

Electromyographic Studies of Articulation in Aphasia

Donald Shankweiler, Ph.D.

Katherine S. Harris, Ph.D.*

and

Martha L. Taylor, M.A.**

New York, N.Y.

* Phonetic studies of speech production were made on five patients with residual articulatory disorder after damage to the left cerebral hemisphere resulting from stroke. Analysis of misarticulated words led to the identification of those classes of speech sounds which were consistently produced defectively. This information was used to guide direct investigation of the disordered movements in articulation. Pilot studies of muscle action in speaking were conducted on two of the patients and a normal speaker using the technic of surface electromyography. The electromyographic data obtained were in good agreement with other means of description. This technic provided valuable information about the temporal and spatial organization of normal and defective speech gestures that could not have been gained by methods of analysis which start from the acoustic end-products of speech.

Impairment of articulation poses 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 patients with cortical lesion resulting from stroke in the left cerebral hemisphere. The patients are unable to produce the sounds necessary to form words with sufficient accuracy and speed, although 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 beyond comprehensibility. This condition, which sometimes is called "cortical dysarthria" and "apraxic dysarthria," must be distinguished from dysarthric dis-

orders arising from damage restricted to lower levels of the motor system. We have chosen to call the syndrome "phonetic disintegration" according to the nomenclature of Alajouanine and associates.^{1,2} The disorder is familiar to everyone concerned with the rehabilitation of stroke patients, yet remarkably little is known about it.³

Precise information regarding which gestures of speech are defective and the physiologic basis of the defects are requirements 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 subjects, using the same strategy and methods for investigating both.

The preliminary findings presented here are part of a larger ongoing comparative study of articulatory function in patients with damage at different levels and sites in the sensorimotor system. Our program has two related aspects: We have tried first to gain an accurate picture of the kinds of errors of articulation that occur in the syndrome

Staff psychologist, Haskins Laboratories.

*Staff psychologist, Haskins Laboratories; Adjunct Professor, City University of New York.

**Director, Speech Pathology Service, Institute of Rehabilitation Medicine, New York University Medical Center.

This research was supported in part by grants to Haskins Laboratories from the National Institute of Dental Research (DE-01774-08) and from the National Institute of Child Health and Human Development (1 PO1 HD01994-01), and, in part, by a Rehabilitation Research and Training Center Grant (RT-1) from the Vocational Rehabilitation Administration, U.S. Department of Health, Education, and Welfare to the Institute of Rehabilitation Medicine, New York University Medical Center.

Presented at the Forty-Fourth Annual Session of the American Congress of Physical Medicine and Rehabilitation, San Francisco, August 31, 1968.

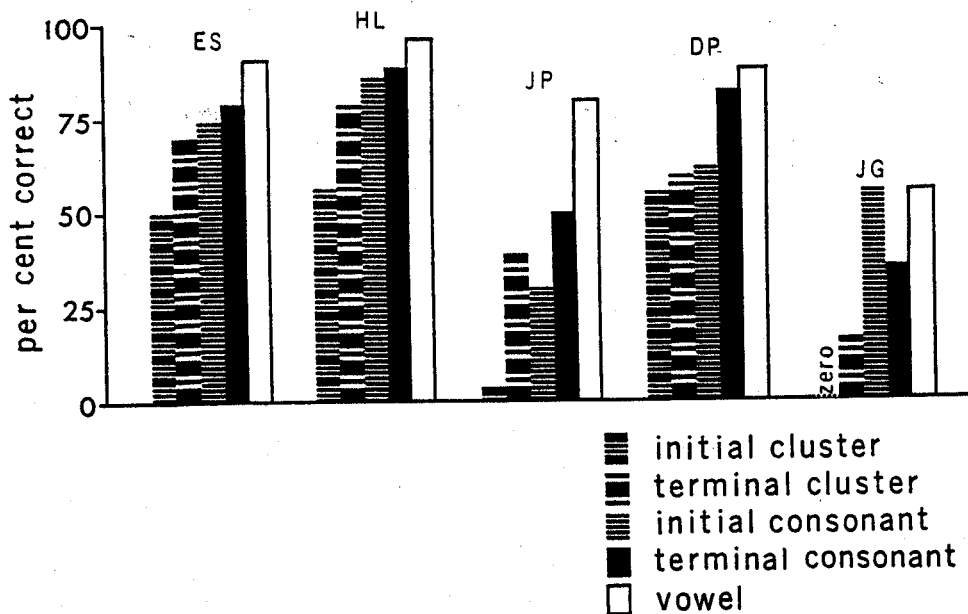


Fig. 1—Speech production test: per cent correct for each indicated class of sounds for each patient.

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 technic of surface electromyography (EMG). Electromyography, as we shall see, is a technic of great power, but it allows us to examine only a very limited field at any given time. Therefore, its successful application depends on 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 electromyographic studies on patients with phonetic disintegration, we conducted a detailed phonetic study of the speech of five patients who exhibited the syndrome. This work has been described elsewhere,⁴ but we should indicate briefly the method and summarize the principal findings before turning to the electromyographic studies now in progress.

In the completed investigation, we studied five patients with lesions of vas-

cular 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 6 months to 7 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 less than 50 years of age. 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 were 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 had convinced us that they were nearly normal in comprehension of speech. Nevertheless, we wished to subject this question to a controlled test to be fully satisfied that the errors of articulation are attributable to impaired motor organization and control, and are not due to receptive aphasia. A speech perception test⁵ was used to learn whether or not the acoustic cues that 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. 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 then were broken down into their component sounds and tabulated to show the frequency with which each sound was "correctly" produced, or replaced by another sound. In the instances in which a wrong sound was substituted for the "correct" sound, the method allowed us to learn whether certain substitutions occurred consistently. From this information we could infer what the patient could or could not do with the articulators when he attempted to speak.

Tabulations for the five patients are presented in figure 1. Each word can be broken down into its initial consonant sound (or sounds), a vowel nucleus, and a final consonant sound (or 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 usually were produced more defectively than sounds in the final part. It should be noted 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, which argues against any selective impairment of the tongue.

Considering the five patients as a group, there is a great deal of variability in the pattern of sound substitutions which occurred, but some sounds were consistently misarticulated. The fricatives and affricates, [θ] as in "thin," [ʃ] as in "shoe," [ð] as in "then," [tʃ] as in "chin," [dʒ] 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 do 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] usually were split up by the insertion of a vowel, as [pəlɪz] for "please." The resulting word sounds defective but its intelligibility is preserved. These stereotyped substitute productions give us valuable hints regarding the mechanisms of compensation after damage to the motor cortex. Knowledge of these mechanisms would permit us to learn which features of normal articulation are essential for recognition of the intended sound and which are not; it would also



Fig. 2—Electrode placements on the lips and tongue for surface electromyography.

help the therapist 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 by 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, and we should like to describe our work in progress with use of this technic. Electromyography 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,⁶ and have obtained some knowledge of patterns of muscle action in normal speech. We believe the technic can now be profitably 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 vacuum cups as electrodes.⁷ 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 16-channel tape recorder. A throat microphone placed against the thyroid cartilage records periods of voicing during speech.

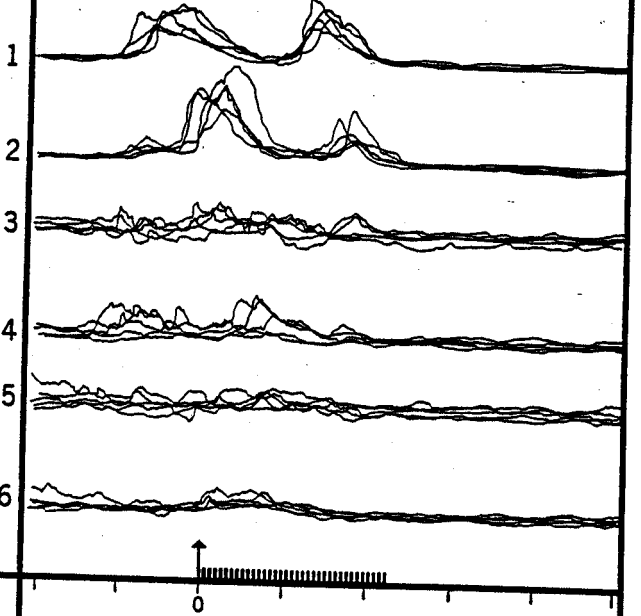
Electromyographic recordings of speech have been made for two patients who had been thoroughly investigated in the first study. We were encouraged to discover several points of agreement between the electromyographic data and the earlier findings. The placement of the electrodes as used in this study is shown in figure 2. 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, the experiment began. 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.

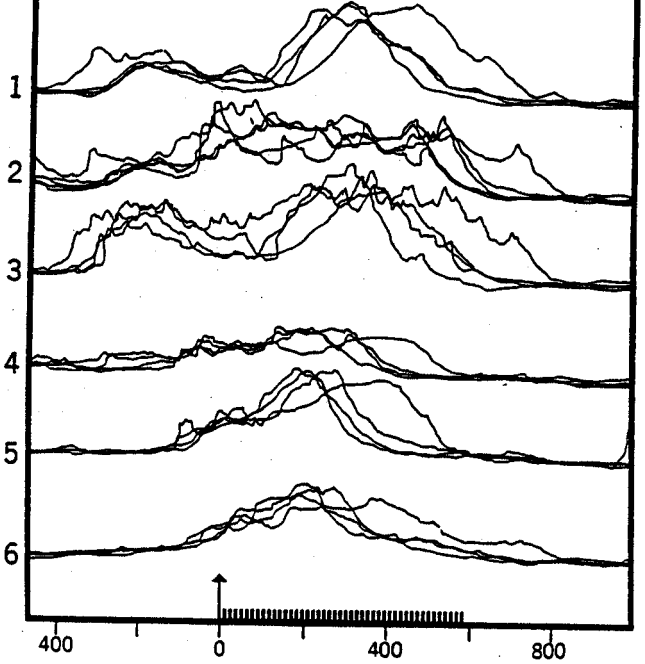
A comparison of a severely affected speaker (JG) and a normal subject (KSH), each saying "peep," is presented in figure 3, which shows superimposed traces for five utterances of the word. Time in milliseconds is shown on the horizontal axis, and the vertical axis displays a measure of voltage. The heavy 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

peep

KSH



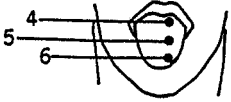
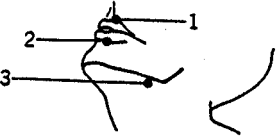
JG



Time in Msec.

Duration of Voicing

Fig. 3—Comparison of superimposed electromyographic traces for the utterance "peep" in a patient (JG, below) and a normal speaker (KSH, above). The diagrams on the left illustrate placement of electrodes.



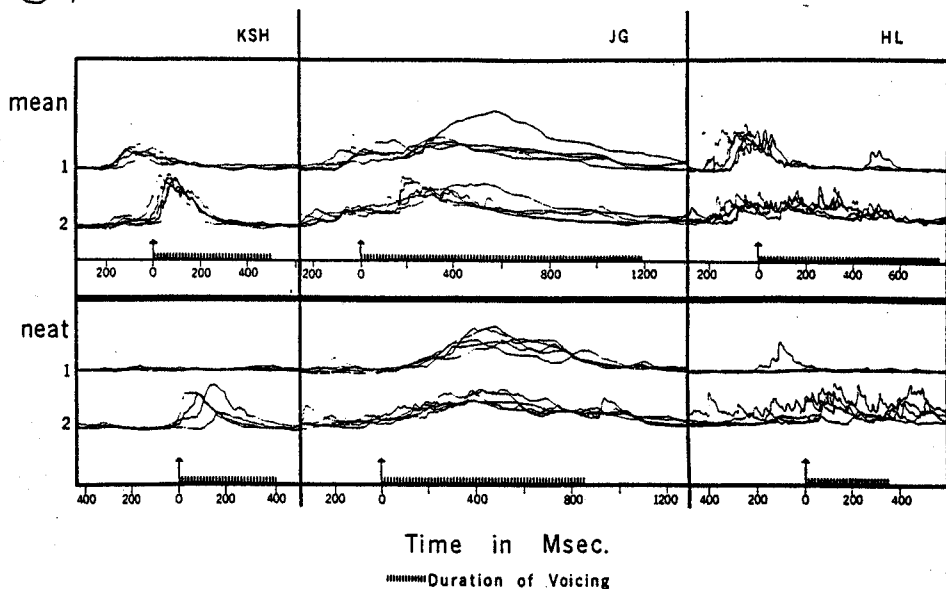


Fig. 4—Comparison of superimposed electromyographic traces from electrodes on the upper and lower lips in production of labial consonants, [m] and [n] by patients (JG and HL) and normal speaker (KSH).

a lip closing movement followed by a lip opening movement, both executed in precise coordination with movements of the velum and glottis. Earlier work⁸ 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 have a 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.

Figure 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 nonbilabial consonant. The normal subject shows discrete voltage peaks from both lips during the formation of [m] as we indicated earlier. The characteristic absence of upper lip activity can be noted for a nonbilabial 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 discernibly 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.

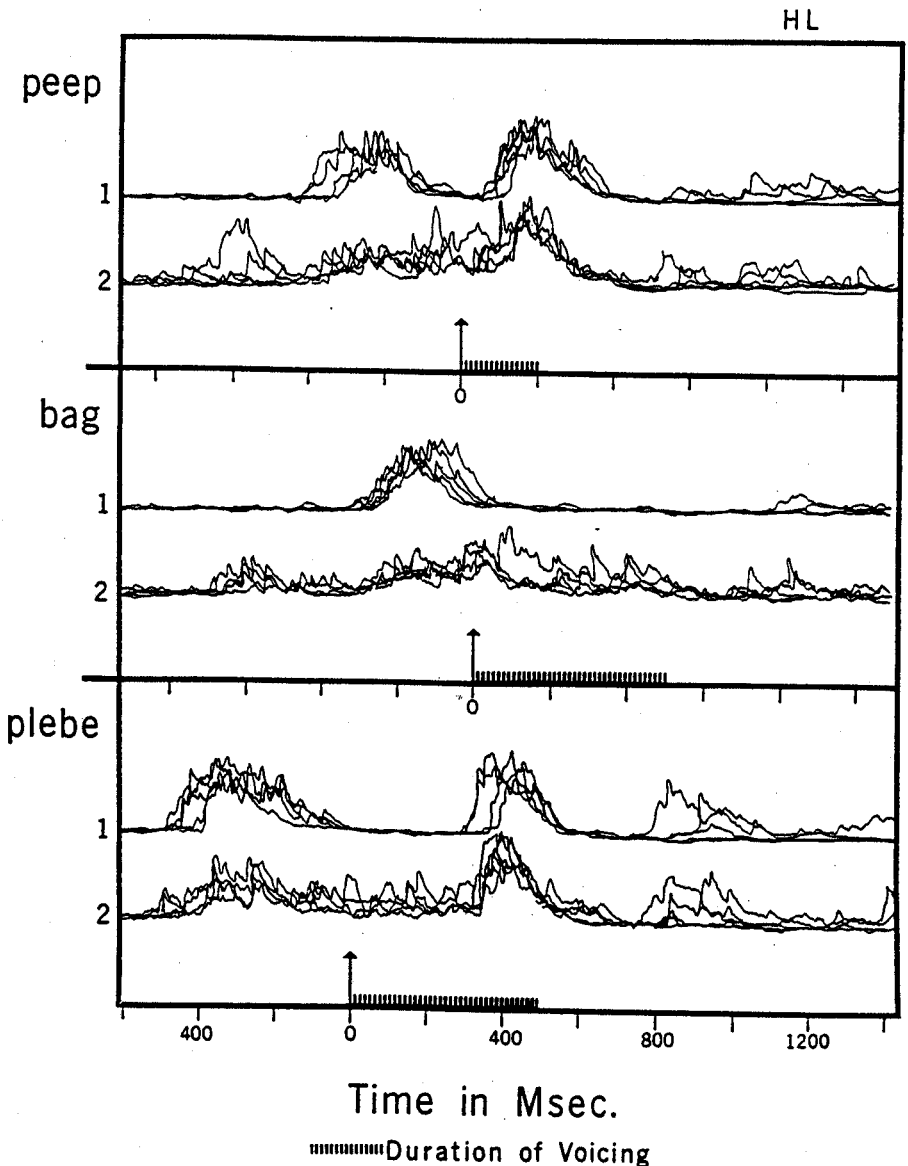
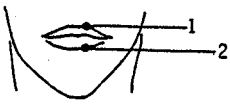


Fig. 5—Comparison of superimposed electromyographic traces from the lip electrodes in production of labial stop consonants in initial and terminal position.

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

The electromyographic traces of bilabial stop consonants in the initial and in the terminal position for patient HL are shown in figure 5. At the top of the figure are shown lip electrode records for "peep," a word which begins and ends with the same bilabial stop con-

sonant. The lower lip activity appears less diffuse and better organized for the terminal [p] than for the initial [p]. The same observation can be made in two words, "bag," which begins with the bilabial stop consonant [b] and "plebe," which ends with 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 description in suggesting that consonants at the beginning of words are more poorly articulated than those at the end of words.

Summary

Phonetic studies of speech production were made on five patients with residual articulatory disorder after damage to the left cerebral hemisphere resulting from stroke. Pilot studies of muscle action in speaking were conducted on two of the patients and a normal subject with use of surface electromyography. The studies revealed the following: (1) traces for both patients with phonetic disintegration were grossly abnormal in form; (2) repeated utterances of the same word showed great variability in the timing of sequential movements; (3) vowels were prolonged and variable in length; (4) labial consonant sounds in the initial position were more defectively formed than those in the terminal position in one patient; and in the other patient distinctive lip gestures for labial consonants could not be identified. Also, the occurrence of simultaneous peaks from all electrode locations showed a striking reduction of the capacity for independent movement of the articulators.

Electromyography, in addition to yielding good agreement with other means of description, provided valuable information about the temporal and spatial organization of defective speech gestures that could not have been gained by methods of analysis which start from the acoustic end-products of speech.

Haskins Laboratories
305 East 43rd Street
New York, New York 10017

References

1. Alajouanine, T.; Ombredane, A., and Durand, M.: *Le Syndrome de Désintégration Phonétique dans l'Aphasie*. Paris, Masson, 1939, 138 pp.
2. Alajouanine, T., and Lhermitte, F.: *Les Troubles des Activités Expressives du Langage dans l'Aphasie. Leur Relations avec les Apraxies*. *Rev Neurol* 102:604-629 (June) 1960.
3. Critchley, M.: *Semon Lecture: Articulatory Defects in Aphasia*. *J Laryngol Otol* 66:1-17 (Jan.) 1952.
4. Shankweiler, D., and Harris, K. S.: *An Experimental Approach to the Problem of Articulation in Aphasia*. *Cortex* 2: 277-292, 1966.
5. House, A. S.; Williams, C. E.; Hecker, M. H., and Kryter, K. D.: *Articulation-Testing Methods: Consonantal Differentiation With a Closed-Response Set*. *J Acoust Soc Amer* 37:158-166 (Jan.) 1965.
6. Cooper, F. S.: *Research Techniques and Instrumentation: EMG*. *Proc. of Conference on Communicative Problems in Cleft Palate*. ASHA Reports 1:153-168, 1965.
7. Harris, K. S.; Rosov, R.; Cooper, F. S., and Lysaught, G. F.: *A Multiple Suction Electrode System*. *Electroenceph Clin Neurophysiol* 17:698-700 (Dec.) 1964.
8. Harris, K. S.; Lysaught, G. F., and Schvey, M. M.: *Some Aspects of the Production of Oral and Nasal Labial Stops*. *Language and Speech* 8:135-147 (July) 1965.

