

Neuromuscular Structuring of Human Energy

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First I would like to put my subject into a large framework by reviewing the major emphasis in science today. For over a hundred years science was primarily involved in the manipulation of exact measurements, attempting to discover the very elemental facts and properties of matter. In the Twentieth century the emphasis has shifted. Measurement and precision although necessary, must be recognized as only giving raw material for science. The aim of science now is primarily to find relationships which give order to the raw material discovered throughout the years, and to detect patterns into which these measurements fit. We might say that today science is not constantly preoccupied with mere facts, but rather with the relationships these facts have to one another and with the whole that they form; how facts fill in the gaps of that whole.

Scientists have recognized that the key properties of different materials are determined by the way in which their atoms and basic molecules are put together, arranged and joined rather than as earlier assumed according to the basic material with which they are composed. Let me give some examples. Different solids, liquids and gaseous states can be explained only by patterning of the atoms, and the space relationships of the molecules. Graphite differs considerably from diamond, not in the basic element because both are composed of carbon, but in the arrangement of that carbon. When carbon rings are laid flat they have a capacity to shift on one another, making a soft material, a rather ordinary material which is called graphite. And when the carbon rings are spiraled or interlocked these produce a diamond that is very hard and very precious. And the basic element of these ingredients are identical. Another example of the effect of patterning is seen in sulfa drugs. Because of the geometric arrangements of the atoms, bacteria mistake sulfa for the chemicals of the body on which they feed, and as a result the bacteria are attracted to the sulfa which destroys them. Perhaps the most dramatic illustration that we've seen related to structure patterning came from an understanding of the molecular structure underlying the genetic mechanism differentiating species. Inherent in the spiral structuring of DNA is the ability to reproduce itself with a built-in program of growth and development for the unfolding animal structure. The nature of this pattern was not discovered until in the 40's and 50's. Studies of perceptual and conceptual processes, particularly by Gestalt psychologists, show that psychological events do not occur through the accumulation of individual elements of sense data but through the patterned network of sensation. Recent investigation into the nature of language shows that the structural properties of language have a far-reaching effect upon the ways of thinking of a group, because language offers certain categories for thought and denies other categories, based upon how it is patterned. Recent research by cultural and

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ethnographic anthropologists discovered a profile, a patterning of folk song and dance styles which reflect the very dominant enduring patterns of the social structure from which these came. There is a quote from Kepes which says, "From organic animal and plant structure to movement of animals, their social behaviors and to human relationships structuring is essential." Structure is not a thing in space as he perceives it. It is a series of relationships and these relationships have order. Structure appears whenever elements combine into meaningful wholes whose arrangements provide definite and significant laws. The ordering principles that govern these laws are principles having to do with the wholeness of the structure and not just its isolated parts. In science, then, such an approach is replacing older concepts of what constitutes the nature of man and material. This is the approach from science which I think we must listen to and we should listen to it now.

What does such a framework from the broader fields, from other behavioral disciplines, mean to us as movement specialists? All of us who have worked with human performance or attempted to fathom movement as an overall aspect of structure, know that ordering or structuring is very essential. For example, we have all observed that individuals structure movement responses differently for the same task. Some people structure effectively and efficiently, and we call them skillful; and other people do not, and we call them motor aberrants. Many people waste energy and accomplish little. We have noted that individuals, races and various age groups organize their behavior dissimilarly. We have seen styles of athletes or frequently a style of moving particular to a skill — not just a style related to the particular skill of throwing or catching a ball but a style of movement that transcends skill and becomes the movement of the person. We've observed such uniqueness in dancers, in runners, or persons who excel in combatives. The individual expressiveness in gesture, in dance, in music, in handwriting, and even speech are universally recognized even by the untrained as having uniqueness and specific style patterns. As teachers of skills, we know that merely to duplicate a skilled act in space does not capture the real fundamental essence of that movement. Those who teach dance realize that a Greek folk dance is more than just a step pattern; it is a rhythmic pattern, if it is truly authentic. And we've had the experience of doing a movement which intuitively felt correct. When we attempted to recapture the movement, we were at a loss to know why it was easy, why it felt so correct, and why it produced such an excellent performance.

We in physical education have taken numerous approaches in an attempt to get at movement patterning. We have observed, described and classified sports skills and techniques based upon the act itself. Birdwhistell, Laban and Hunt developed protocols for the observation and analysis of energy release through the time, space, and force involved and the path the energy displayed in space. We have kinesiologically analyzed muscle contraction during different skills obtaining information about the action of specific muscles. However, electromyographic studies of performance reveal that some persons use some muscles more than they use others. There appears to be no standard. In fact no really definitive patterns of movement have emerged from electromyographic studies, at least as these have been done. Our approaches range from a global description of a surface phenomena to the meticulous scrutiny of corpuscles and enzymes trying to understand the wholeness of movement. Each of these approaches is essential. Each is important because: the same thing has one type

of organization at a level at which we can examine it with our eyes, another at a level in which we hold it in our hand, and another type of organization at a level of nuclear mechanics. Each is as real as the next, and each is just as incomplete.

In my research I have taken yet another approach, the neuromuscular structuring of human energy, in an attempt to bridge a gap between the global description and the molecular analysis. The approach is parallel to the structural emphasis in many areas of physical and behavioral research. The complexity of energy patterning is staggering when considering the many parts moving as a whole and attempting to interrelate these data. While the task is difficult and we have few answers as yet, it is not impossible.

To approach pattern organization of movement requires a review of some basic facts about energy release. We know all living cells at a molecular level, contain potential energy. And that this energy is released by a stimulus. The stimulus results either from tissue needs, from immediate environment-organism interaction, or from a latent organism interaction through the memory of past experience. And we also know that when cellular energy is released it flows like a ripple throughout the entire body like a stone thrown into water causes energy to radiate out in all directions. But we know also that energy does not continue random dispersal. There will be higher and different tension levels in various parts of the body similar to the radiating waves in water hitting an impediment and changing direction or becoming accelerated as they join the flow in midstream. Such immediate influences create temporary energy organization which in turn can and does effect a more permanent organization. As energies take one form or direction these contribute to a more global structure which has a tendency to perpetuate a like form. So a person who moves or is moved in a particular way over time establishes habit patterns or energy ordering. One can almost predict his energy form in new skills as well as the way he will perform a habitual act. When his movement becomes stylized his nervous system has a residual, functional organization. He is programmed. Probably energy programming is both the product of maturation and learning. Although we do not understand the exact nature of programming, apparently the mechanism is a synaptic facilitation between neurons on the spinal level, within the mid-brain, and the reticular formation causing inhibition or facilitation of efferent impulses and alerting the cerebral cortex.

To understand energy organization requires a look at the most elementary organized neuromuscular process — the depolarization of muscle fibers which provides energy for shortening. Although there remains much to be discovered about this most basic element of muscle contraction, we do know that depolarization produces an action potential which can be measured electronically by electromyography. Many researchers have seen the rhythmic character of myographic recordings, but categorizing the variations in wave rhythms as organized energy has not been attempted previously — partly because of the complexity, but mostly because of inadequate equipment to capture the raw data and because there were no tested techniques or procedures for reducing these data. Therefore no one has been able to derive basic principles of patterns or to establish techniques for reconstituting the data in a way to clearly explain observed movement.

So far my remarks are introductory by way of setting a framework for the importance, the need and the problems encountered in discovering the neuromuscular order of energy. What are we doing about these?

The University provided a beautiful, large soundproof laboratory which we named the Movement Behavior Laboratory. Additionally the Department employed two marvelous associates, Sally Sevey who also serves as my teaching assistant and Larry Davis who is the manager of the six Department laboratories. While he manages the others he really works in mine.

We turned to space age electronics to overcome the limitations of conventional myography to obtain a miniaturized, modular, telemetered electromyographic instrument. Telemetry for the transmission of any energy refers to a process whereby impulses are beamed across space on FM frequencies without the need for hard wire connections. The monitoring of the astronauts' responses was telemetric. The person is free to behave unrestrictedly. We have received impulses from a distance of 50 to 100 feet while the person is in maximum effort of putting a 16-pound shot, throwing and striking. The energy is beamed by FM radio frequencies through the building into a receiver in the laboratory. We have placed electrodes on the lips, the larynx, the eye, and hand muscles of a person who is talking and gesturing as well as the major muscles in gross action. Dancers on stage have been instrumented under costumes and recorded off-stage. The clumsy Faraday Cage needed for hard wire instruments to eliminate radio and other confounding electronic frequencies is no longer necessary.

In addition, our telemetry transmitters and amplifiers are miniaturized, weighing a few ounces. The subjects carry such a light weight that they are unaware of the fact that they are instrumented and recording. Our equipment is peripatetic because the transmitter is battery operated and the receiver either battery or conventional electrically operated. The receiver is portable and can be taken into the field anywhere the person and action is to record data on a battery-operated tape recorder. We have only a four-channel system because of our exhausted budget, but I am sure we will obtain eight, twelve or sixteen channels soon.

In addition to new equipment we developed new procedures. We were not concerned with the action of isolated muscles except as these reflect the energy pattern. Rather than record separate muscles, we placed electrodes across joints to sample the pertinent parameters of the movement. We named this procedure movement electromyography as contrasted to conventional muscle myography. We recorded the depolarization in all of the muscles that created a specific movement of a joint. By such a technique we discovered that the rhythmic patterns were identical for all muscles involved in a movement although persons differed in the amount of contraction of the several muscles acting. In such a way we were able to record the rhythmic pattern, for example, at the shoulder with two sets of electrodes — one set on the agonists and one on the antagonists. Already we have arrived at placements for the shoulder joint, the anterior deltoid, and upper pectoralis major with their antagonists the posterior deltoid and teres major. On the trunk we placed electrodes diagonally across the abdomen and spine because we were not interested in whether the movement was to the right or left or rotary. Rather we wanted to know the quality and patterning of the movement.

Our first data has been based upon a global observation that there is a qualitative difference in the rhythm of movement from its beginning to its end regardless of the direction or space of the movement. We wanted to see if the rhythmic nature of the action potentials accounted for the qualitative difference.

In the following slide you will see myograms displaying the four rhythmic

envelope forms. The first three slides show the *undulating* rhythm in the shoulder, the back and abdomen. Note that the overall envelope pattern is a gradual increasing and decreasing energy of short duration. Small amounts of activity are followed by relative passivity. The agonist and antagonist contract reciprocally. This type of movement is characteristic of the Polynesian culture, the black race, and young children. The next rhythm which we call *sustained* is displayed in shoulder, abdomen and spine. Notice that energy is spread over a longer span of time and that the amount of energy is approximately equal from onset to termination of the movement. The antagonist like the undulate is also inactive.

The third rhythm or *burst* seems characteristic of Western cultures which explosively control their environment and enjoy striking, throwing and speed sports. The first two slides are of golf swings of Jody Martin and Nan McIntyre in which their gluteal muscles are instrumented. The third slide is a varsity baseball player batting. His shoulders are instrumented. Some writers have referred to this quality of movement as ballistic with energy released suddenly like a spring or elastic recoil, followed by immediate relaxation. Observe that the time duration of action potentials is about two-tenths of a second. At the time the agonist contracts the antagonist is inactive, yet within a tenth of a second the antagonist responds strongly — probably a stretch reflex.

The last rhythmic pattern we call *restrained* because of its inhibited, held back, controlled nature. Notice that the energy is released suddenly like the burst yet continues over time like the sustained. The antagonist operates simultaneously but with lesser amplitude. This pattern seems more prevalent in the aged or during frustration. It has been described as a defensive movement capable of sudden change.

Now we will show a five-minute movie of a person performing the same rhythms in which the moving electrical activity of the muscle is superimposed on the photography. Here you will see the quality of the actual observed movement synchronized with the electromyographic data. At the top of the film will be the shoulder flexors and at the bottom the shoulder extensors.

You have seen in the movie and slides, recordings of what we call the envelope pattern of energy release. But we realized that global inspection of raw data also required further reduction and analysis. We believed that the frequency spectra of the envelope myogram held additional information. We wondered in what part of a movement — from beginning to end, the high or low frequencies clustered. What did the frequency scatter have to do with the movement quality? What were the patterns within patterns? What were the finer components?

With such sophisticated space age recording equipment we were not prone to return to the horse-and-buggy days of manually counting spike potentials to determine frequencies. And so the electronic engineers who developed our transmitter and receiver made for us an integrator analyzer with various frequency discriminator bands. We have not become adept with the many capacities of this analyzer but we should be able to determine the relative frequencies in the envelope rhythms.

We have come to some tentative conclusions from our exploration. Apparently muscles which act synergistically and contribute to any given act get the same kind of neurological instruction. And furthermore the neurological instruction determines how these muscles respond qualitatively. Also it seems that a

group of muscles operating to produce a movement in a given plane, such as flexion at the shoulder, can receive different patterns of neural stimuli which cause rhythmic contraction patterns that account for observable differences in the movement. We have seen from the data that different parts of the body often have the same myographic patterns. That the patterns which we have shown you appear to be a basic ordering of human energy not restricted to a muscle, an area, or an act.

We realized that other forms of representation like successive histograms might display other energy dimensions. A week ago Larry Davis took our tape recorded data to San Diego to process on a computer spectrum analyzer on display at a conference. We hope to have this twenty-two thousand dollar computer some day. Next we will show you a motion picture of the wave forms photographed from an oscilloscope as the spectrum was analyzed by the computer. As you observe the film, the bottom base line displays frequencies; to the left will be recorded low frequencies, and to the right of the grid will be high frequencies. The frequency spectrum ranges from zero to five hundred cycles per second. Most of our data range up to two hundred fifty cycles per second. The amplitude or amount of energy at the various frequencies is registered upward on the vertical scale.

The first analysis is of the *undulate rhythm* that is organized down in the lower scale of frequencies. Note that energy grows slowly, smoothly like a sine wave and terminates in about one-fourth of a second. The pattern resembles that of a stretch reflex operating on many motor units. The major innervation is probably from the spinal cord. The high spiking at about two hundred fifty cycles per second is the EKG. At any time during the analysis we can stop the computer so as to measure the exact amount and location of the frequencies.

This is a *burst*, an explosive movement which differs both in energy spectrum and by observation. You see the high frequencies recorded to the left of the grid, and the greater amount of energy or amplitude on the vertical. You note that the amount of energy grows rapidly and stops likewise. This rhythm is probably innervated on a higher neural level than the undulate.

Next is a *sustained movement* containing frequencies in the mid to low level yet continuing for several seconds. Note that the amplitude is likewise in the mid ranges.

The last rhythm, the *restrained movement*, resembles the sustained in the overall time consumed yet it can last for a much longer time when the antagonists are strongly active. It resembles both the burst and the undulate by containing both high and low frequencies of great amplitude.

I believe that from spectrum analysis we will be able to write an index of the spinalization of a mover or the amount of spinalization required for a particular skill. The concept of spinalization in movement although not totally clarified by neurophysiologists generally means lower frequencies stemming from the spinal level. Frequencies are higher, of greater amplitude and more irregular when innervation comes from the brain stem and cerebral cortex.

The rhythmic forms we have shown you today are a beginning. Being able to resolve, analyze and resynthesize these data should assist in the training of observers to objectively note and diagnose energy organization for whatever reason.

As experienced teachers we know that inappropriate energy use is a major drawback when trying to improve skill. One application of our research may be

remedial in nature. If a skill demands certain kinds of rhythms that the person cannot reproduce, we could record his action electromyographically and show him his pattern from an oscilloscope or instant playback television. As is used to educate deaf persons to speak by playing back his sounds along with the desired ones, we could encourage the mover to experiment until he could duplicate the desired rhythm. Inevitably such procedures would be more successful than merely communication on a verbal level.

You surely have recognized the many tasks before us to augment the basic instrumentation, to improve techniques and display forms, and to further analysis. We must instrument the entire body. Rather than affixing electrodes to every muscle I predict that twelve to sixteen different placements will pick up all the important energy parameters of movement. After this is accomplished we can relate energy flows in various body areas. Possibly a finer form of analysis will show dissimilar rhythms occurring in parts of the body, a sort of schizophrenic reaction or possibly characteristic of all complex movement.

Also there will be new analytic approaches. We must look at energy transition, the growing and shrinking, the rising and falling of energy. We must scrutinize the alternation between high and low frequencies, and between great and small energy displayed by amplitudes. We must search out the phrases of energy — not just what happens within one movement but the repetition or replication of rhythms within numerous movements. Dancers when improvising or free associating in movement appear to repeat certain energy phrases over time. And then we should look at the hierarchy of structural qualities. What forms are primary and what are secondary, and what are alliterations? We should discover levels of complexity. We may find that some skill movements are complex only by the rapid shifting of basic patterns while others are compounded due to the arrangement or alliteration of the energy forms.

Inspection of data as to consistencies, variabilities and redundancies may give exciting information about individual or group movements. We should look at time relationships between energy and non-energy — the pacing of exertion. Data transformed into profiles and clusters of profiles, histograms and histograms on histograms should provide new insights.

I believe that structural analysis of energy involves geometric relationships and that the arithmetical techniques employed in correlation co-efficients are insufficient, perhaps misleading. Correlation techniques will be used when necessary but we will not be bound by these.

Although at this stage we are not particularly interested in skill per se, the movement situations must come from sports, dance, communication and from task-oriented work. We expect to record children at play, actors on the stage, musicians and dancers in concert, actors and sculptors, racial and age groups, and those with pathological, perceptual and neurophysiological aberrations.

Well, what is my goal? It is admittedly difficult but I believe not impossible. Surely my goal will not be accomplished by me or within my professional lifetime — but the direction is started. The ultimate goal, I believe, is a generalized behavioral model of the shapes, patterns and orders of human energy released by movement. And such information is vital to many professional disciplines. I think it is not beyond reality that someday someone will be able to write an energy index of a human being, of cultures or even subcultural groups. It may be that a grid will emerge in which coping and expressive forms of behavior lie at various planes to one another and the individual's ordinary

everyday patterning lies somewhere graphed in the middle. The ultimate goal will be reached when we discover principles and networks of relationships of the elementary process of human movement, the muscle action potentials, put into a different framework reflecting neuromuscular ordering. I believe these principles will be found to be intrinsic to the organization of the central nervous system.

Let me close my remarks with a quote from the eminent physicist, Robert Oppenheimer. He said, "It is the business of science to be wrong." I'm humble and a bit frightened by the extent and possibilities of the business I am involved in, but I take comfort from the acceptance of wrongness in pioneer research. Because I know that the concept of pattern analysis is justifiably foremost in research today, I will continue to explore this unknown in human movement.

About the author: *Dr. Valerie Hunt is Director of the Movement Behavior Laboratory, University of California at Los Angeles. Dr. Hunt is currently doing research on Structural Integration at UCLA. This paper was delivered at the Forty-fifth Conference of the Western Society for Physical Education of College Women.*

— A.L.A., editor