SINGLE MOTOR UNIT POTENTIALS IN SPEECH MUSCULATURE

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In recent years phonetic researchers have used electromyography (EMG) in the analysis of speech control mechanisms. The primary inference derivable from this technique is that of temporal organization of muscle function correlated with acoustic events or articulator displacement. Inferences as to the relative contribution of muscles in articulator movement and the subtler variations in muscle performance due to phonetic environment have largely eluded the researcher, since no objective criterion exists for measurement of these parameters. In an effort to provide a basis to make further inferences from EMG, we have begun a study of the single motor unit muscle action potential, the basic event of these records.

The single motor unit muscle action potential recorded extra-cellularly is an interference pattern of the activity of the various fibers in the same motor unit which are detectable at the recording electrode. The factors which determine the final shape of these potentials may be divided into three major categories: neuronal transmission; muscle-fiber transmission; and recording technique. Because of differing lengths and diameters of the axon terminal collaterals, the neuronal impulse will reach the myoneural junctions of the motor unit with some asynchronism introduced. These factors will increase in importance with greater spatial distribution of the muscle end-plates in a motor unit. In the speech musculature, where many muscles have pennate architecture, the end-plates of a single motor unit are probably distributed over a greater area than in muscles with parallel fiber architecture, where the end-plates lie in a narrow band near the middle of the muscle. The myoneural transmission itself is not thought to introduce any further asynchronism.

Variations in the propagation velocity within the muscle fiber would also introduce additional asynchronism. However, the work of Buchthal, Guld and Rosenfalck (1955) has shown that the velocity of propagation remains constant at 4.7 m/sec over large variations in muscle fiber diameter. Once these potentials have been transmitted into the muscle volume, the final determinant of their recorded shape is the recording technique.

In order to localize the receptive field and to provide minimum discomfort to the subject, bipolar, hooked-wire electrodes have been widely used in investigation of

voluntary movement. Bipolar recording restricts the receptive field by differential amplification, where signals common to both electrodes are canceled. This means that the greater the distance the signal source is from the electrodes, the greater the degree of cancellation, since differences in amplitude and arrival time at each electrode will be minimized. In order to characterize the interaction between the difference in arrival time at each electrode, and the duration of the potential, a computer program was prepared, which calculated the output waveform from an input action potential and a selected value of Φ — the ratio of arrival time difference to potential duration (see Figure 1). When Φ is equal to or greater than one, there is no signal interaction since the potential field has passed one electrode before reaching the other. This situation gives a double-image record, the second image of the potential being reversed in polarity with respect to the first. When Φ equals zero, the signals from each electrode cancel as mentioned above. For values of Φ between zero and one, many complex waveforms are attained which are common in bipolar recordings.

In these examples we have assumed that the summated potential reaching the electrode resulted from many fibers in the same unit firing and propagating a potential

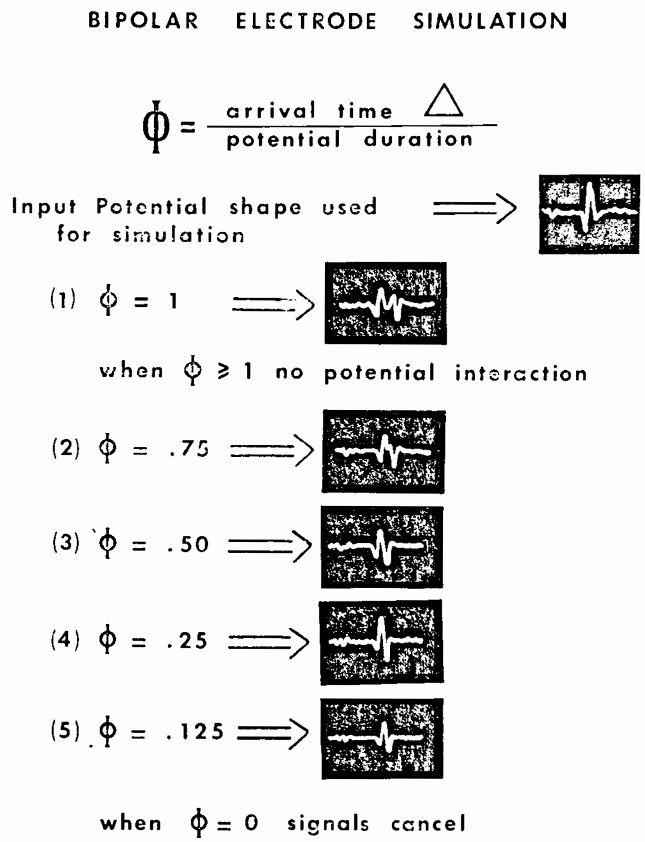

Fig. 1.

in the same direction along the muscle fiber. However, in muscles with pennate architecture this is not a valid assumption. Evidence for this comes from EMG records of activity in pennate muscles where single unit potentials of one polarity can be seen interspersed with potentials of opposite polarity, indicating that the potentials were propagated in different directions past the electrodes. Also present in these records are 'M' or 'W' shaped potentials indicating that fibers within the same motor unit are not lying in parallel (see Figure 2). These are to be distinguished from similarly shaped potentials which could be attained with parallel fiber propagation and a Φ of about 0.5. This is a highly unlikely situation since with a propagation velocity of 4.7 m/sec and a potential duration of 5 msec the interelectrode distance would have to be on the order of 11.75 mm.

The bipolar potential is usually about fifty percent shorter in duration than the monopolar potential recorded simultaneously. This is due to cancellation of low amplitude initial and final phases and, more importantly, on the directionality of the receptive field of the bipolar electrode. Other parameters of interest in describing the single unit potential are the rise-time and the ratio of negative-to-positive amplitudes. These parameters were measured by hand from time-expanded plots of the waveforms obtained by digitizing short samples of the signal. The average durations of these potentials are in the range of 2.0-3.5 msec, their rise-time's average 0.57 msec, and their negative/positive ratios average 1.31. The primary trend in this data seems

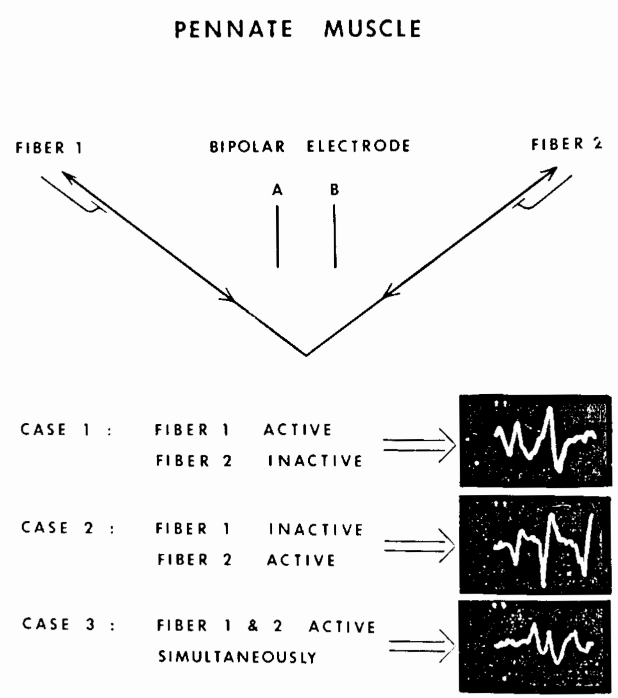

Fig. 2.

to be the difference between potentials from the craniomandibular complex, which have an average duration of 2.58 msec and average rise-time of 0.50 msec, and those from the hyomandibular complex, which have an average duration of 3.53 msec and average rise-time of 0.74 msec. Whether these differences reflect a difference in functional ability is not yet clear.

In summary, the continuing aims of this study are to better understand and characterize the single motor unit muscle action potential insofar as it will enable us to make more meaningful inferences from EMG records about the control of the speech mechanism.

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REFERENCE

Buchthal, F., C. Guld, and P. Rosenfalck
1955 "Innervation Zone and Propagation Velocity in Human Muscle", *Acta Physiologica Scandinavica*, 35:174-190.

DISCUSSION

SHIPP (San Francisco)
Caution must be exercised in describing interelectrode distance once the muscle has undergone isotonic contraction, since the wires are displaced from their original location.

HANSON
This is a very good point and we intend to devise electrodes with fixed interelectrode distance.