly depending on the speed with which syllables are produced. Usually, speaking rate is expressed by the number of syllables produced in a unit of time. In English, for example, it is reported that adults produce an average of five syllables per second (Miller, 1951), while in French, the rate is 5.73 syllables per second (Malécot et al., 1972). The rate can also be expressed by the value of the mean syllable duration. In particular, since Japa-

nese is usually regarded as a syllable-timed language, the mean syllable duration is often used to indicate the speaking rate in Japanese. According to Saito (1977), the average syllable duration at a normal speaking rate is around 130 msec and the range is from 75 to 200 msec. Hiki (1967) also reported similar values.

Syllable duration changes even for normal subjects when they attempt to speak slowly or fast. In the slow speech of normal Japanese subjects, syllable duration is reported to be elongated at a rate of 1 : 1.19 (Saito, ibid.).

In the present study, the speech samples obtained from the dysarthric subjects were judged to be significantly slow only when the mean syllable duration exceeded 140% of the normal mean. The result appears to agree with that of the perceptual test using synthesized speech, in which a unanimous judgment of slowness was obtained for those samples having a duration of more than 140% of the normal. Incidentally, the mean syllable duration of the original samples used to synthesize the test utterances was within the range of the normal values described above (133.6 ± 21.6 msec).

These results would seem to indicate that the subjective judgment of slowness of speech, or bradylalia, might not be given until the mean syllable duration of a given speech sample exceeds 140% of the normal mean. This value is certainly beyond the rejection threshold of normal samples and is slower than that of the slow speech produced by normal subjects.

Although bradylalia is not necessarily a principal characteristic of ataxic speech, it is often noted in clinical cases of cerebellar degeneration as indicated above. In ALS cases, on the other hand, bradylalia is an important feature of the abnormality of their speech. In these cases, the reduction of the mobility of the articulators should be a primary cause of bradylalia, although the effort of such patients to speak more distinctly may secondarily enhance this slowness of speech.

It has been reported that the vowel/consonant ratio becomes higher when normal subjects attempt to speak slowly (Hiki, ibid.). In the pathological cases examined in the present study, however, the ratio was generally lower than the normal. In particular, the ratio was significantly lower in those cases who were judged to have a slow speaking rate. The reason for the low vowel/consonant ratio would seem to be that elongation of consonantal segments is relatively more marked than that of vowel segments in these pathological cases, possibly due to the fact that their consonantal articulations are more severely disturbed in general. In any case, the mechanism of the elongation of syllable duration in pathological cases seems to be different from that of slow speech in normal subjects.

Summary

Segmental durations of selected speech samples obtained from dysarthric patients were measured on sound spectrograms, and the results were compared to those from a perceptual rating of the speaking rate of the same subjects.

It was found that those subjects whose segmental duration exceeded 140% of the normal mean were judged to have a slow speaking rate. A perceptual test using synthesized speech also indicated that a subjective judgment of slowness of speech

was made only when the duration of the original speech samples was expanded more than 140%.

The vowel/consonant ratio obtained from the pathological cases was generally low. In particular, the ratio was significantly lower than the normal in those cases who were judged to have a slow speaking rate. It was suggested that the mechanism of the elongation of syllable duration in dysarthric cases might be different from that for the slow speech of normal subjects.

Acknowledgment

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