Ann. Bull. RILP, No. 12, 87-96(1978)

ARTICULATORY DYNAMICS IN A PATIENT WITH APRAXIA OF SPEECH: X-RAY MICROBEAM OBSERVATION

Motonobu Itoh*, Sumiko Sasanuma**, Hajime Hirose
Hirohide Yoshioka and Tatsujiro Ushijima

In our recent paper (Itoh et al., in press), we reported on fiberoptic observations of a patient with apraxia of speech, which has been defined as a disorder of motor programming for speech (Darley et al., 1975). This fiberscopic observation led us to assume that the motor programming for the temporal organization of different articulators might be disturbed in the apraxic patient. The present report is a further attempt to obtain a more accurate clinical picture of apraxia of speech by use of a computer-controlled X-ray microbeam system (Kiritani et al., 1975), which enables the simultaneous observation of several articulators during speech articulation. Through this approach, it is hoped that the pattern of disturbance in the temporal organization of articulatory movement in apraxic speech can be clarified. In addition, the velocity of the articulators during speech was estimated.

Subject

The subject was the 61-year-old male investigated in our previous study of articulatory velar movements. He suffered a stroke due to cerebral thrombosis on March 14, 1970. Computerized axial tomography (CT scan) indicated an infarct involving the cortical surface near the anterior tip of the Sylvian fissure of the left hemisphere and the immediately subjacent subcortical white matter. The case history, medical findings, as well as the results of speech and language examinations obtained from the patient have been reported elsewhere (Sasanuma, 1971; Itoh et al., in press).

The data obtained from the apraxic subject were compared with those of normal and dysarthric subjects.

Procedure

A simultaneous observation of the movements of several articulators was made by means of an X-ray microbeam system (Kiritani et al., 1975). Through the use of this system, the movement of the articulators can be observed by tracking lead pellets attached to the surface of the articulators. For the present observation, lead pellets were attached to the nasal surface of the velum, the tongue dorsum, the lower lip and the lower incisors of the subject. (It was impossible to observe tongue tip movement because the subject had artificial teeth of metal which disturbed the tracking of the pellets on the tongue tip.) The subject was requested to repeat the nonsense syllables /pa/, /ta/, /ka/ and /teN/ at his fastest rate of speech. In addition, he was asked to utter a meaningful Japanese test word /deenee/

* Tokyo Metropolitan Institute of Gerontology
** Yokohama National University, Tokyo Met. Institute of Gerontology

embedded in a carrier phrase / --- desu/ (it is ---) at a conversational rate, which was demonstrated by the experimenter. In effect, however, his utterance rate was much slower than the normal conversational rate.

Results

1. Timing control of different articulators

(1) Repetition of nonsense syllables

Figure 1 shows the pattern of movement of the lower lip and the jaw for repetitions of the monosyllable /pa/ with a maximum utterance rate, comparing the apraxic subject with a normal subject (a 40-year-old male) and an ataxic subject (a 53-year-old male). (The data for the normal and ataxic subjects were taken from Hirose et al., 1977, 1978a.)

In this figure, the up and down displacements of the lip and the jaw are plotted as a function of time. The coordinate values for the jaw were subtracted from those of the lip in order to observe the pattern of lip movements independently of the jaw. It appears that the movement patterns of the lip and the jaw of the apraxic subject were as regular as those in the normal subject and contrasted with those of the ataxic subject, which were characterized by a marked irregularity in terms of both the range and the

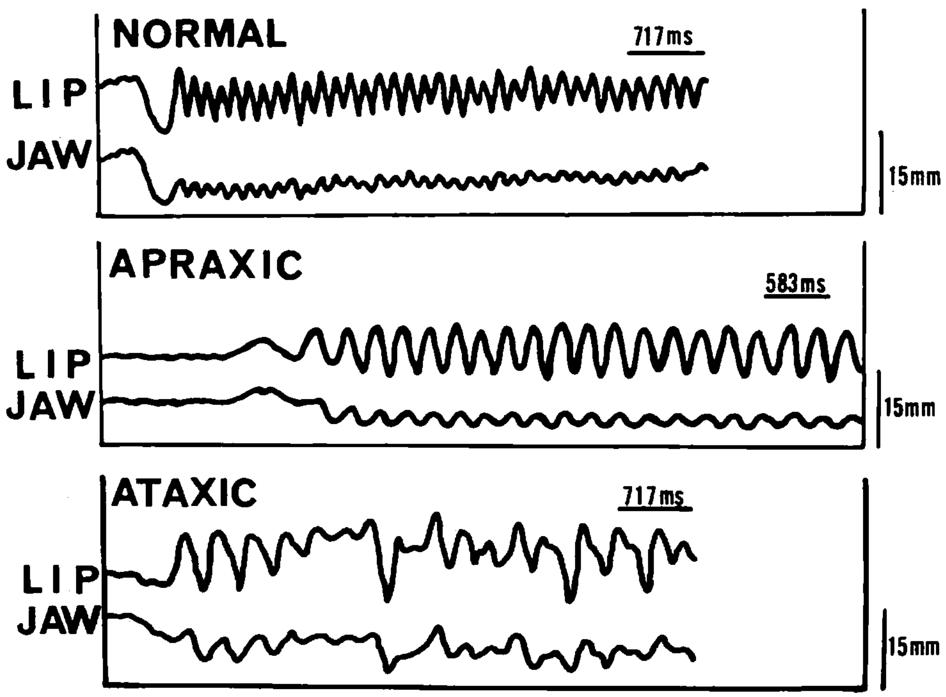

Fig. 1. Up and down displacements of the lower lip and the jaw as a function of time in the normal subject (top), in the apraxic subject (middle) and in the ataxic subject (bottom) for repetitions of the monosyllable /pa/. The time scale of the apraxic subject is different from that of the other subjects.

velocity of movement. The figure also indicates that there was a temporal correspondence between the lip and the jaw in the apraxic subject as well as in the normal subject and even in the ataxic subject.

Similar results were obtained for the repetitions of /ta/, /ka/ and /teN/.

(2) Production of the word /deenee/

Figure 2 compares the movement patterns of several articulators in the normal subject who uttered /deenee/ in a carrier phrase /sono---desu/ (it is the ---) on two occasions at two different utterance rates (slow and moderate). The speaking rate was controlled by timing signals of 3Hz (for the slow rate) and 4Hz (for the moderate) click sounds given to the subject through a set of earphones. The vertical lines in the figure indicate the moment when the velum lowering for the /n/ of /deenee/ was at its maximum and can serve for comparing the timing of the articulatory movements among the different articulators.

The observed articulators included the lower lip, the velum, and the tip and dorsum of the tongue. (For the second utterance at a moderate rate of speech, the displacement pattern of the tongue dorsum was not obtained.) The figure shows that there was an apparent temporal correspondence among the several articulators. For example, the velar lowering for /n/ corresponds well with the upward tongue tip movement for the alveolar closure although the peak of the tongue tip movement shifted to the right to some degree at the slow utterance rate.

On the other hand, as Figure 3 indicates, there is an apparent disorganization of timing among the several articulators in the apraxic subject. Although tongue tip movement was not observed for this subject, it was possible to infer an upward movement of the tongue tip for the alveolar closure for /n/ from the downward movement of the tongue dorsum*. The movement of the tongue dorsum in the apraxic subject was characterized by a marked downward movement for /n/, followed by an upward movement for the following segments, resulting in a dip in the movement pattern. Thus, we can determine the timing relationship between the velar lowering and the tongue tip movements for /n/ by means of examining the point where the velum lowering for /n/ was at its maximum and the dip in the movement pattern of the tongue dorsum. Furthermore, the idiosyncratic pattern of lower lip movement of the subject can be utilized for examining the timing relationship between the velum and lip movements. That is to say, the subject exhibited an upward movement of the lower lip for /n/, followed by a downward movement for the segments following /n/, resulting in a sort of peak in the movement pattern of the lower lip.

Again, the vertical lines in the figure indicate the moment when the velum lowering for the /n/ of /deenee/ was at its maximum.

It can be seen from Figure 3 that there was a great variability in terms of the timing relationship between the velar lowering and lip and tongue movements for /n/ when the same word /deenee/ in the carrier phrase was repeated three times. In the utterance shown in Figure 3-1,

---

* As seen in Figure 2, the tongue dorsum usually moved downward when the tongue tip moved up for the alveolar closure in the normal subject.

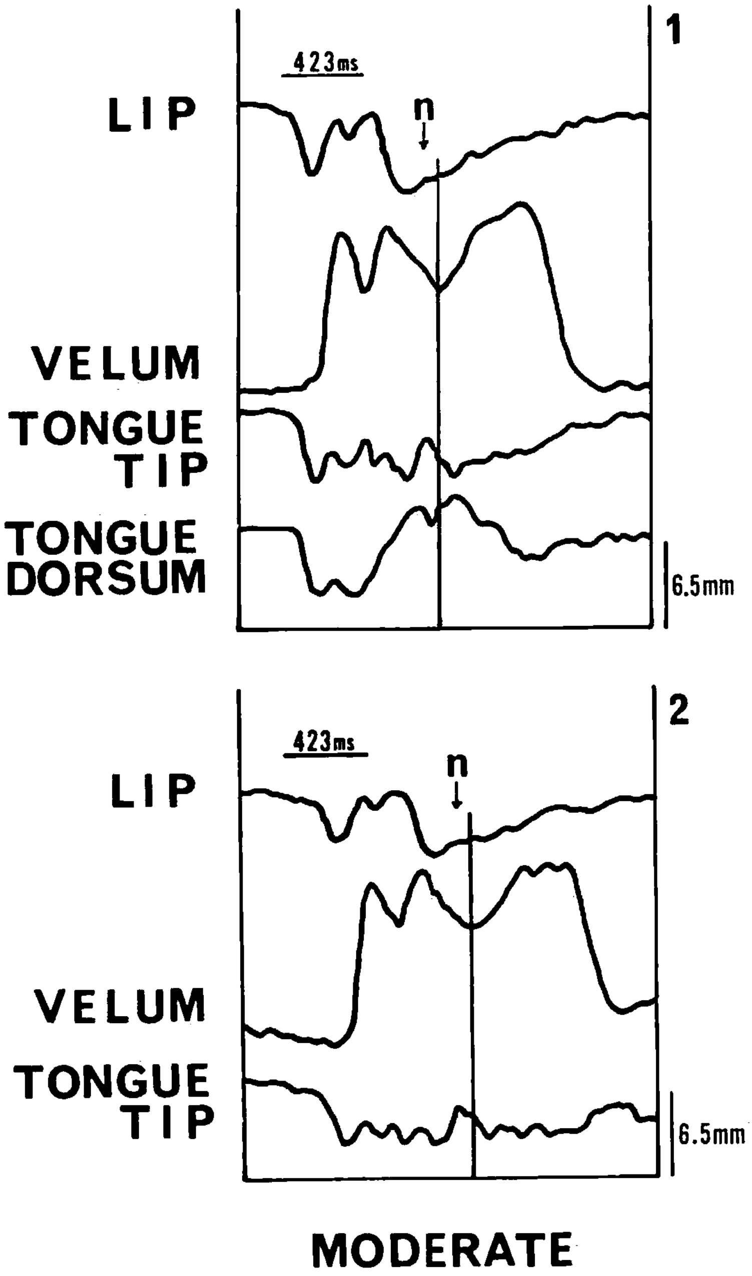

Fig. 2(a) Up and down displacements of several articulators of the normal subject as a function of time during two productions of /deenee/ in the carrier phrase /sono --- desu/ (it is the ---) at a moderate rate (a) and at a slow rate (b).

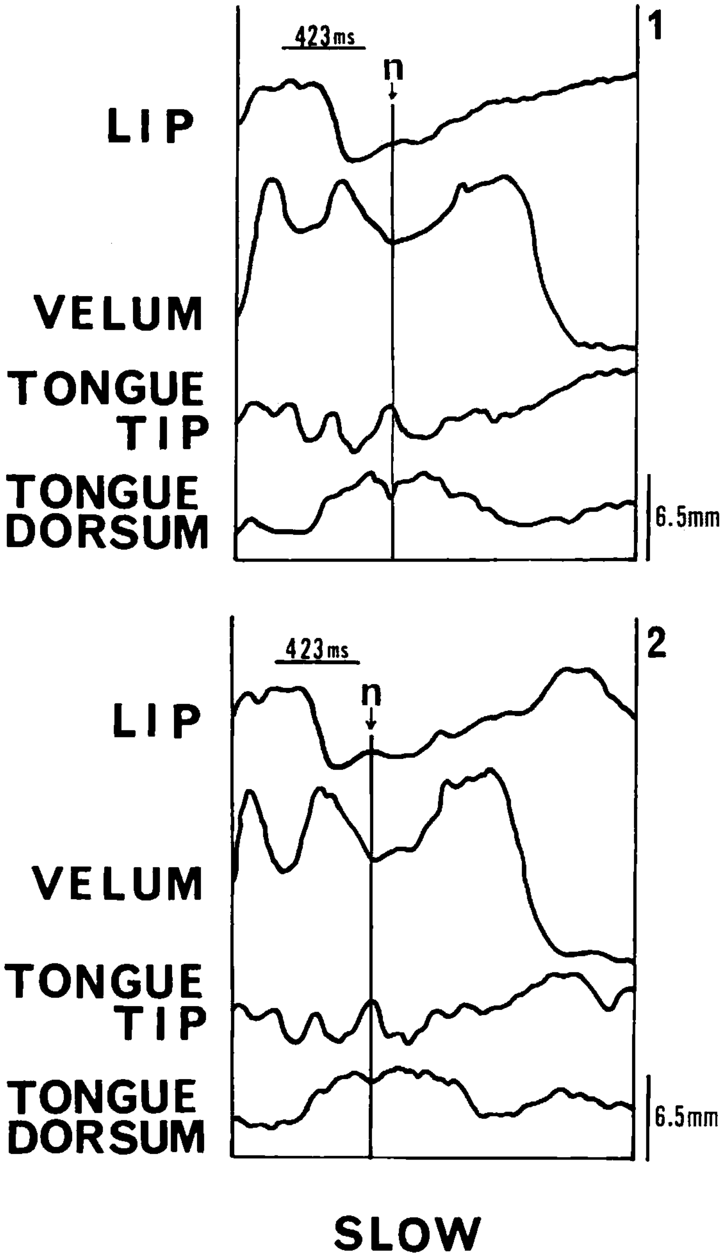
423ms
n
LIP
VELUM
TONGUE TIP
TONGUE DORSUM
1
6.5mm
423ms
n
LIP
VELUM
TONGUE TIP
TONGUE DORSUM
2
6.5mm
SLOW

Fig. 2 (b)

the dip of velar lowering for /n/ corresponds well with the peak of the lip elevation and the dip of the tongue movement. Such a timing relationship does not exist for the utterance shown in Figure 3-2. Namely, the dip of velar lowering for /n/ preceded the peak of the lip elevation and the dip of the tongue movement. In this case, /n/ was denasalized to some degree according to an acoustic evaluation. In the utterance shown in Figure 3-3, the velar lowering for /n/ preceded the peak of the lip elevation again. It can also be noticed here that the velum does not descend as much as in the utterances of Figures 3-1 and 3-2, and /n/ changed to /d/. (The movement of the tongue dorsum was not obtained on this occasion.)

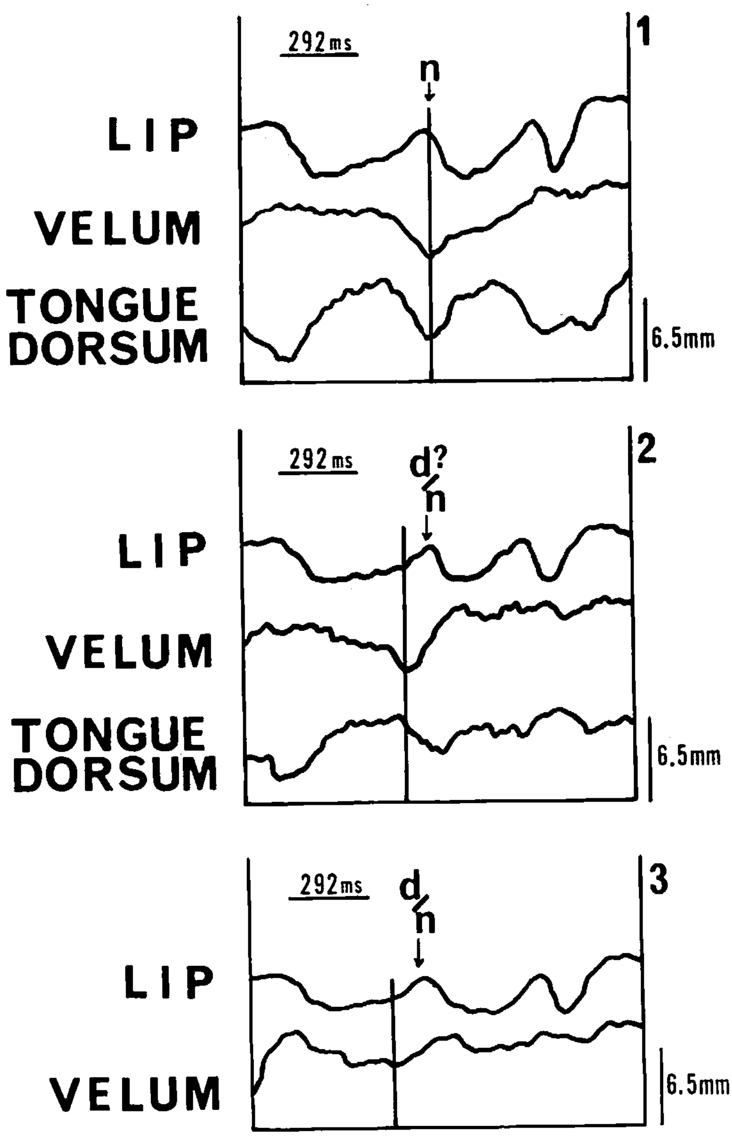

Fig. 3.
Up and down displacements of several articulators of the apraxic subject as a function of time during three productions of /deenee/ in the carrier phrase /---desu/(it is---). The time scale of this figure is different from that shown in Figure 2.

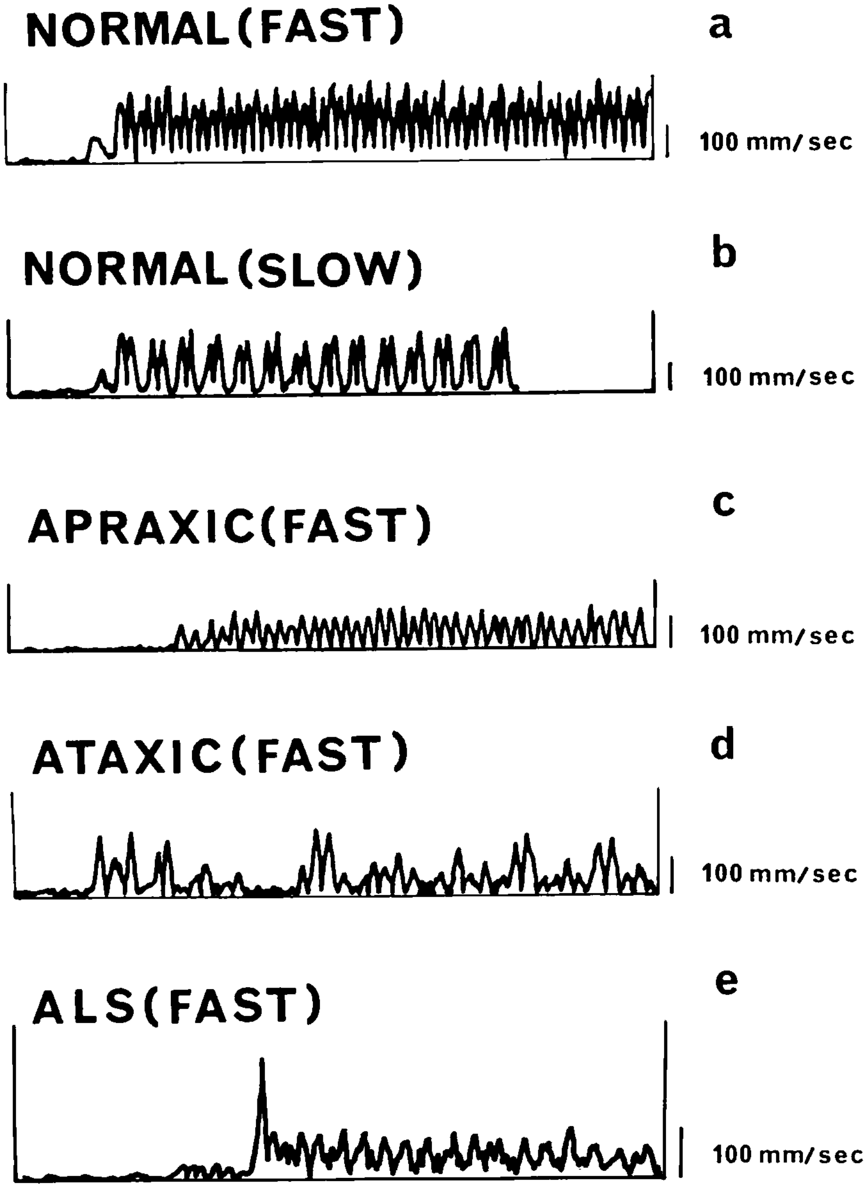

Fig. 4. Comparison of the velocity of lip displacement in the normal subject at a fast rate (a) and at a slow rate (b), in the apraxic subject (c), in the ataxic subject (d) and in the ALS subject (e) for repetitions of /pa/.

2. Velocity of articulators

Figure 4 compares the velocity of lip displacement in repetitions of the monosyllable /pa/ in the normal subject, the apraxic subject, the ataxic subject and a subject with amyotrophic lateral sclerosis (ALS) (a 34-year-old female). While the normal subject repeated /pa/ at two different utterance rates (at his fastest rate and a somewhat slower rate), the other subjects produced the same sequences at their fastest speed. (The data for the normal, ataxic and ALS subjects were taken from Hirose et al., 1978a.) The velocity was obtained by differentiating the displacement through the use of a pertinent computer program.

In the fast rate utterance of the normal subject, the values are quite consistent and high in both the opening and closing directions. On the other hand, the velocity is consistently low in the apraxic subject, i.e., approximately one half the value of the fast rate utterance of the normal speaker and is similar to that of the ALS subject.

Figure 4 further indicates that the slowness of the lip movement of the apraxic subject is different from that of the slow utterance of the normal subject. That is, in the case of the slow repetitions of the normal subject, the velocity of displacement does not decrease remarkably in comparison with that of the fast rate of speech, but the duration of the closure period is simply prolonged.

Table 1. Velocity of the articulators for different articulatory tasks with maximum utterance speed.

Articulators	Types of articulatory tasks	velocity(mm/sec)	
		Normal	Apraxic
Lower lip	Repetitions of /pa/	190-250	81-136
Tongue dorsum	Repetitions of /ka/		56-118
	Repetitions of /ka/ in /pataka/	200-220	
Velum	Repetitions of /teN/	Maximum 105	28-93

It can also be noticed that the velocity is relatively consistent throughout the repetitions of /pa/ in the apraxic subject in comparison with that of the ataxic and ALS subjects. The ALS subject showed less variability when compared with the marked irregularity of the ataxic subject; however, a certain degree of variability still exists.

Table 1 summarizes the velocity of several articulators for the normal and the apraxic subjects for the repetitions of various syllables with maximum utterance speed. (The data for the normal subject were taken from Sawashima and Hirose, 1977.) It appears that the value of the velocity in the apraxic subject is much less than that of the normal subject.

Discussion

The simultaneous observation of several articulators revealed that the temporal organization among different articulators was sometimes disturbed in the production of a word /deenee/ in a carrier phrase in our apraxic subject. It is recognized, however, that such a disorganization was not observed in the repetitions of nonsense syllables. These findings seem to indicate that the motor programming for the temporal organization of different articulators becomes difficult in apraxia of speech under certain conditions such as in the production of complex sound sequences, but not in the repetition of monosyllables which require relatively simple repetitive movements of articulators. It remains to be determined, however, what are the conditions under which the time programming for articulation becomes difficult.

It was also found that the velocity of the articulators of the apraxic subject was consistently low when compared to that of the normal subject. This finding does not agree with DiSimoni and Darley's conclusion as to the rate of movement of the articulators in apraxia of speech (DiSimoni and Darley, 1977). They measured the duration of the segment /p/ in a VCV environment in one apraxic subject and found that the duration of /p/ in their subject was much briefer than that of normal speakers. Based on this observation, DiSimoni and Darley concluded that "while the overall rate of speech measured in words or syllables per second may be slower, the rate of movement of the articulators in the intrasyllabic condition appears to be more rapid in apraxia than in normal speech." Their conclusion is based on the assumption that a briefer segmental duration indicates a more rapid articulatory movement. This assumption is not tenable, however, since a briefer duration does not necessarily indicate a more rapid articulatory movement. Actually, Hirose et al. (1978b, c) found in Parkinsonian patients that the velocity of lip movement gradually decreased while the frequency of repetition increased and syllabic duration became briefer towards the end of the repetitions when they repeated /pa/ with a maximum utterance rate.

The impairment pattern of apraxic speech has been found to be clearly different from that of dysarthria, another type of motor speech impairment which, by definition, is directly related to paralysis or incoordination of the speech musculature (e.g., Johns & Darley, 1970; Darley et al., 1975). The results of the present study agree with these findings. That is, it was found that the articulatory movements of the apraxic subject in the repetition of monosyllables are different from those of the ataxic and ALS subjects in terms of the patterns, consistency and velocity of movements.

Finally, it should be pointed out that a computer-controlled X-ray microbeam system has proved to be a powerful technique for investigating temporal disorganization in apraxia of speech. Additional observations of more patients with this procedure can provide valuable information for a better understanding of the underlying mechanisms of apraxic speech.

Acknowledgment

This study was supported in part by Grants in Aid for Scientific Research (Nos. 140003, 148271, 157515, 248363 and 310707), Japanese Ministry of Education.

References

Darley, F. L., Aronson, A. E., & Brown, J. R. 1975. Motor Speech Disorders. W. B. Saunders.

DiSimoni, F. G., & Darley, F. L. 1977. Effect on Phoneme Duration Control of Three Utterance-Length Conditions in an Apractic Patient. Journal of Speech and Hearing Disorders, 42, 257-264.

Hirose, H., Kiritani, S., Yoshioka, H., Sawashima, M., & Ushijima, T. 1977. A Study of Articulatory Dynamics in the Dysarthrias Part I: Cerebellar Degeneration. Journal of Otolaryngology of Japan, 80, 25-32. (In Japanese).

Hirose, H., Kiritani, S., Ushijima, T., & Sawashima, M. 1978a. Analysis of Abnormal Articulatory Dynamics in two Dysarthric Patients. Journal of Speech and Hearing Disorders, 43, 96-105.

Hirose, H., Kiritani, S., Yoshioka, H., Ushijima, T., & Sawashima, M. 1978b. A Study of Articulatory Dynamics in the Dysarthrias Part II: Parkinsonism. Journal of Otolaryngology of Japan, 81, 547-553. (In Japanese).

Hirose, H., Kiritani, S., Ushijima, T., Yoshioka, H., & Sawashima, M. 1978c. Patterns of Dysarthric Movements in Patients with Parkinsonism. Annual Bulletin, Research Institute of Logopedics and Phoniatrics, University of Tokyo, No. 12, 73-85.

Itoh, M., Sasanuma, S., & Ushijima, T. In press. Velar Movements During Speech in a Patient with Apraxia of Speech. Brain and Language.

Johns, D. F., & Darley, F. L. 1970. Phonemic Variability in Apraxia of Speech. Journal of Speech and Hearing Research, 13, 556-583.

Kiritani, S., Itoh, K., & Fujimura, O. 1975. Tongue-Pellet Tracking by a Computer-Controlled X-ray Microbeam System. Journal of Acoustical Society of America, 57, 1516-1520.

Sasanuma, S. 1971. Speech Characteristics of a Patient with Apraxia of Speech. Annual Bulletin, Research Institute of Logopedics and Phoniatrics, University of Tokyo, 5, 85-89.

Sawashima, M., & Hirose, H. 1977. On the Timing of Articulatory Movements. Transactions of the Committee on Special Research "Language", Japanese Ministry of Education. (In Japanese).