Electromyographic Studies of Articulation in Aphasia*
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Impairments of articulation pose a major problem in the rehabilitation of many patients with brain damage. Articulatory defects, rather than reduced vocabulary and errors of syntax, constitute the chief residual impairment in many cases of cortical lesion due to stroke in the left cerebral hemisphere. The patients are unable to produce the sounds words are made of with sufficient accuracy and speed, though their ability to comprehend speech may be unaffected. Speech is extremely effortful and slow, not because the patient cannot retrieve the word he needs, but because the machinery for producing speech sounds no longer functions properly. When the wrong sounds are substituted for the ones intended, intelligibility is reduced, sometimes to the vanishing point. This condition, which is sometimes called "cortical dysarthria" and "apraxic dysarthria," must be distinguished from dysarthric disorders arising from damage restricted to lower levels of the motor system. We have chosen to call the syndrome "phonetic disintegration" following Alajouanine and his associates.¹,² The disorder is familiar to everyone concerned with rehabilitation of stroke patients, yet remarkably little is known about it.³

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Precise information as to which gestures of speech are defective and the physiological basis of the defects is a requirement for rational therapy. Certainly the greatest obstacle to understanding articulatory disorders has been insufficient knowledge of the dynamics of articulation in normal speech. Our approach reflects the belief that the best way to learn about speech mechanisms in general is to study normal speakers together with well-chosen clinical cases, using the same strategy and methods for investigating both.

The preliminary findings presented here are a part of a larger ongoing comparative study of articulatory function in cases of damage at different levels and sites in the sensorimotor system. Our program has two related aspects: we have first tried to gain an accurate picture of the kinds of errors of articulation which occur in the syndrome of phonetic disintegration associated with "motor" aphasia. Secondly, we have begun to study directly the gestures of speech in order to relate the phonetic description of the disordered speech output to the parameters of muscle movement. In the first aspect of our studies, we have relied on the conventional methods of articulation testing; in the second phase, we have used the technique of surface electromyography (EMG). EMG, as we shall see, is a technique of great power, but it allows us to examine only a very limited field at any given time. Therefore its successful application depends upon the care and thoroughness with which we have prepared the way for its use by prior identification of the salient features of the disorder.

Before beginning EMG studies on patients with phonetic disintegration, we carried out a detailed phonetic study of the
speech of five patients who exhibited the syndrome. This work has been described elsewhere, but we should indicate briefly the method and summarize the principal findings before turning to the myographic studies now in progress.

In the completed investigation, we studied five patients with lesions of vascular origin involving the anterior portion of the dominant left cerebral hemisphere. All were patients of the Institute of Rehabilitation Medicine of New York University Medical Center. The group was composed of intelligent individuals with business and professional backgrounds, selected for their willingness to engage in intensive speech therapy. Each had suffered a stroke six months to seven years prior to the examination, followed by right hemiparesis and severe expressive aphasia with preservation of comprehension. At the time of testing, aphasic symptoms were greatly diminished, leaving a major residual deficit in articulation.

The patients' ages ranged from 39 to 61 years; three were under 50. None presented difficulties of chewing or swallowing. All were able to perform movements of the lips, face and tongue on command, but with less than normal dexterity and speed. No cerebellar signs were present and there was no evidence of lower motor neuron paralysis. Audiometry revealed hearing within normal limits. No patient showed evidence of generalized intellectual deterioration.

Although very different degrees of recovery of speech are to be found in the group, the sequence of events during recovery was similar for all. All patients had reached a definite plateau at the time of testing.

Our contacts with the patients over a long period of time
had convinced us that they were nearly intact in comprehension of speech. Nevertheless, we wished to subject this question to a controlled test in order to be fully satisfied that the errors of articulation are attributable to impaired motor organization and control and were not due to receptive aphasia. A speech perception test was used to discover whether the acoustic cues which signal phonemic differences could be utilized normally by these patients. Two of the patients performed as well on this test as their therapists. The others were less accurate, but we were able, in general, to rule out receptive impairment as a factor contributing to the patients' difficulties in speaking.

Articulatory function was assessed by a test consisting of 200 tape-recorded words of one syllable, chosen to give even coverage of the major speech sounds in English. The patient heard each word once through earphones and was required to repeat the word back. The patients' responses were tape recorded so they would be permanently available for study. The recorded utterances were transcribed by a phonetically-trained listener. These were then broken down into their component sounds and tabulated so as to show the frequency with which each sound was "correctly" produced or replaced by another sound. On those instances in which a wrong sound was substituted for the "correct" sound, the method allows us to discover whether certain substitutions occur consistently. From this information we can begin to infer what the patient can and cannot do with the articulators when he attempts to speak.

Figure 1 summarizes the tabulations for the five patients. Each word can be broken down into its initial consonant sound (or sounds), a vowel nucleus, and a final consonant sound (or
Fig. 1. Speech production test: percent correct for each indicated class of sounds for each patient.
sounds). The figure shows the tabulation of the total number of sounds "correctly" produced in each position in the word for every patient. It is apparent that the errors of articulation are not evenly distributed throughout the word. Not surprisingly, linked groups of consonants, such as [kl] (as in "clean") and [sm] (as in "smile") were more difficult to produce adequately than single consonants. Sounds at the initial portion of words were usually produced more defectively than sounds in final position. Note that one patient failed to produce any initial consonant linkage intelligibly. The vowel portions of words were produced with strikingly greater accuracy than the consonant portions. This argues against any selective impairment of the tongue.

Considering the five cases as a group, there is a great deal of variability in the pattern of sound substitutions which occur, but some sounds were consistently misarticulated. The fricatives and affricates [θ] as in "thin"; [ʃ] as in "shoe"; [ʒ] as in "then"; [tʃ] as in "chin"; [ŋʒ] as in "just", together with linked groups of consonants were most often misarticulated. The difficulty in producing fricative and affricate sounds is shared with many other disorders of articulation. These sounds require the use of more muscles and closer control of the amount and timing of movement than any other class. We concluded that no particular structure or region can be implicated to the exclusion of other parts of the articulatory apparatus. All the findings point to a disturbance of coordinated sequencing of several articulators.

Certain wrong articulations regularly occurred which nevertheless could be identified as the intended sound. For
example, consonant clusters involving [l] were usually split up by the insertion of a vowel as [paliz] for "please". The resulting word sounds defective but its intelligibility is preserved. These stereotyped substitute productions give us valuable hints as to the mechanisms of compensation after damage to the motor cortex. Knowledge of these mechanisms would permit us to discover which features of normal articulation are essential for recognition of the intended sound and which are not. It would also help the therapist to teach the patient to make the best use of his remaining capacities.

Our studies of phonetic disintegration have shown that a good deal can be inferred indirectly about articulatory movements from listening to speech under controlled conditions. One ought, however, to be able to learn much more by studying the motor processes directly. That is why we moved on to electromyography. In the time remaining, we will describe our work in progress using this technique. EMG is especially suited to the analysis of speech movements, since it gives graphic information about the electrical activity which accompanies muscle contraction. The group at Haskins Laboratories have developed a system for recording speech movements and have obtained some knowledge of patterns of muscle action in normal speech. We believe the technique can now profitably be used to study certain speech disorders.

Since our interest is in making measurements of overall muscle activity rather than in recording from single fibers, we have used surface electrodes instead of the more familiar needle electrodes. The need to have electrodes on the tongue and lips and inside the mouth which would stay in place during repeated speech movements led to the development of a system using small
Fig. 2. Electrode placements on the lips and tongue for surface EMG.
vacuum cups as electrodes. A flexible tube leading from the electrode is attached at its other end to a manifold where vacuum and electrical connections are made. The muscle potentials are amplified, rectified and smoothed before being fed to a penwriter and a sixteen-channel tape recorder. A throat microphone placed against the thyroid cartilage records periods of voicing during speech.

Myographic recordings of speech have been made for two patients who had been thoroughly investigated in the first study. We were encouraged to discover several points of agreement between the EMG data and the earlier findings. Fig. 2 shows the placement of the electrodes used in this study. Electrodes were placed at three locations on the lips and three on the tongue: (1) upper lip just to the left of the midline, (2) corner of the mouth, (3) lower lip near the midline on the left side, (4) on the back of the tongue on the mesial dorsal surface, (5) on the tongue blade, and (6) on the front of the tongue. A seventh electrode was placed under the chin beneath the hyoid bone.

After allowing sufficient practice for the patient to become accustomed to speaking with the electrodes in place, we began the experiment. The task consisted of repeating one-syllable words much the same as before. Twenty words were presented to the subject in five random orders, so that each word was repeated five times during the session, but always preceded and followed by a different word.

Fig. 3 shows a comparison of a severely affected speaker (JG) and a normal subject (KSH) saying "peep." The figure shows superimposed traces for five utterances of the word. Time in msec is shown on the horizontal axis and the vertical axis
Fig. 3. Comparison of superimposed EMG traces of the utterance "peep" for the patient JG and Normal speaker KSH.
displays a measure of voltage. The heavy line shows the duration of voicing obtained from the throat microphone traces. The arrow marks the onset of voicing, and this was taken as the line-up point when traces were superimposed. For the normal speaker shown at the top of the figure, the pattern generated by different utterances of the same word is gratifyingly consistent in form. The consonants [m,p,b] are distinguished by characteristic lip action which involves a lip closing movement followed by a lip opening movement, both executed in precise coordination with movements of the velum and glottis. Earlier work 8 has shown that any location on the upper lip, near the vermilion border, showed a large peak in activity during the closing gesture, and any location below the lower lip showed a peak for the opening gesture. The electrical activity at the upper lip starts well before lip closure and peaks when the lips make contact. Peak voltages at the tongue electrodes occur during the vowel portion of the word. We have enough evidence to show that the muscles involved, the relative amounts of activity and the timing of events show considerable similarity for different normal speakers.

In contrast, the patient, whose tracings are displayed in the lower half of the figure, does not show distinct peaks at the lip electrodes for the bilabial stop consonants. Instead, there is only one peak at the lip electrodes, which resembles the tongue activity in form, and occurs, most abnormally, during the vowel. The peak voltage at all electrodes occurred at about the same point in time. The expected temporal differentiation between tongue and lip action was not found. Instead, the patient produced a poorly-differentiated movement of all the articulators en bloc.
Fig. 4. Comparison of superimposed EMG traces from electrodes on the upper and lower lips in production of labial consonants [m] and [n] by patients JG and HL and normal speaker KSH.
Fig. 4 shows only the lip traces for the beginning portion of the utterance "mean," which begins with a bilabial consonant, and the utterance "neat," which begins with a non-bilabial. The normal subject shows discrete voltage peaks from both lips during the formation of [m], as we indicated earlier. Note the characteristic absence of upper lip activity for a non-bilabial sound, [n] in "neat." Patient JG does not have clearly contrasting distinctive gestures for these consonants. Data from the second patient, HL, are shown on the right side of the figure. Her traces are less grossly deformed than JG's but discernably abnormal. The lower lip activity for both consonants is poorly organized. A clear voltage peak at the upper lip is shown for [m], but on one occasion she produced an inappropriate peak for [n] where there should be none.

We were reassured to discover that the gross appearance of the EMG traces corresponds to judgments of intelligibility of the speech of these two patients, inasmuch as JG sounds much more impaired than HL.

Fig. 5 examines EMG traces of bilabial stop consonants in initial and terminal position for patient HL. At the top of the figure are shown lip electrode records for "peep," a word which begins and ends with the same bilabial stop consonant. The lower lip activity appears less diffuse and better organized for terminal [p] than for initial [p]. The same observation can be made in two words, "bag," which begins with the bilabial stop consonant [b], and "plebe," which ends in the same sound. Here it can be seen that [b] in "plebe" is more discrete and better formed than [b] in "bag." The results of these pilot studies agree with the indications obtained by conventional phonetic
Fig. 5. Comparison of superimposed EMG traces from the lip electrodes in production of labial stop consonants in initial and terminal position (patient HL).

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peep

1

2

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bag

1

2

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pilebe

1

2

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Time in Msec.

------Duration of Voicing
description in suggesting that consonants at the beginning of words are more poorly articulated than those at the ends of words.

In summary, (1) traces for both patients with phonetic disintegration are grossly abnormal in form. (2) Repeated utterances of the same word show great variability in the timing of sequential movements. (3) Vowels were prolonged and variable in length. (4) Labial consonant sounds in initial position were more defectively formed than in terminal position by one patient. The other patient could not produce identifiably distinctive lip gestures for labial consonants. The occurrence of simultaneous peaks from all electrode locations shows a striking reduction of the capacity for independent movement of the articulators. The EMG, in addition to yielding good agreement with other means of description, has provided valuable information about the temporal and spatial organization of defective speech gestures which could not have been obtained by methods of analysis which start from the acoustic end-products of speech.

References


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