SOME RECENT DEVELOPMENTS IN THE USE OF ELECTROMYOGRAPHY IN SPEECH RESEARCH

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This paper describes current instrumental methods of obtaining and processing electromyographic data for the study of speech. Methods described include electrode systems, data reduction operations; and computer averaging techniques. The particular problems associated with each method are discussed.

F. S. Cooper, in a discussion of the theory and applications of electromyography in speech research (1965), pointed out that this technique gives us a rare opportunity to study the dynamics of speech production, not only in the descriptive terms of what muscles are contracting and when, but also, the relationships between the component gestures of speech and their linguistic counterparts. He also described the then current instrumental methods used for obtaining and processing electromyographic data and the particular applications and problems associated with their use for studying speech. In essence, this paper is a progress report on the instrumental advances made since that time.

MUSCLE ACTIONS AND ELECTRICAL ACTIVITY

The functional component of the neuromuscular system is the motor unit. This is a structure comprised of a single nerve fiber and, for most of the muscles of speech at least, several hundred muscle fibers. When a neural impulse arrives at the motor end plates of these fibers, contraction results, having a duration of only a few milliseconds. Accompanying this contraction is a small electrical potential which is dissipated into the surrounding tissue. By placing a pair of electrodes near the muscle, these potentials can be picked up and displayed on the face of an oscilloscope. In addition, and perhaps more importantly for our purposes, a relationship exists between the strength of the muscle contraction and the number of motor units actively firing, i.e., a strong contraction involves the actions of many more motor units than a weak contraction. This also means, of course, that a direct relationship exists between the force of contraction and the accompanying electrical activity.

ELECTRODES

Three types of electrodes are used in electromyography: needle, hooked wire, and surface.

The needle electrodes most commonly used in speech research are of the concentric type. Simple concentric needles consist of a platinum lead embedded in an insulating plastic which is housed in a hypodermic-type cannula. Action potentials are led off between the angled surface of the platinum lead and the shaft of the cannula. True bipolar concentric needles are similar to the above except that two platinum leads, insulated from each other are housed in the shaft. This results in a considerably smaller field size as the shaft of the cannula serves only as a shield.

The primary advantage of conventional needles compared with surface electrodes, is that they are inserted directly into the muscle thereby minimizing interference from the activity of adjacent muscles. Their use, however, presents certain drawbacks. The rigidity and relatively heavy weight of most needles can cause movement artifacts and sometimes dislodgment not to mention a considerable amount of subject discomfort. Placement procedures are often complicated and finally, it must be assumed that the particular motor unit at the electrode accurately reflects the actions of the other motor units of the muscle.

Some of these problems seem to have been overcome recently by the use of hooked wire electrodes (Shipp, Deatsch, and Robertson, 1968; Hirano and Ohala, 1969). This procdure, used as early as 1955 by Basmajian and Spring, consists of threading a thin wire through the cannula of a hypodermic needle. The exposed end of the wire is bent back over the needle to form a hook. During insertion, the needle carries the wire electrode to the desired location and then is withdrawn. Upon withdrawal of the needle, the hooked portion of the wire becomes anchored in the muscle. Removal of the wire requires only a slight tug. Each wire can be inserted separately, requiring two cannulas and insertions per muscle, or in pairs, with two wires being led through the same needle.

Investigators report that hooked wires stay in place, are flexible enough to permit natural movement and are relatively painless once embedded. However, two major problems are associated with this procedure. One is the possibility that the hooked portion of the wire will break off during removal. The chances of breakage depend on the type of wire used and the location of the muscle. Second, correct electrode positioning is very difficult. Whereas needle electrodes can be inserted and withdrawn into a given muscle until the best location is ascertained, hooked electrodes allow only further insertion because they cannot be repositioned outward.

Although both needle and hook electrodes present problems, the hooks are probably better suited to the study of the speech musculature. In a reliability study, Dedo and Hall (1969), found that both bipolar needle and paired hook electrodes are clearly superior to simple concentrics and separated hooks, in rejecting adjacent muscle pickup. However, in our experience, the bipolar concentric electrode, due to its larger diameter, produces unacceptable levels of both needle movement and pain. In contrast, the hooked wire's flexibility and relative comfort make the added problem of positioning only a minor inconvenience.

The problems inherent in using needles and, to some extent, hooks, have led some investigators to consider the use of surface electrodes. Unlike needles and hooked wires, surface electrodes are easily placed and afford minimal discomfort. In addition, since surface electrodes sum over many motor units, they provide an indication of overall muscle activity, a sometimes more useful measure for studying the speech gesture. On the other hand, surface electrodes often pick up activity from adjacent muscles. This limits their use for the speech musculature to only a few locations.

DATA PROCESSING

In order to obtain a convenient quantitative record of muscle activity, the raw EMG signal is customarily transformed into a display of amplitude versus time. This is easily accomplished by full-wave rectification and RC smoothing (integration) of the original signal. Figure 1 shows the same signal in both its

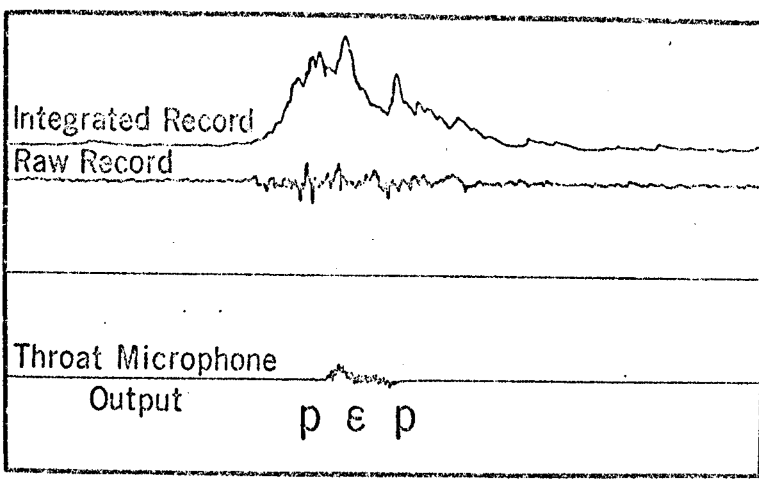

FIGURE 1. Record of integrated and original EMG signals.

original and integrated forms. Generally speaking, the envelope of the integrated curve is a running indication of the strength of the muscle contraction. This is only an approximation however, since the amplitude of the recorded signal varies with the distance between the electrodes and the active motor units. Further, since the integrated curve represents the vector sum of a number of uncorrelated muscle potentials, and since productions of identical utterances vary from one token to the next, a number of curves must be averaged before we can arrive at a reasonably accurate picture of the muscle activity at a given electrode position. The envelope of the averaged curve depends upon both the time constant (RC value) of the integrator, and the total number of tokens averaged.

The basic data processing procedure then, is to collect myographic data for a number of tokens of a given utterance or utterances, and to average the integrated signals at each electrode position. This general procedure, most easily accomplished by using a computer, has proved quite satisfactory in numerous experiments performed by several research groups, notably those at the Department of Linguistics, U.C.L.A., The Language Centre at the University of Essex, and at Haskins Laboratories.

A block diagram of the EMG system presently used at Haskins is shown in Figure 2. The procedure involves three separate operations: first, the myo-

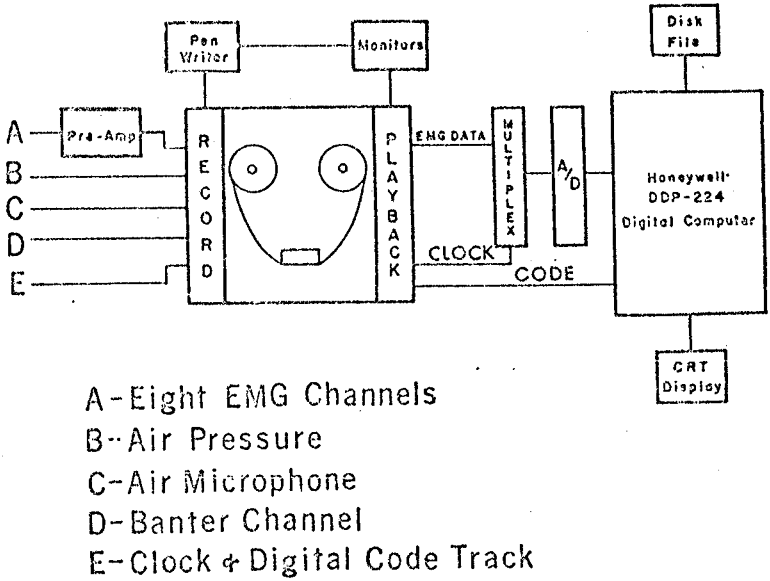

FIGURE 2. Block diagram of system used to record and process electromyographic data.

graphic data are recorded on one-inch magnetic tape; second, the data are transferred to the computer's disk file where the utterances are edited; and finally, the integrated curves are averaged for each electrode position.

The system has fourteen-data channels of which eight are for the recording of the myographic signals. Electrodes can be either surface (active suction type, connected to a manifold which in turn is driven by a vacuum pump; see Harris, Rosov, Cooper, and Lysaught, 1964) or any needle or wire system. The other inputs are for the acoustic signal, air-pressure data, a banter channel for the operator's comments, and finally, three channels for a calibration signal, a clock pulse, and an octal code pulse. All data inputs are recorded on a fourteen-channel magnetic tape recorder. During the recording part of the experiment, a record is also made on an eight-channel pen writer. This serves to monitor both the EMG and acoustic signals. There are also provisions for visually monitoring the gain levels and listening to any of the recorded signals.

The purpose of the octal code pulse is to identify each utterance for the computer. This pulse, which precedes each utterance, can be triggered either automatically by the second channel of a cue tape or manually by a pushbutton. A calibration signal alternates with the EMG data intermittently throughout the run. This signal is fed to the computer for purposes of obtaining a final readout in microvolts. The clock track (3200 Hz) drives a time division multiplexer which alternately samples each of the eight EMG channels.

Before the actual processing, the computer receives instructions on how any group of utterances are to be superimposed or lined up with each other. This is done by marking the time interval between the code pulse and any preselected line-up point. This point can be positioned anywhere along the duration of the utterance as can the start and stop averaging points. At present, we are using the acoustic event as the line-up point (for example, locations such as the onset or offset of voicing or the onset of frication, in the case of a fricative consonant). However, the system can accept any type of line-up point, such as the peak height of the integrated curve, or even multiple line-up points (by time normalizing various components of the speech gesture).

During the data processing run, all calculating and tabulating operations are done automatically. The print out of the amplitude curve is in microvolts at sampling points of as short as five msec. Standard deviation estimates are also computed. Figure 3 shows a typical set of curves derived from the mean

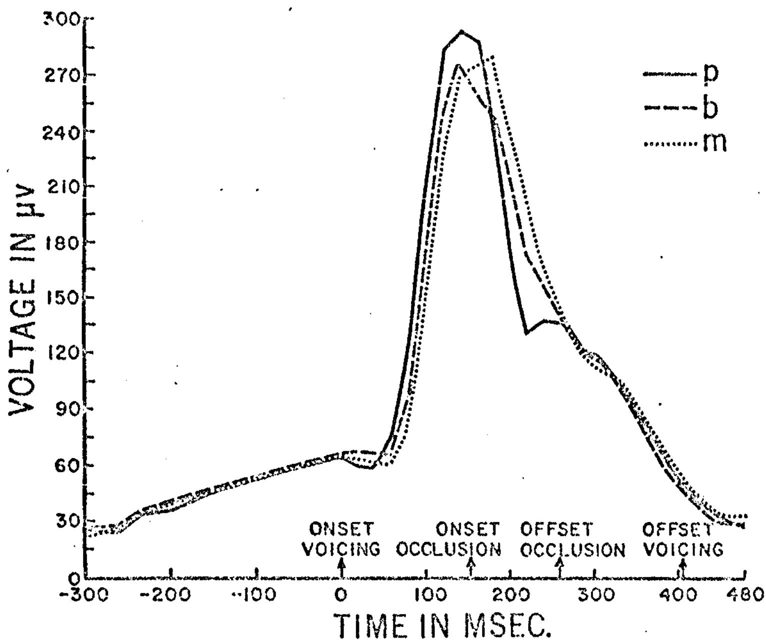

FIGURE 3. Illustration of averaged EMG curves.

voltages at each of the sampling points. The curves are referenced against various points along the duration of the utterance. The line-up point in this case is the onset of voicing.

The great advantage of this procedure is the flexibility of selecting any portion of an utterance for averaging. Unlike CAT averaging techniques, for example, this allows the use of randomized lists and sentence contexts. This is extremely important because of observable differences in EMG activity depending on the context of the utterance (Harris, Gay, Lieberman, and Sholes, 1968).

Finally, it should be stated that EMG is not a very simple or routine laboratory technique. Because of their overlapping locations, various muscles of the speech mechanism cannot be accurately mapped. Even with reliable locations, procedures for electrode implantation are not always straightforward; and finally, the processing of myographic data is often a laborious task. Complications notwithstanding though, the type of information gained through EMG justifies its use as a major tool in physiological speech research.

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