

## MOVEMENT ELECTROMYOGRAPHY AT U.C.L.A.

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Electromyography means the study of the electrical activity of muscle. It was not always known that the activities of nerve and muscle have to do with electricity. The foundations of electromyography go back to the 18th century and a famous dispute between Luigi Galvani, who had discovered a form of electrical discharge which he believed was due to the production of electric currents by nerve and muscle tissue, and Alessandro Volta who contended that the current observed was due to the formation of a kind of battery at the contact between tissues and metals.

Since that day, a whole stream of experiments and ideas in physiology, physics and biochemistry has flowed from the impetus of the original controversy. As subsequent advances in electrical theory and technique have permitted more accurate measurements, the electrical activity of nerve and muscle have been explored in ever greater detail. This electrical activity has proved more complicated than was originally suspected. Many details of the underlying mechanisms have been explained -- many await explanation.

It is possible, nevertheless, to present a general idea of muscular electricity. The currents involved are not those with which we are familiar from our everyday experience in the electronic age. "Ordinary" electric currents flow through "conductors", for example, copper wire. The electrons circling the nucleus of each atom in the material move easily from orbit to orbit and "flow" under the influence of electrical pressure like water through a hose. The electrons move at enormous speed, but due to the resistance of the conductor, the further they must travel, the less energy they can deliver.

By contrast, the electrical activity in muscles resembles the burning of a fuse on a firecracker. It proceeds more slowly, but can deliver every bit of energy it originally received. And why? Because the electrons themselves do not travel the length of the muscle. In fact, voltage differences in muscle (as in most living tissue) are not so much electronic (caused by the flow of electrons) as ionic, that is, between atoms and molecules (ions) having an excess of electrons (negative ions) or a deficiency of electrons (positive ions) orbiting around their atomic nuclei. Another difference between the electrical activity of muscles and the flow of electrons in a conductor is the direction of electrical discharge. In copper wire the current flows between one end and the other. In a muscle cell the difference exists between the inside of the cell and the outside. The membrane which surrounds the muscle cell admits potassium ions but not sodium ions from the surrounding fluid. The mechanism of this selective exclusion has not been entirely explained, but the result is a greater concentration of potassium ions inside the cell

than outside. For sodium ions the situation is reversed. This causes a difference in voltage across the cell membrane, the inside negative with respect to the outside.

When the motor nerve delivers to the muscle a message to contract -- a so-called "action potential" -- a small area of the membrane loses its resistance to the passage of sodium, which rushes into the cell. The increased concentration of sodium makes this portion of the muscle cell positive with respect to adjacent portions where the membrane is unchanged, and a local current flows between them. This current causes these adjoining portions of membrane to lose their resistance to sodium ions, which flow in and the process is repeated. The area of discharge moves along the muscle fiber and initiates the complex chemical activities which produce contraction.

The study of electric potential in muscle has largely been concentrated on the microscopic processes within the muscle itself; how the impulse arrives to the muscle from the motor nerve, how the muscular action potential is begun, how it spreads, how the "discharged" membrane is recharged. The direction of the most important work so far has been towards an explanation of these processes in the terms of chemistry and physics.

Dr. Valerie Hunt of the Movement Behavior Laboratory at the University of California at Los Angeles has begun a new direction of research designed to relate the patterns of muscular electricity to human movement patterns. For, despite the similarity of underlying metabolic processes, there is in the movement of every person an individual quality. It is a common experience to identify some friend by his walk at a distance too great to distinguish his face. However, it is difficult to describe such an individual movement pattern, even when it can be unmistakably recognized.

Thus, one of the first problems which confronted Dr. Hunt's project was the need to develop some means of recording human movement which would be unambiguous, yet sufficiently subtle to include the nuances of style which distinguish one person's movement from that of another, even when both are performing the "same" task. And this record of movement, to be useful, must be capable of synchronization with the other experimental data.

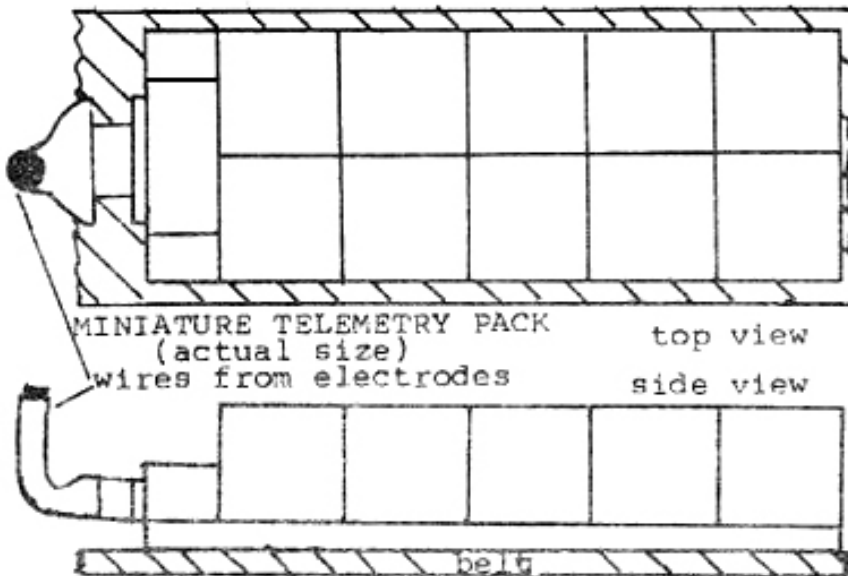
Another crucial problem was presented by the very number of muscles in the human body. These muscles are composed of thousands of cells and each cell has its own pattern of electrical activity. How many records of electrical activity are necessary to characterize a person's movement? And how are these changing patterns to be recorded without so encumbering or limiting the subject that the individual quality of his spontaneous movement disappears?

Dr. Hunt's approach to these problems has combined original thinking with the possibilities of some equipment recently made available in the aerospace and communication industries.

The electrical activity of muscles is picked up by small surface electrodes, attached with adhesive to the skin at various locations over the muscle.

The staff of the movement behavior laboratory is presently conducting an exhaustive survey of electrode placements and comparing the results with records obtained by other investigators who used

needle electrodes injected directly into the muscle cells. The results of this preliminary research will reveal how many individual records of electrical activity at specific locations will be required to characterize the overall electrical changes during movement. The signals coming from these electrodes are led by wire to a miniature battery-powered telemetry system connected to a belt around the subject's waist. The size of this package does not encumber the



subject, who can range freely up to 300 yards from the receiver. The telemetry pack amplifies each incoming signal, combines all these signals on a single carrier and transmits them by FM radio to a receiver where the individual channels are unscrambled and recorded on magnetic tape. They are observed on an oscilloscope and, since the individual signals change so rapidly, they are also written out on chart paper by an oscillograph for later visual inspection.

When the electrode placement study is complete, the records of muscle electricity will be taken from subjects at the same time their movement is being recorded by a television camera connected to a videotape recorder. The two recorders -- videotape and telemetry signal -- are synchronized and may be replayed together at normal speed, slow motion or stop motion. The two images, movement and multi-channel myogram, may even be displayed on the same TV screen, so that interesting changes in the movement pattern can be observed in the electrical record and vice versa.

A systems analyst on the laboratory staff is compiling programs for computer analysis of the myographic records. Spectral and Fourier analysis and other techniques will be utilized to search for underlying patterns hidden in the great variety of material.

When new analytic techniques become available, the records of earlier experiments can be re-interpreted, since both movement patterns and electrical changes will be retained.

Dr. Hunt plans to explore the development and change of human movement behavior in longitudinal studies utilizing subjects from infancy to old age. She also intends to investigate movement in other cultures, with particular attention to the patterns "characteristic" for members of that culture.

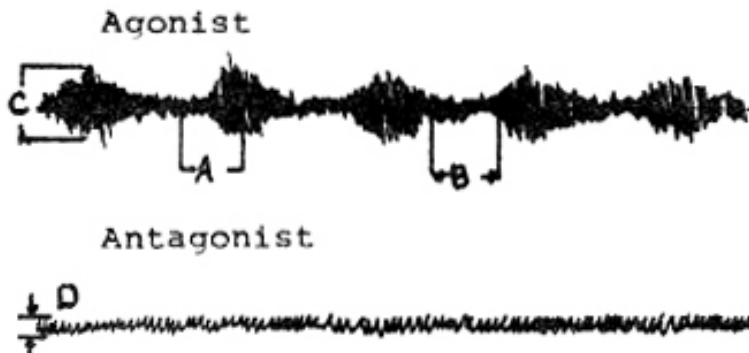
One of the most promising aspects of this whole research effort is the amount of information present in human movement which has not been systematically described. Experienced observers from many fields -- medicine, psychology, anthropology, and physical education -- have reported "perceptions" about subjects or patients which they dismissed at first as being unfounded, but which were later verified by objective methods. Many of these observers have concluded that the "clue" must have been some change in the subject's move-

ment patterns, although they were unable to specify what set of characteristics had changed.

The ability to interpret movement behavior remains an art because human movement is so complex. Different observers notice different parts of the whole. Communication tends to be limited to what everyone can agree upon.

Yet, since it has been demonstrated beyond question that electrical activity in muscles is directly related to muscular contraction, the variety of patterns which constitute human movement must be represented by a similar range in the underlying electrical patterns.

Dr. Hunt and her staff have already begun to establish relationships between certain fundamental qualities of movement and the electromyographic patterns which generate them. For example, consider the pattern of one movement flowing into another, so aptly named "free flow" by Laban. This movement has an unmistakable quality no matter what the position of the body or which parts are moved. It is clearly seen in the movement of infants. The pattern of electrical activity which underlies it is equally distinct.



The absolute frequency (A), the time between "spindles" (B) and the absolute amplitude (C) may vary within rather wide limits, but the shape of the pattern and lack of resistance in the opposing muscle (D) are unmistakable. The broader picture of the whole range of patterns which humans can produce will only emerge as recordings are made of many people. But once the data begins to accumulate

the prospects are excellent, I believe, for a general delineation of human movement patterns. This may very well allow classification of particular individuals according to their movement characteristics much as Sheldon's body types grouped individuals according to anthropometric statistics.

The long range implications of these studies are exciting for Structural Integration, as indeed for all disciplines concerned with understanding and developing the whole man. The effect of processing on movement patterns can be documented and explored. Particularly, the patterns produced by a "disorganized" body can be contrasted with those produced by the same body when it has been organized. Patterns of two organized bodies can be compared. There are almost endless possibilities for exploring the nature of the changes which Structural Integration brings about.

Certainly the human body is the most exciting laboratory in the world. It is of the greatest consequence, I believe, that research efforts such as the movement behavior laboratory are seeking not only to understand the minute and complex processes by means of which we are alive, but to relate this understanding to broad categories of human behavior. Only so can our knowledge truly become part of our life.