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ACOUSTIC PROPERTIES OF ATAXIC AND PARKINSONIAN SPEECH IN SYLLABLE REPETITION TASKS

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Impairments of the neuromuscular system which controls the articulatory movements yield various types of dysarthria, and the patients with given types of dysarthria reveal different speech characteristics depending on the nature of the neuromuscular impairments. Darley et al. (1969 a, b) delineated the characteristics of various types of dysarthria. They conducted systematic auditory evaluations of speech samples of their patients along a number of dimensions of speech, e.g., pitch, voice quality, articulation, etc., using an equal-appearing intervals method.

A similar study using Japanese patients was conducted by Hirose (1973). More recently, a series of investigations on speech characteristics of Japanese dysarthric patients were conducted by Kobayashi et al. (1976), Fujibayashi et al. (1977), and Kumai et al. (1978). Tatsumi et al. (1979) found that dysarthric patients could be classified almost entirely in terms of a linear discriminant function derived from the results of speech evaluation based on the above method.

While this type of auditory evaluation of dysarthric speech is clinically useful, an additional, more objective study, such as one using acoustic measurements of speech characteristics of dysarthric patients seems to be necessary in order to further elucidate the mechanisms and processes underlying the dysarthric speech. In the present study, therefore, acoustic measurements were carried out on (1) the overall rate and (2) irregularity in rate and intensity for two types of dysarthric speech, i.e., ataxic and Parkinsonian.

PROCEDURES

The subjects were 21 patients with ataxia, 30 patients with Parkinsonism, and 65 normals. The age range was from 25 to 62 years old for the ataxic patients, 36 to 70 for the Parkinsonian patients, and 17 to 87 for the normal subjects. The normal subjects were divided into two groups on the basis of their age, i.e., a group of 36 subjects with an age range from 17 to 44 (younger normal group) and another group of 29 subjects with an age range from 60 to 87 (older normal group). They were asked to repeat the syllable /pa/ as fast as possible. Speech was recorded on an audio tape for later acoustic measurements.

The recorded samples were then read into a computer through an A-to-D converter, sampled at a rate of 12 kHz with an accuracy of 10 bits, and rectified and smoothed over a 10 msec interval by a computer program. Envelopes obtained were displayed on a CRT-display, and unvoiced and voiced durations of a syllable (Ud and Vd) were measured by visual inspection. The maximum intensity of every voiced interval (Vmax) was also measured. Based on Ud, Vd and Vmax, the following measures were computed: (1) The mean of syllable duration ($\overline{Sd}$, where Sd=Ud+Vd), (2) the standard deviation of the syllable duration (s(Sd)), and (3) the standard deviation of the relative values of the maximum voice intensity

(s(Vm), where Vm=Vmax/$\overline{\text{Vmax}}$). These are considered to be indices, respectively, of the rate of syllable repetition, irregularity in the rate of syllable repetition, and irregularity in voice intensity.

Hirose and his colleagues (1978 a, b) observed articulatory movements of the lip, jaw, and velum during the task of syllable repetition for an ataxic patient, a patient with amyotrophic lateral sclerosis, and a Parkinsonian patient. They found that random change of articulatory movements characterized ataxic speech, while gradual change characterized Parkinsonian speech. It should be noted, however, that standard deviation as an index of irregularity of articulatory movement is not a sensitive measure for the differentiation of these two types of irregularity. Due to this the two additional indices of irregularity in rate and intensity ($\overline{\Delta Sd}$ and $\overline{\Delta Vm}$) were employed, which give small values for gradual change but large values for random change. Designate the ith syllable duration and maximum intensity of a given utterance as Sd_i and $Vmax_i$, then the indices $\overline{\Delta Sd}$ and $\overline{\Delta Vm}$, the mean differences in Sd's and Vmax's between the two consecutive syllables, are defined as follows:

$$\overline{\Delta Sd}=\frac{1}{n-1}\sum_{n=1}^{n-1}\left|Sd_i-Sd_{i+1}\right|$$

$$\overline{\Delta Vm}=\frac{1}{n-1}\sum_{n=1}^{n-1}2\left|Vmax_i-Vmax_{i+1}\right|/(Vmax_i+Vmax_{i+1}),$$

where n indicates the number of syllables involved in the utterances. Note that the difference of the consecutive Vmax's was normalized by their moving average so as to exclude an effect of the recorded level of the utterance upon $\overline{\Delta Vm}$.

RESULTS AND COMMENTS

In Figure 1 the mean syllable duration $\overline{Sd}$, an index of the rate of syllable repetition, is plotted against the age of each subject. A dot in the figure represents a younger or older normal subject, and the filled and open circles represent ataxic and Parkinsonian patients, respectively. In addition, the range of $\overline{Sd}$'s for the normal subjects is illustrated by two curves which were drawn excluding some isolated dots. While the $\overline{Sd}$'s and their range for the normal subjects tend to increase with age, the $\overline{Sd}$'s for the pathological subjects distribute independently of their ages. Almost all of the ataxic patients revealed larger $\overline{Sd}$'s than those for normal subjects, while only a small portion of the Parkinsonian patients showed larger $\overline{Sd}$'s .

In Figure 2-(a), the standard deviation of syllable duration s(Sd), an index of overall irregularity in the rate of syllable repetition, is shown. It can be seen from the figure that in comparison to normals, the majority of the ataxic patients showed greater irregularity in the rate of syllable repetition. In contrast, only a small number of Parkinsonian subjects exhibited irregularity in rate.

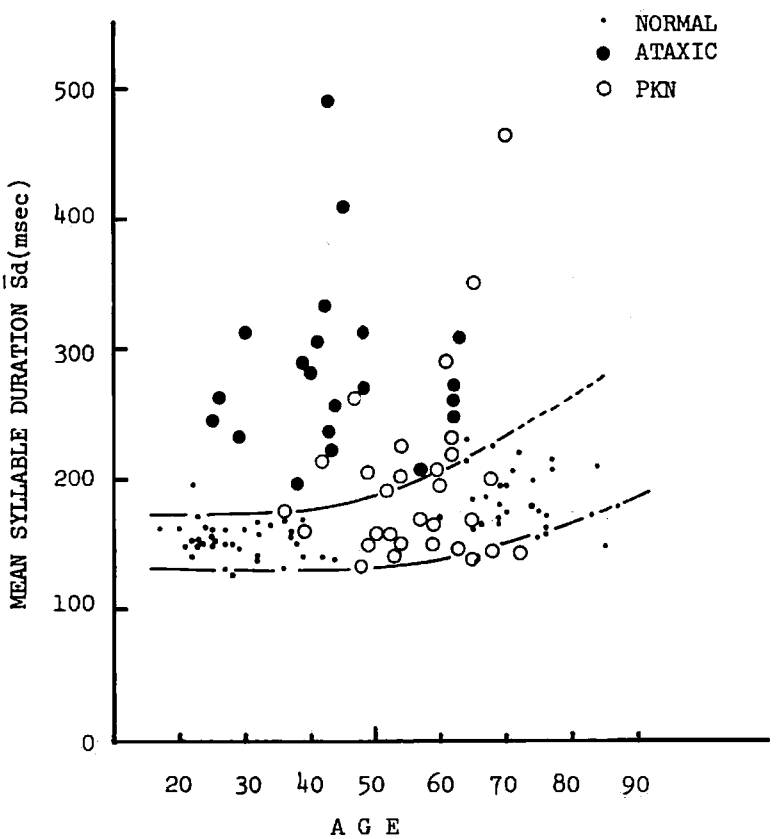

Fig. 1. Mean syllable duration as plotted against the age of each of normal(dot), ataxic(filled circle), and Parkinsonian(open circle) subject.

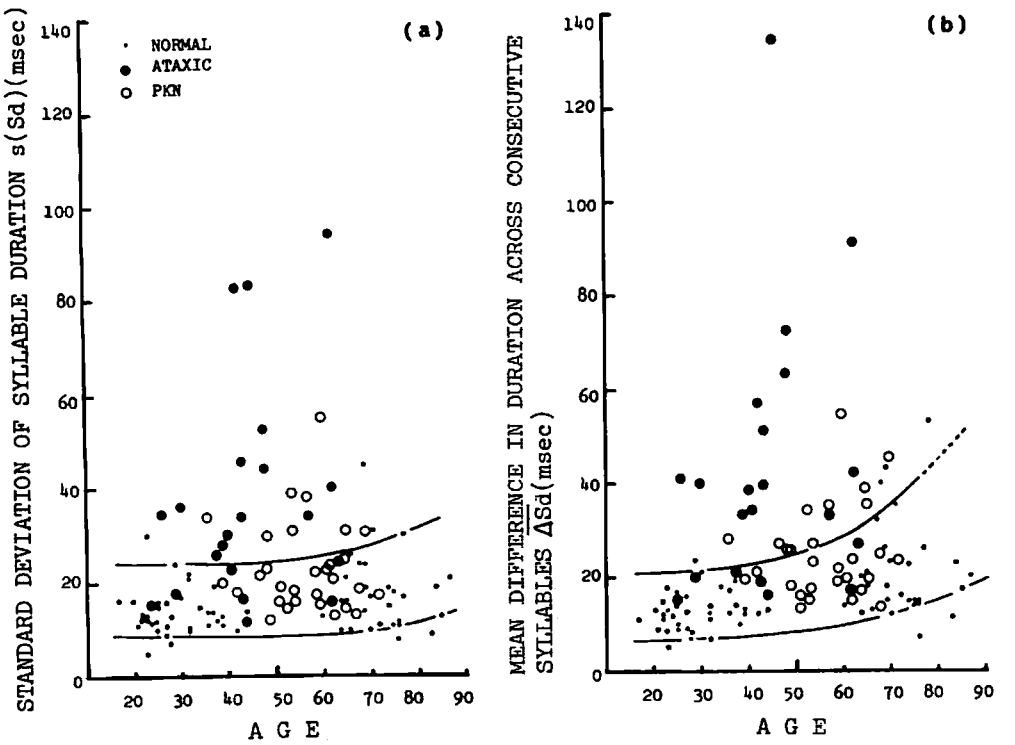

Fig. 2. Two indices of irregularity in rate of syllable repetition. An index of overall irregularity, the standard deviation of syllable repetition s(Sd), is shown in (a), and an index of the irregularity in consecutive syllable duration $\overline{\Delta Sd}$ in (b).

The results on $\overline{\Delta Sd}$, the other index of irregularity of syllable repetition, are displayed in Fig. 2-(b). Of interest is the fact that less overlap between $\overline{\Delta Sd}$'s for the ataxic and the other three groups of subjects is observed in this figure than in Fig. 2-(a). The result indicates that there is a difference in the irregularity patterns of the repetition rate in the ataxic and other groups of subjects, i. e., the speech of ataxic patients is characterized by more abrupt durational changes across the consecutive syllables.

Figure 3-(a) depicts the results concerning the overall irregularity of the maximum voice intensity s(Vm). It can be seen that there is an effect of aging on s(Vm) for the normal subjects, though a considerable individual difference is observed as well. The performance of the majority of subjects in the two pathological groups was within the normal range, although some subjects revealed greater irregularity in voice intensity as compared with the normal subjects.

In Figure 3-(b), the mean difference in the maximum intensity between the two consecutive syllables $\overline{\Delta Vm}$ is plotted against the age of the subjects. Individual differences with respect to $\overline{\Delta Vm}$ tend to decrease both for the younger and older normals, when compared to those for the overall index s(Vm). Similarly, individual differences among $\overline{\Delta Vm}$'s

became smaller for the Parkinsonian patients. Furthermore, $\overline{\Delta Vm}$'s for most of the Parkinsonian patients seemed to be concentrated along the lower limit of the normal range, suggesting that in these patients, intensity changes across the two consecutive syllables are small and gradual. The ataxic patients, on the other hand, showed almost no difference between s(Vm) and $\overline{\Delta Vm}$ scores, indicating that the ataxic speech pattern of these patients is characterized by an abrupt change of intensity across consecutive syllables.

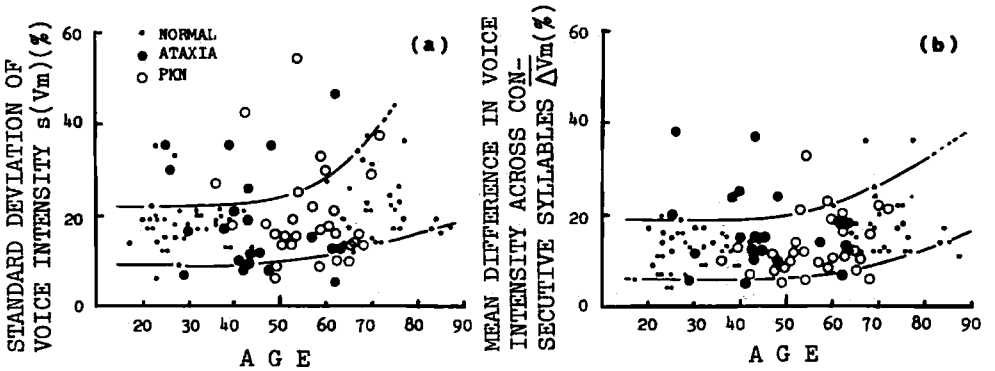

Fig. 3. Two indices of irregularity in voice intensity. (a) represents the standard deviation of voice intensity s(Vm), and (b) the mean difference in voice intensity across two consecutive syllables $\overline{\Delta Vm}$.

In summary, almost all ataxic patients repeated syllables at an abnormally slow rate with considerable irregularity in rate and/or intensity. The pattern of this irregularity in ataxic speech may be represented by an abrupt change in the rate and intensity across the successive syllables. In contrast, the performance of the majority of Parkinsonian patients was within the normal range with respect to the rate of speech and the degree of irregularity in rate and intensity. This finding will reflect the effect of the administration of L-dopa upon their speech, as pointed out by Hirose et al. (1978 b) and Kumai et al. (1978). A small number of the Parkinsonian patients, however, exhibited abnormal speech behavior, but it was characterized by a gradual change in rate and intensity.

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