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A KINESIOLOGICAL STUDY OF LABIAL ARTICULATORY MOVEMENTS IN ATAXIC PATIENTS

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Introduction

In our previous study of articulatory dynamics in different types of dysarthric subjects, it was revealed that the articulatory pattern of ataxic subjects with cerebellar pathology was characterized by inconsistency in both the range and velocity of movements, particularly in sequences of repeated monosyllables (Hirose, et al., 1978).

Later, our preliminary analysis of normal subjects revealed that there was a high positive correlation between the degree of articulatory displacement and the maximum velocity of the articulators (Hirose, et al., 1982). This result was generally in agreement with the findings previously reported by Sussman et al. (1973) who had studied the movement pattern of the upper lip, lower lip and jaw using a straingauge transducer system during the production of VCV tokens.

In the study of limb dynamics, movements of greater amplitude have been found to have greater peak velocities in voluntary anisometric contractions of the mucles of the hands and arms in humans. In addition, it has also been reported that the interval from the onset of movement to the point of maximum velocity appears to be independent of differences in the extent of the movement in rapid elbow and finger flexions (Freund and Budingen, 1978).

Ostry and his colleagues (1983) examined the kinematics of the tongue dorsum using a pulsed ultrasound system during articulatory movments and found that the maximum velocity of tongue dorsum raising and lowering was correlated with the extent of the gesture. Further, they observed that at each stress level, the correlation between displacement and peak velocity was accompanied by a relatively constant interval from the initiation of the movement to the point of maximum velocity.

The present study was a further examination of the kinesiological nature of ataxic speech by means of the x-ray microbeam system in which the relationship between the amplitude of labial articulatory movement and its maximum velocity was obtained and compared to that of normal subjects. The correlation between the labial articulatory displacement and the time interval from the initiation of movement to the point of maximum velocity was also investigated.

Procedures

The movement of lead pellets attached to the lower lip and jaw of the subjects were tracked and analyzed using the computer-controlled x-ray microbeam system (Kiritani, et al., 1975). The data output was read into a computer memory core through an x-ray detector and an analog-to-digital (A/D) converter. The trajectories of the pellets tracked by the system were then analyzed. Since the lip movement depends, to a certain extent, on the movement of the jaw, the coordinate values for the jaw were subtracted from those of the lip to obtain new coordinate values representing the independent movement parameters for the lip. The coordinate values were displayed as time functions from which the extent of the articulatory displacement was calculated.

The velocity of the labial articulatory displacement was obtained using a pertinent computer program in which a linear approximation was made for seven consecutive frames to represent the trajectory of the pellet within that very short period of time.

In the present study, three ataxic patients with cerebellar degeneration and two normal subjects were examined. The data from the two normal subjects were pooled. As a control, a subject with amyotrophic lateral sclerosis also underwent the x-ray microbeam analysis. The subjects were required to repeat Japanese monosyllables containing the labial consonant /p/, such as /pa/, /paN/, /piN/ and /puN/, separately at their fast speaking rate.

Results

As in previous reports, the normal subjects showed a regular and rhythmic pattern of opening and closing movements for the lower lip corresponding to the articulation of the consonant /p/. Figure 1-a illustrates the movement patterns of the lower lip for a normal subject in the repetitive production of the monosyllable /pa/ where the X and Y coordinate values are displayed as functions of time. In Figure 1-b, the time curve of the velocity of the lip movement is displayed. Each consecutive peak corresponds to the maximum velocity of the closing and opening gestures for the production of /p/. The coordinate values and the peak velocity values are also given in digitized form for further comparison.

Figure 2 compares the time courses of the lip velocity for the repetitive production of the monosyllable /pa/ in a normal subject and an ataxic subject. As compared to the normal velocity pattern (top), the velocity of the lip movement for each consecutive syllable in the ataxic subject (bottom) is quite variable.

The relationship between the amount of labial displacement and the maximum velocity in the two normal subjects for the production of different types of test utterances is plotted in Figure 3. It was confirmed that there is a high positive correlation between the two parameters (r=0.857) for labial articulatory movement in nomal subjects.

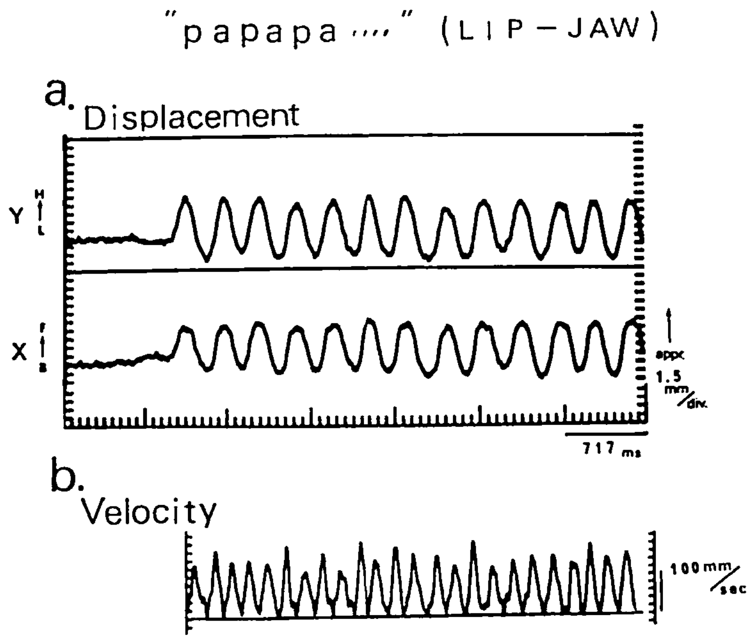

Figure 1. An example of the lip movement pattern (top) and velocity(bottom) in a normal subject producing sequences of the monosyllable /pa/. The displacements are displayed as a time function of the X (back [B] to front [F]) and Y (low [L] to high [H]) coordinates. The coordinate values for the jaw are subtracted from those of the lip so as to obtain the values for the lip itself.

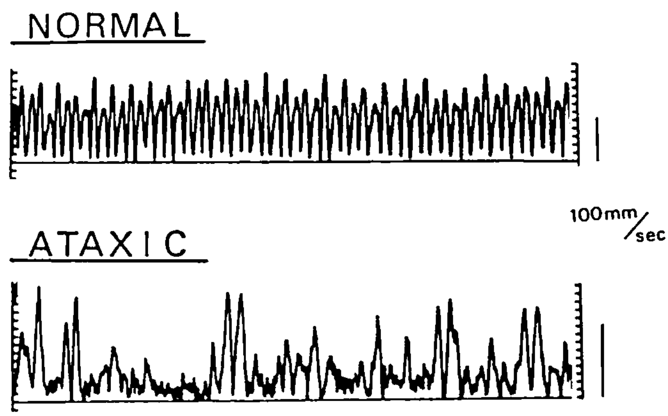

Figure 2. A Comparison of the velocity of lip movement in the normal (top) and ataxic subjects (bottom).

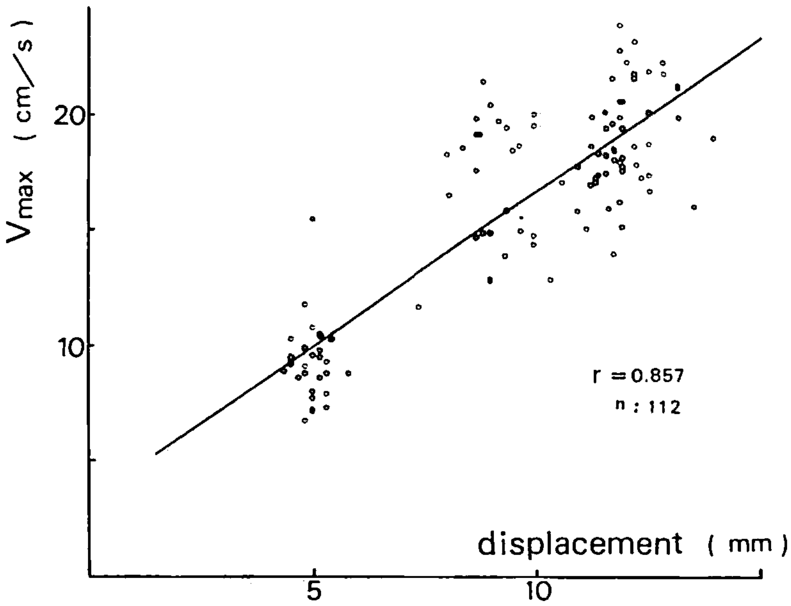

Figure 3. The relationship between the amount of labial displacement and the maximum velocity in the normal subjects.

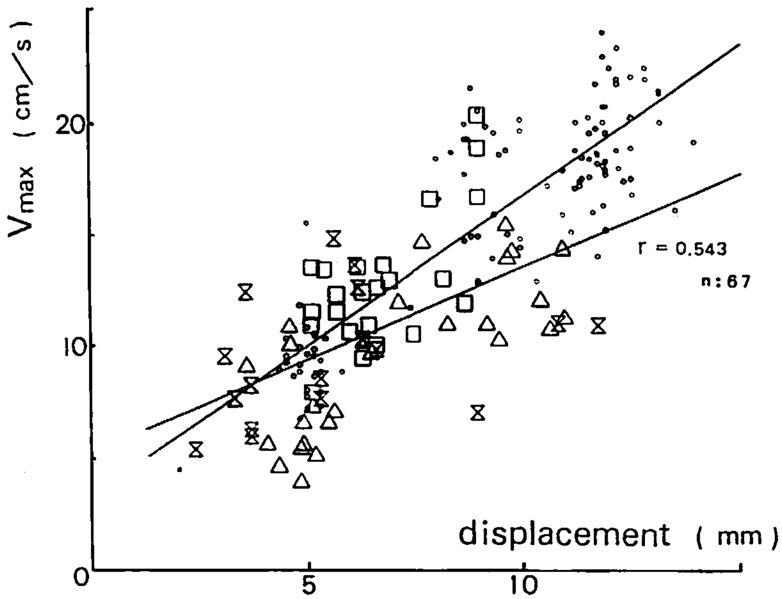

Figure 4. The relationship between the labial displacement and the maximum velocity in the three ataxic patients. The data obtained from each patient are plotted using different symbols for each.

The relationship between the two parameters was also investigated for the three ataxic subjects and the results are plotted using three different symbols for each of the three subjects in Figure 4. The data from the ataxic subjects were pooled together for statistical comparison with those obtained from the normal subjects, which are also plotted in the same figure. There was a significantly high positive correlation between the two parameters in the ataxic subjects as well, although the correlation coefficient is lower (r=0.543) than that obtained from the normal subjects.

In Figure 5, the relationship between the time interval from the initiation of the labial articulatory movement to the point of the maximum velocity and the extent of the labial displacement is shown for normal subjects. It is apparent that the time interval from the initiation of movement to the point of the maximum velocity was relatively invariable regardless of the difference in the extent of the movement. In this figure, the 95% range for the distribution of the data is circled by an elipse showing a flat contour with a long horizontal axis.

The interval from the initiation of movement to the point of the maximum velocity, relative to the labial articulatory displacement, was also obtained from the three ataxic subjects for the production of each monosyllable, and the results are plotted in Figure 6 on which the eliptic area corresponding to the normal data distribution is superimposed. It can be seen that a significant number of the data points are out of the normal range, and that there is a tendency for the interval from the initiation of movement to the maximum velocity, relative to the articulatory displacement to be elongated.

As a control,this relationship was also examined in a case of amyotrophic lateral sclerosis (ALS) with paralytic dysarthria, the results of which are illustrated in Figure 7. The distribution of the data is mostly within the range obtained from the normal subjects.

Comment

The high positive correlation between the maximum velocity and the extent of the labial articulatory displacement in the ataxic subjects would seem to indicate that the apparent variability in maximum velocity in repetitive articulation in ataxic speech corresponds to the variability in labial displacement for each repetitive production of a monosyllable.

Thus, it can be assumed that the dynamic characteristics of labial movements at the peripheral level in terms of the displacement-velocity relationship is nearly as operative in ataxic subjects as in normals.

On the other hand, it was found that the time interval from the initiation of movement to the point of peak velocity was

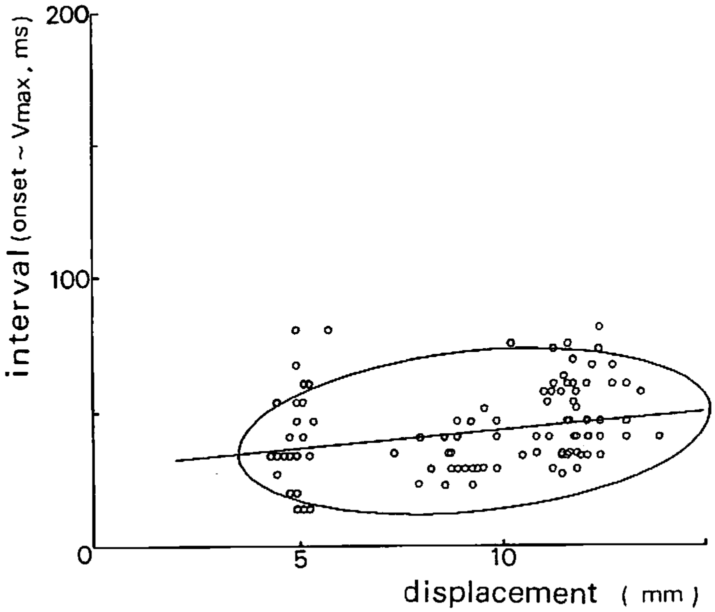

Figure 5. The relationship between the time interval from the initiation of the labial movement to the point of the maximum velocity and the extent of the labial displacment in the normal subjects. In this figure, the 95 % range for the distribution is circled by an elipse.

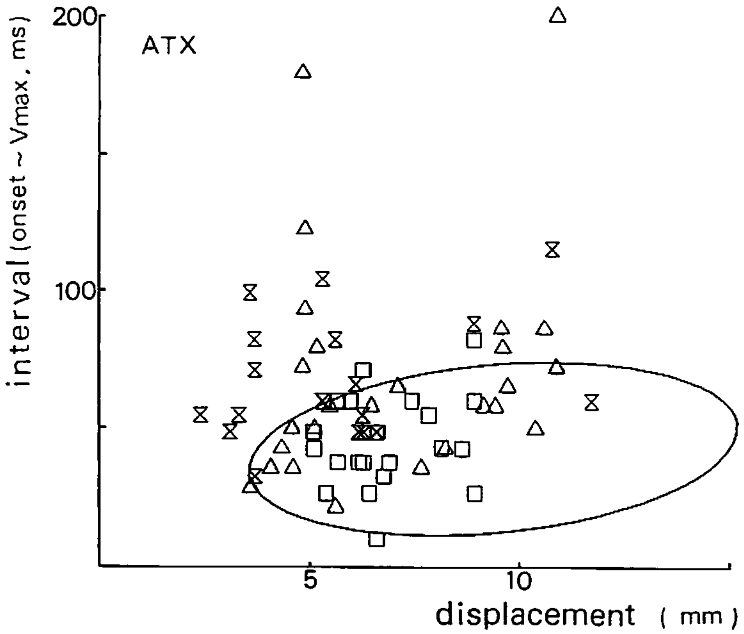

Figure 6. The relationship between the time interval from the initiation of movement to the maximum velocity and the extent of the labial displacement in the ataxic patients. The normal data distribution is superimposed.

quite variable and generally prolonged in the ataxic subjects relative to the normals and the ALS subject. These findings can be taken as an indication that ataxic movement in labial articulation is characterized by an abnormal temporal pattern in muscular force development.

According to Ito (1984), three major principles have now been raised regarding the charactersitics of the cerebellar control mechanisms: open-loop, multivariable, and adaptive-learning. He also claims that, among the ataxic symptoms which are clinically characteristic of cerebellar dysfunction, dysmetria and delayed movement initiation could be related to the failure of an open-loop motor control, while incoordination should represent a disturbance in the multivariable control.

It can be argued that the disturbance in muscular force development in the temporal domain suggested in the present study for the ataxic pattern of movement is also related to a disturbance in the open-loop control mechanism in ataxic patients. More studies are needed to further explore the nature of the abnormal dynamics of ataxic speech.

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