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VELAR MOVEMENTS DURING SPEECH IN A PATIENT WITH APRAXIA OF SPEECH

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Apraxia of speech has been defined as a disorder of motor programming for speech (Darley, 1968) and can be diagnostically differentiated from aphasia or dysarthria (Johns and Darley, 1970). The disorder, however, has only recently been investigated in a systematic way and its nature is still not well understood.

A deeper understanding of apraxia of speech is not only vitally important for establishing the diagnostic as well as the therapeutic procedures for the disorder but also provides important information concerning the role of higher cortical functions in speech production.

It is our belief that direct observations of the articulatory gestures in apraxia of speech are necessary for obtaining an accurate picture of this syndrome and for gaining further insight into its underlying neuropsychological or neuro-physiological mechanisms. As a first attempt at such observations, we analyzed velar movements during speech in a patient diagnosed as having apraxia of speech.

1. Method

1.1. Subject

The experimental subject, Mr. K., was a 61 year-old male with apraxia of speech and the control subject was a 51 year-old male who was free from any speech or hearing disorders. Mr. K. suffered a stroke due to cerebral thrombosis on March 14, 1970. 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). In August 1976, six years after the onset, computerized axial tomography (CT scan) revealed an infarct involving the cortical surface near the anterior tip of the Sylvian fissure of the left hemisphere and immediately subjacent subcortical white matter.

1.2. Procedure

A fiberscopic observation of velar movements during speech was made according to the procedure developed by Sawashima et al. (1971). The velar view was photographed with a 16-mm cinecamera at a rate of 50 frames per second with simultaneous recording of the speech signal and synchronization time marks. Oscillographic traces of the speech signal with the time marks were made to obtain the correspondence between film frames and speech sounds. Three kinds of speech materials were prepared: nonsense syllables, meaningful words and a meaningful sentence. The nonsense syllables were /teNteNteNteN/, where /N/ was the syllable final nasal in Japanese. The meaningful disyllabic words were combina-

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tions of the vowel /e/, nasal sounds /n/ and /N/, or nonnasal consonants: /deenee/, /seenee/, /seeneN/, /teeneN/, /teedeN/, /see'eN/, /teN'ee/ and /see'ee/. None of these words contain any accent kernel. These words were embedded in a carrier phrase of /----desu/ (it is----). The meaningful sentence was /darumani ookina medamao ireru/. The subjects were requested to read these speech materials at a conversational rate, which was demonstrated by the experimenter. The subjects read the nonsense syllables and the sentence three times and each of the meaningful words in the carrier phrase five times.

2. Results

2.1. General Patterns of Velar Movements During Speech

The patterns of velar movements during speech obtained from the normal subject are in general agreement with those obtained from the normal subjects in Sawashima et al.'s study (1976). On the other hand, the patient with apraxia of speech exhibited unique articulatory movements of the velum to be described in the following.

2.1.1. Consistency of Velar Movements

In Figure 1 the patterns of velar movements under different phonetic environments are plotted as functions of time for the normal subject (left) and for the apraxic subject (right). The ordinate gives an arbitrary scale for the velar height and the abscissa the time course. The short vertical bars across the curve indicate the voice onset or offset, which were obtained from the audio signal. The thick long vertical bars indicate the voice onset of /e/ after the initial nonnasal consonant, which served as the line-up point for a comparison among several velar patterns under different phonetic environments.

The top two illustrations (a and b) of Figure 1 present superimposed patterns of velar movements for three repetitions of /teNteNteNteN/ and the rest of the illustrations present superimposed patterns of velar movements for five repetitions of /deeneedesu/ (c and d) and /teedendesu/ (e and f).

The normal subject shows regular oscillatory movements of the velum in /teNteNteNteN/. That is, in each cycle of the velar movement, there is a peak of elevation for /t/ followed by a marked descent for /N/, and the segmental durations of /t/, /e/ and /N/ are relatively invariable throughout the four repetitions of /teN/. In addition, there is a high degree of agreement in terms of velar patterns for the three repetitions of the task. On the other hand, the apraxic performance is characterised by less regular oscillatory velar movements with a marked variation in velum height and segmental duration. Moreover, the velar pattern varies considerably throughout the three repetitions of the task.

Similar results were obtained from repetitions of meaningful words. While the normal subject exhibited a high degree of consistency through five repetitions of a given word, the apraxic patient showed a great variability. Such a variability was observed both in the velum height and the duration of phonemic segments. For example, through five repetitions of /deeneedesu/ the slope of velar lowering for /n/ varies considerably,

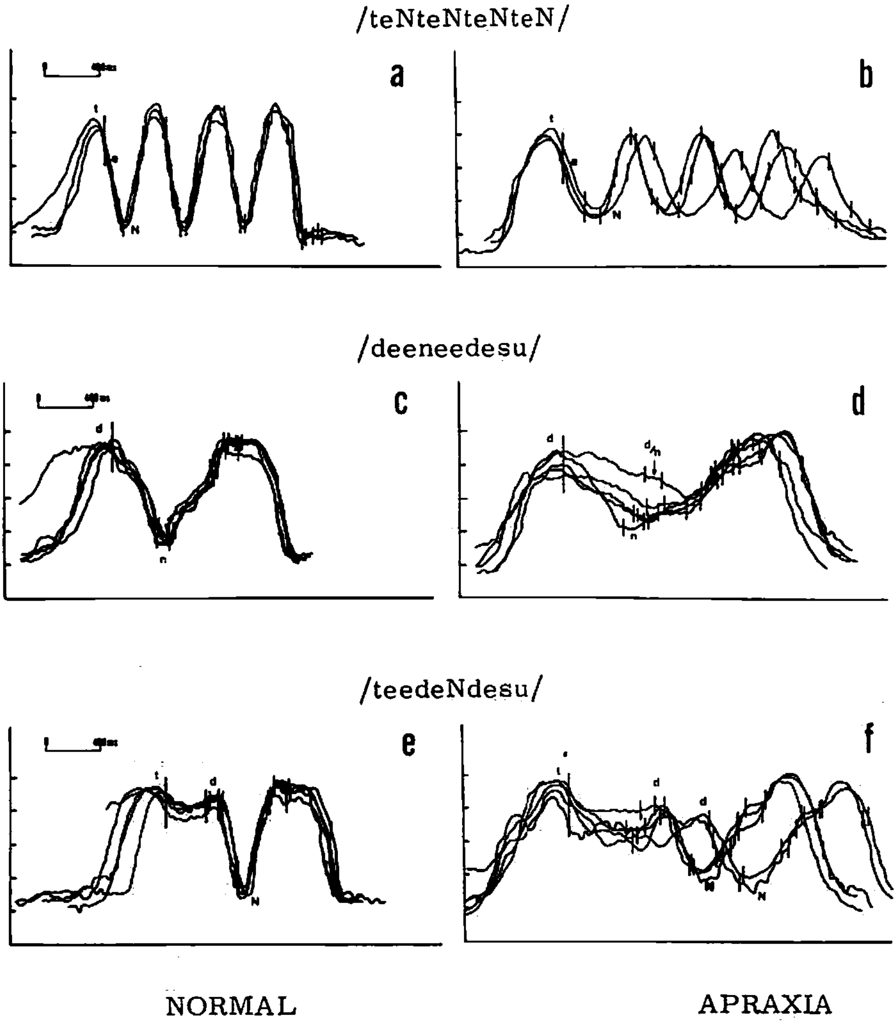

Figure 1. Movements of the velum during the production of /teNteNteNteN/, /deeneedesu/ and /teedeNdesu/.

accompanied by an inconsistent phonetic change from /n/ to /d/ (Figure 1, d). In addition to such a variability, there are apparent differences in the segmental durations, especially of the vowel segments. In spite of such a variability, however, a general successional pattern of velar movements, that is, a marked descent for /n/ followed by an elevation for /ee/, is preserved well throughout five productions of /deeneedesu/.

A similar observation was made for /teedeNdesu/ (Figure 1, f). At first glance, it appears that the movement pattern of the apraxic patient is quite irregular. A general successional pattern for this utterance is preserved here too, however, i.e., the velum is kept in a high position during the production of the segments /t/ through /d/, then it abruptly descends for /N/, followed by a velar elevation for /desu/.

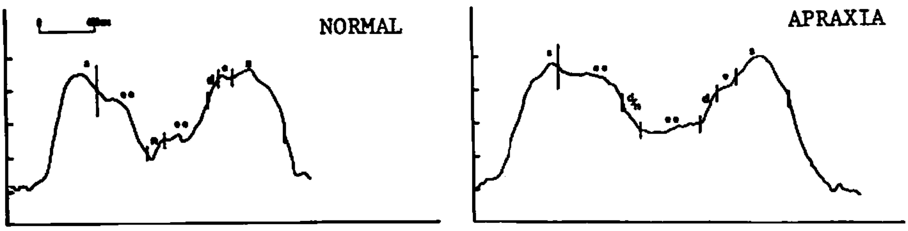

Figure 2. Movements of the velum during the production of /seeneedesu/.

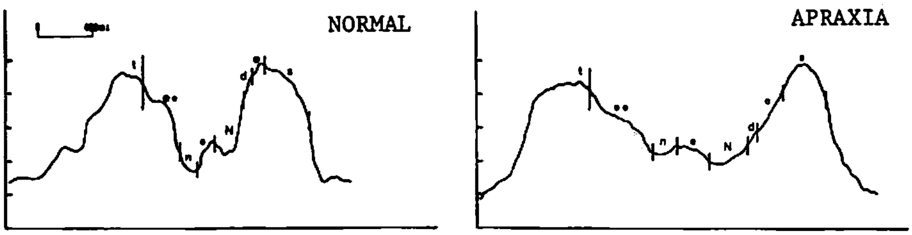

Figure 3. Movements of the velum during the production of /teeneNdesu/.

2.1.2. Velar Height of Nasal and Nonnasal Consonants.

As a second characteristic of apraxic movements, it was observed that during the production of nasal and nonnasal consonants the velum tended to take what might be called neutral positions (neither low nor high). For example, in /seeneedesu/ of the normal subject (left side of Figure 2) the velum positions for nonnasal consonants /s/ and /d/ are kept high and those for the nasal consonant /n/ are kept low. The velum height for /n/ does not necessarily reach the rest position, but is considerably lower than for either vowels or nonnasal consonants. On the contrary, in the utterance of the apraxic patient (right), the velum height of /d/ is quite low, while that of /n/ is high, resulting in a phonetic change from /n/ to /d/.

A similar result was obtained for /N/. As will be seen in Figure 1, a and e in the normal's utterances the velum height of /N/ is quite low, reaching or approaching the rest position. In contrast, the velum position of /N/ in the apraxic utterances is considerably higher, as shown in Figure 1, b and f.

Finally, as Figure 3 indicates, a considerable change in velar height takes place during the time course of the syllable final /N/ and the vowels /ee/ in the normal's utterance. In the apraxic utterance, however, the velar position during the production of /N/ does not vary much.

2.1.3. The Pattern of Velar Movements During Sentence Production

Figure 4 compares the patterns of velar movements during the production of the meaningful sentence /darumani ookina medamao ireru/ of the normal subject (top) and the apraxic subject (bottom). In the normal utterance, in spite of the fact that the velum positions for the nonnasal consonants are somewhat lower than those in the nonsense syllables and meaningful words in the carrier phrase, the velum positions for nasals are kept low enough, resulting in a clear distinction between the velum positions for nasals and nonnasals.

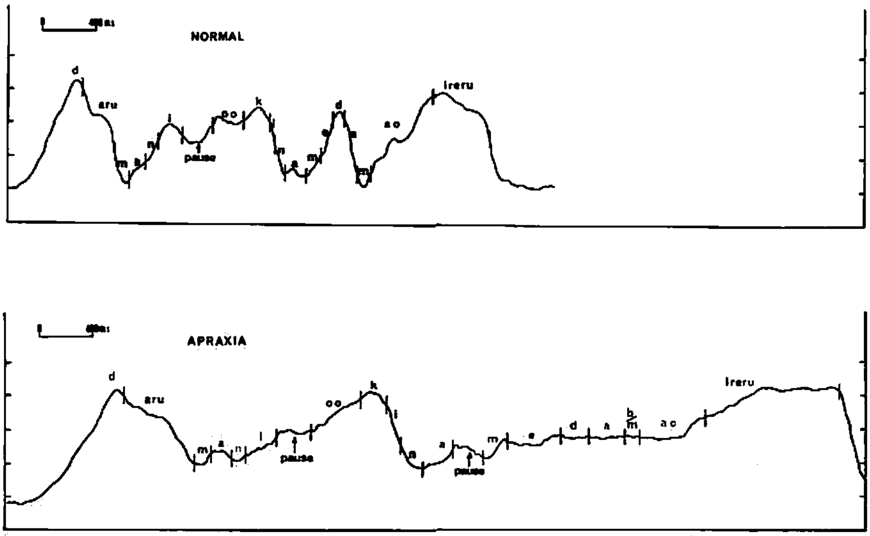

Figure 4. Movements of the velum during the production of the sentence /darumani ookina medamao ireru/.

On the other hand, the apraxic utterance revealed an abnormal pattern of velar movements during sentence production. That is, during the segment of /medamao/, the velum stays in a neutral position, viz, the velum does not descend or ascend. As a result, the velum positions for /m/, /d/ and vowels have become almost identical. This peculiar phenomenon was observed through three productions of the sentence in the apraxic patient. Furthermore, the duration of the last half of the sentence, which includes the segment of /medamao/, is extremely lengthened in comparison with that of the normal subject. Namely, the duration of the last half of the sentence; i.e., from /m/ after the second pause to the end of the sentence, is stretched to twice as much as that of the normal subject, while the duration of the first half of the sentence; i.e., from the voice onset of /a/ after the initial /d/ to the voice offset of /a/ in /ookina/, is about 1.5 times as long as that of the normal subject. Moreover, the second /m/ of /medamao/ is replaced by /b/.

2.2. Anticipatory Coarticulation of the Velar Movements

The contextual influence of one speech segment upon another has been described as coarticulation (Daniloff and Hammarberg, 1973). The coarticulatory phenomenon, especially anticipatory coarticulation, is regarded as some manifestation of cortically generated motor programming. Data of the present study might be examined from a coarticulatory point of view also.

Figure 5 compares the patterns of velar movements of /see'eedesu/, /seeneNdesu/ and /see'eNdesu/. In the normal's utterances (left), the velum is kept in a high position for the nonnasal phonetic environment

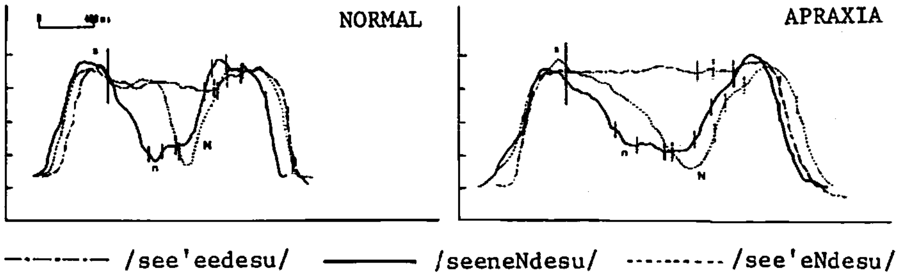

Figure 5. Movements of the velum during the production of /see'eedesu/, /seeneNdesu/ and /see'eNdesu/.

/see'eedesu/, indicated by a dashed line, while for /seeneNdesu/, shown by a solid line, the velum lowering for /n/ starts already at a time point near the /s/-/e/ boundary. This is the anticipatory coarticulation of velar lowering. The velar opening coarticulates over two vowels preceding the nasal. A similar phenomenon is also shown in the apraxic utterance (right). This anticipatory coarticulation was consistently observed in all of the /CVVN----/ sequences, such as /deeneedesu/, /seeneedesu/ and /teeneNdesu/ both in the normal and apraxic utterances. On the other hand, in /see'eNdesu/ (a dotted line) of the normal subject the velar lowering is not initiated immediately at the start of the first vowel in the sequence. The velum keeps its high level for a certain period of time after the onset of the first vowel as in /see'eedesu/. In /see'eNdesu/ of the apraxic patient, however, the velum starts its lowering movement at the very beginning of the first vowel, or near the /s/-/e/ boundary, reducing the distinction between the patterns of velar movements for /see'eNdesu/ and /seeneNdesu/ to a minimum.

3. Discussion

An important finding obtained from this study is that, in spite of a marked variability in the pattern of velar movement when the patient repeated the same word several times, the general successional pattern of velar gestures for a given phonetic context was preserved well. For example, in /deeneedesu/, there is a wide variation of the slope of velar lowering for /n/ as well as of the durations of the vowel segments between /d/ and /n/, even accompanied at times by a phonetic change from /n/ to /d/. Despite such variability, the pattern of the anticipatory velar lowering for /n/ is consistently preserved in repeated utterances. This result seems to indicate that the observed variation of the pattern of velar movements and the resultant phonetic change do not stem from selection errors of target phonemes in the process of speech production, namely, errors of phonological processing.

In order to realize a given value of the velum height for a given phoneme under different phonetic environments, motor commands must be organized in such a way that all the relevant factors including degrees of variations of the velum height and velocities of velar elevation or lowering are taken into consideration. In fact, EMG and fiberscopic observations of velar movements during speech in normals indicated that in different phonetic environments and at different speaking rate conditions, the nasality feature seemed to be realized by a high-level organization or reorganization of the input commands to the velum (Ushijima and Hirose, 1974; Sawashima et al., 1976; Ushijima et al., 1976). In view of these observations and the present findings, it appears that the mechanism responsible for such an organization (or reorganization) of neural commands is not functioning appropriately in apraxia of speech.

Besides such a problem, we assume that the motor programming for the synchronization of different articulators is disturbed in apraxia of speech. As Figure 1, d indicates, when the apraxic patient repeated /deeneedesu/ five times, the durations of the vowel segments between the initial /d/ and /n/ varied considerably and the intended target phoneme /n/ was replaced by /d/ in one occasion. Furthermore, after the substitution occurred, the velum continued to descend for a certain period of time. Our interpretation of these events is that the time schedule of the velar lowering for /n/ is not synchronized well with the time schedule of the tongue tip movement for alveolar closure due to a disturbance of the motor programming for such a synchronization. This interpretation is based on the assumption that a motor program issues neuromotor commands for different articulators in such a way that the movements of two or more articulators occur in highly synchronous fashions (Kent at al., 1974).

Further study with simultaneous observations of different articulators is needed to examine the disturbance of time programming for articulation in apraxia of speech.

The finding that an abnormal velar movement was exhibited in the apraxic subject during the production of the last half of the sentence may have some relationship to the phenomenon that apraxic subjects make more errors in longer utterances than in shorter ones (Johns and Darley, 1970; Sasanuma, 1971). Since the velar elevation and lowering were observed after the segment of /medamao/, throughout which the velum stayed in a neutral position, this abnormal velar behavior cannot simply be attributed to easy fatigability of the velum. Rather it would suggest that for the apraxic patient motor programming for speech becomes difficult beyond a given length of utterance; i. e., the span of motor programming for speech becomes considerably shortened. In order to examine this assumption, further study with sentences of various length is necessary.

The results described in Section 2. 2 indicate that even in the patient with apraxia of speech, the so-called "look-ahead" principle or "future scanning" mechanism seems to be operating, so that articulatory gestures for the following segments are brought into the preceding segments. It is worthy of note, however, that the delayed anticipatory lowering of the velum for the nasal in the /CVV'VN/ environment, which was observed in the normal's utterances, wes not evident in the apraxic utterances, shown in Figure 5. The phenomenon of delayed onset of anticipatory coarticulation which is in conflict with Moll and Daniloff's (1971) model of nasal coarticulation, has been already observed by Ushijima and Hirose (1974) and Sawashima et al. (1976). No persuasive explanation for this phenomenon has been offered so far, however. If anticipatory coarticulation gives a listener some perceptual cues for identifying the following segments as Moll and

Daniloff (1971) suggested, the "restriction", which seems to be specific only to /CVV'VN/ in Japanese, might well be the result of a "deliberate" reorganization of the neural commands. If this is the case, it is interesting to see that this delayed onset of coarticulation is not observed in the utterances of the apraxic subject.

According to Sasanuma (1971) who made a phonological analysis of Mr. K.'s speech at seven months after the onset of the illness, predominant types of articulatory errors made by him at that time were metatheses and substitutions across word boundaries. Based on such an analysis, she concluded that "the impairment was not confined to the motor aspects of speech --- but extended into the linguistic (but almost exclusively phonological) spheres as well."

As Mr. K. recovers, however, such errors as reflecting a phonological (linguistic) impairment have diminished to almost none at the time of this study. Thus, the pattern of disorders demonstrated by him in this study can be said to represent the more or less "pure" form of apraxia of speech as defined by Darley (1968).

4. Summary and Conclusions

To obtain an accurate picture of the syndrome called apraxia of speech and to gain some insight into its underlying mechanisms, a fiberscopic observation of velar movements during speech was made of a patient diagnosed as having apraxia of speech. Major findings included the following: (1) repeated utterances of the same word showed a marked variability in terms of the pattern of velar movements accompanied by inconsistent phonetic changes; (2) in spite of such a variability, however, the general successional pattern of velar gestures for a given phonetic context was preserved well within the normal range; (3) during the production of nasal and non-nasal consonants the velum tended to take what might be called neutral positions (neither low nor high); (4) anticipatory coarticulation was present, but some deviation from normal patterns was occasionally observed; and (4) abnormal velar movements were observed during sentence production.

These findings are interpreted to indicate that the mechanism responsible for the organization (or reorganization) of neural commands and for the time programming of articulators is not functioning appropriately in this subject with apraxia of speech. In order to gain more insight into the nature of such a disturbance, it is necessary to extend our observations to the behaviors of other speech organs with simultaneous observations of different articulators.

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