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A PRELIMINARY STUDY OF THE ACOUSTIC EVALUATION OF DYSARTHRIC SPEECH

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Introduction

In the diagnostic approach to dysarthric speech, most studies in the past were made on a perceptual basis. For example, Darley and his colleagues[1,2] proposed a classification of dysarthria (motor speech disorders) based on a systematic perceptual analysis of recorded speech samples from neurological cases of different types. They attempted to establish the concept of clusters of deviant speech dimensions being characteristic for different categories of neuromuscular abnormality, including amyotrophic lateral sclerosis, Parkinsonism, pseudobulbar palsy (PBP) etc. Similar studies have been made in Japan, and the results suggest that perceptual study is useful for the differential diagnosis of different types of dysarthria.[3,4]

Although it is apparent from these studies that perceptual judgment by well-trained human ears is reliable and clinically useful for the diagnosis of dysarthric speech, it has often been claimed that the acoustic analysis of speech sounds would be more appropriate for the objective assessment of dysarthric abnormality, particularly for the evaluation of the severity of symptoms.

It has been further claimed that an 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. However, except for those dealing with the relation between a perceptual rating of the speaking rate and segmental durations of dysarthric speech sounds[5], only a few studies have so far attempted to explore the relationship . In particular, while the concept of "imprecise consonants" is one of the dominant dimensions in each category of dysarthria of neuromuscular origin, the acoustic nature of "impreciseness" has not been fully explored.

In 1986, Ziegler and von Cramon[6] examined speech samples obtained from 10 spastic dysarthric subjects by acoustic elaluation using the technique of signal processing. In order to assess the quality of consonant production, they calculated sound pressure level (SPL) contours for each test utterance containing plosives. The SPL was determined every 3.2 msec over a 12.6 msec window, and the resulting contour was smoothed. The maximal rate of SPL change at the closure and release of the plosives in the test words was then derived as the relative SPL differences immediately neighboring the target vowel. It was noted that a

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reduction of SPL differences in plosive-vowel and vowel-plosive transitions occurred in most of their dysarthric cases. Thus, the parameter of "SPL difference" came to be regarded as a quantitative indication of abnormal plosive production in spastic dysarthrics.

In the present study, we have attempted to explore the further possibility of using several different acoustic parameters derived from LPC analysis for an objective evaluation of the abnormal production of plosives in patients with pseudobulbar palsy. One of the main symptoms of dysarthria in pseudobulbar palsy has been known as "weak articulation", with imprecise consonant production particularly for plosives.

Procedures

1. Collection of speech samples

Speech samples were obtained from 1 normal subject and 11 selected patients having PBP secondary to a cerebrovascular accident (CVA). Prior to the present study, the patients were classified into three severity groups --slight, moderate and severe -- based on clinical evaluation, including perceptual judgment.

The subjects were requested to read tow-mora nonsense words of the form /VCV/, where /V/ was /a/ and /C/ was one of the six plosives -- /p/,/t/,/k/,/b/,/d/ and /g/ -- three times each. For the purpose of a preliminary analysis, the normal subject (one of the authors, a speech therapist) read a series of test words mimicking dysarthric speech of the spastic type at three different degrees of severity -- i.e. slight, moderate and severe -- in addition to giving a normal reading. The recording from the normal subject was made in an anechoic room using a PCM processor. The dysarthric cases were recorded in a quiet room of a hospital using a casette tape recorder.

2. Acoustic analysis

Speech samples were low-pass filtered at 4.5 kHz and digitized with a sampling rate of 10 kHz. LPC analysis was then made every 10 msec over a 20 msec humming window to obtain the power and spectral envelopes. In order to assess the rate of change in the power and spectrum for every frame, the difference in each parameter value from the preceding frame was calculated. As an indication of the spectral change, the LPC cepstrum distance was used.

Results

Fig. 1 shows the result of the analysis of the utterance sample /apa/ from the normal subject. The curves are temporal patterns of, from the top, the acoustic wave form, difference in

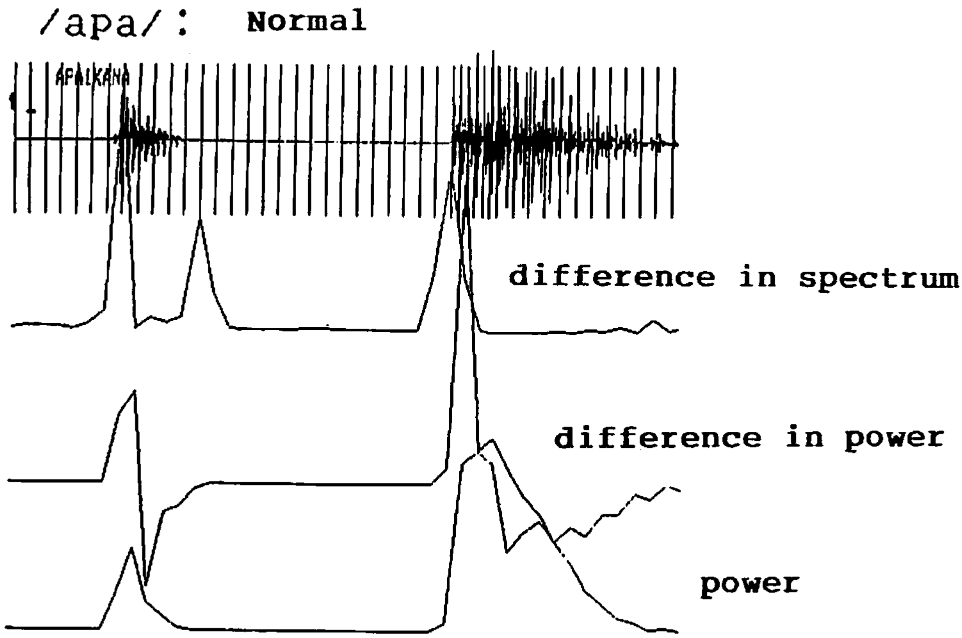

Fig. 1 Result of the acoustic analysis of the test utterance /apa/ produced by the normal subject.

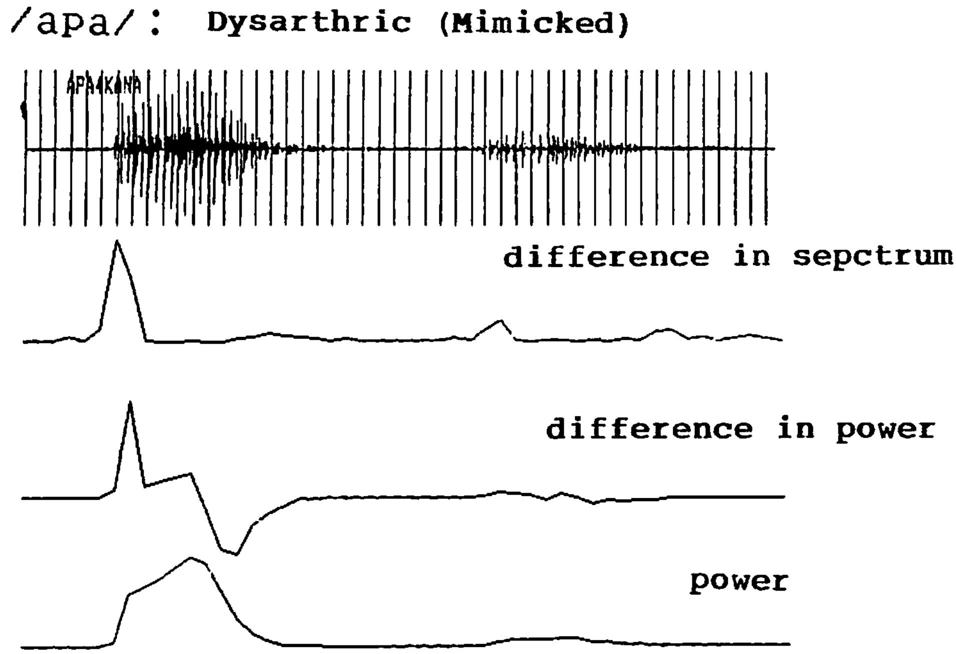

Fig. 2 Result of the acoustic analysis of the test utterance /apa/ produced by the normal subject mimicking severe PBP dysarthrics.

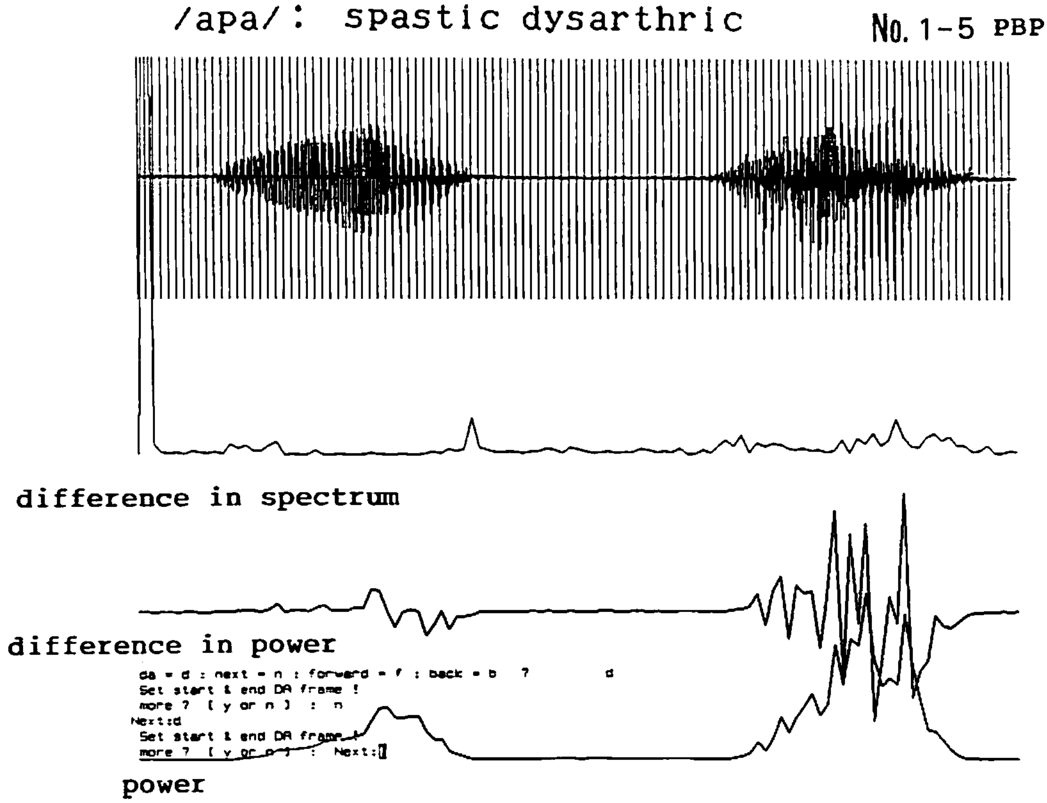

Fig. 3 An example of the result of the analysis of the test utterance /apa/ produced by a PBP patient.

the spectrum (dB), the difference in power (dB), and the power (dB). The vertical bars superimposed on the acoustic wave form indicate 10-msec frame boundaries.

There are sharp rises in both the curves of the spectral and power differences, particularly at the articulatory release of /p/.

In Fig. 2, the four curves are shown, in the same fashion as in Fig. 1, where the normal subject mimicked severe spastic dysarhric speech to produce the test utterance /apa/. It can be noted in both the curves of the spectral and power differences that there is no sharp rise near the articulatory release.

Fig. 3 shows the result of the analysis of the utterance sample /apa/ obtained from a subject with severe PBP. Similar to the pattern shown in Fig. 2, there is no sharp rise in both the curves of the spectral and power differences around the articulatory release. In addition, there is a tendency for the value of power to stay above the zero level even during the period of the articulatory closure of the voiceless plosives. It was further noted that the the power curve often showed irregular fluctuation during the vowel period of the utterances.

The peak values of the spectral and power differences at the articulatory release of all the utterance samples obtained from the 11 dysarthric patients are plotted in Fig. 4, taking the two parameters as the X and Y coodinates. In this figure, the 95 % range for the distribution of the data is circled by an elipse for clinically-determined severity group of the subjects. It is apparent that the three categories are clearly separated on the axis of the spectral difference, while the separation is not remarkable on the axis of the power difference.

Comments

It was revealed in the normal subject that a transition from the articulatory closure of a plosive to a succeeding vowel is represented by a steep rise in the parameters of the spectral and power differences. In mimic dysarthric speech as well as in the dysarthric subjects, on the other hand, the changes appear less obvious. In particular, the value of the spectral difference tends to decrease with an increase in the degree of dysarthirc severity.

The steep rise in both parameters should correspond to a rapid change in the acoustic charateristics at the release of plosives induced by the quick articulatory adjustments. The fact that each value tended to decrease in dysarthric speech would indicate that rapid and effective articulatory gestures cannot be realized in these cases. In particular, as shown in Fig. 4, the value of the spectral difference apparently corresponds well to the clinical degree of the dysarthric severity. This result seems reasonable, since a smaller spectral difference could

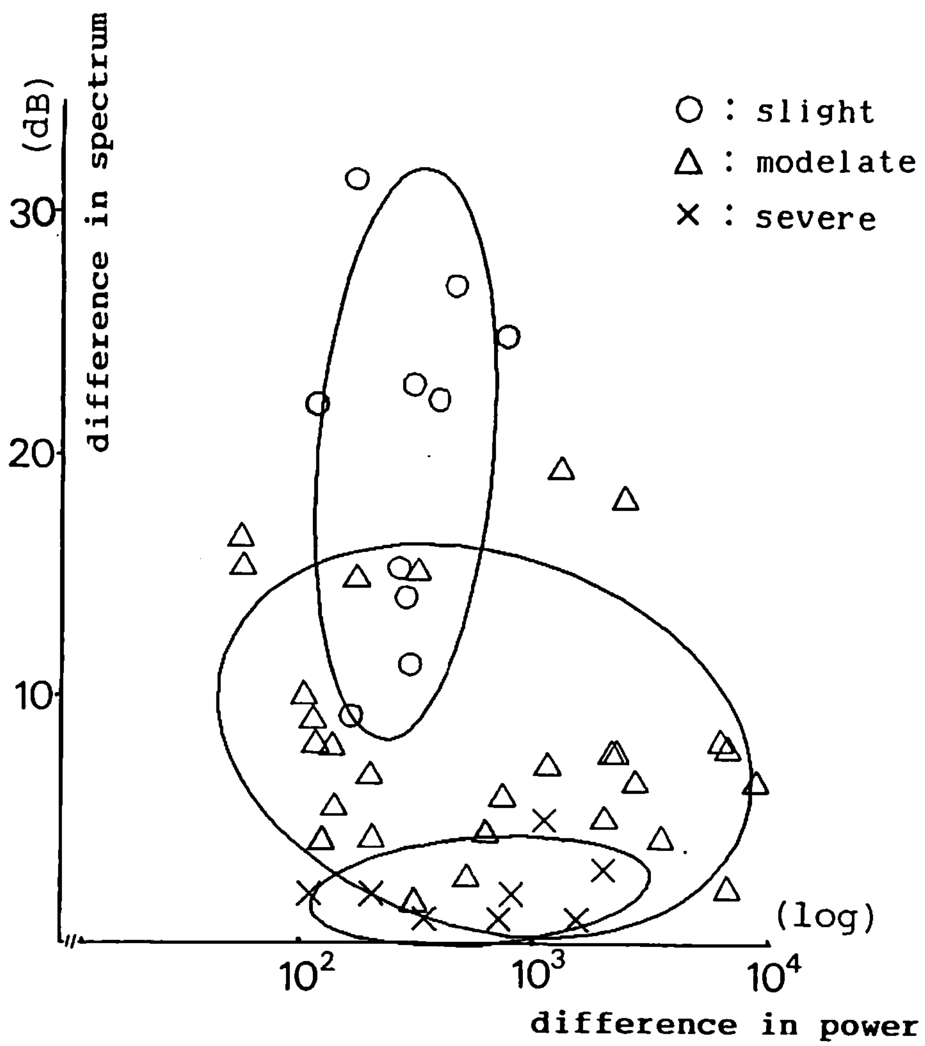

Fig. 4 Scattergram for the parameter values obtained from 11 PBP patients on X-Y coordinates representing the spectral and power differences.

result from a feature of weak articulation in terms of a less remarkable change in the vocal tract configuration in PBP cases.

Other evidence of weak articulation was the apparent increase in power during the production of plossive sounds, indicating a leakage of sound energy due to an incomplete articulatory closure.

In our previous studies[7,8], the articulatory dynamics of PBP patients were analyzed using the X-ray microbeam system, and it was concluded that a reduced range of articulatory movement and a slow-down in the rate of speech are the most manifest signs of this pathological condition.

Since the acoustic manifestation of PBP speech should mainly result from the sluggishness of the articulators, the acoustic parameters examined in the present study, particularly the spectral difference, seem to be useful for the objective evaluation of the degree of weak articulation as a representative feature of the paralytic dysarthria in PBP patients. Further study is needed with an incresed number of cases for evaluation to determine additional parameters useful in the objective evaluation of dysarthrias.

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