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Motor Control and Motor Learning

One of the central questions in the field of motor control is to understand how our motor goals are translated into actions. The Bizzi laboratory has elaborated a theoretical and experimental framework that describes the way in which the central nervous system transforms planned movements into muscle activations. Among the techniques used by the lab are behavioral training, cortical recording from single neurons, electromyographic (EMG) recording of muscle activity, microstimulation, cellular inactivation, kinematic measurement of movements in three dimensions, functional imaging, and computational modeling. Experimental models currently include frogs (including spinalized and spinal cord-isolated preparations), rats, cats, rhesus monkeys, and humans (both patients and normal subjects). The Bizzi lab is affiliated with the McGovern Institute for Brain Research.

Combination of Motor Primitives

In the natural world some complex systems are discrete combinatorial systems - they utilize a finite number of discrete elements to create larger structures. The genetic code, language and perceptual phenomena are examples of systems in which discrete elements and a set of rules can generate a large number of meaningful entities that are quite distinct from those of their elements. A question of considerable importance is whether this fundamental characteristic of language and genetics is also a feature of the vertebrate motor system. In the last few years, my colleagues and I have asked this question: are there simple units (motor primitives) that can be flexibly combined to accomplish a variety of motor tasks? We have addressed this fundamental and long-standing question in experiments that utilize spinalized frogs, rats, and currently monkeys. With an array of approaches, such as microstimulation of the spinal cord, NMDA iontophoresis, cutaneous stimulation of the hindlimb, and vestibular activation, we have provided evidence for a modular organization of the frog's and rat's spinal cord. A "module" is a functional unit in the spinal cord that generates a specific motor output by selecting a specific pattern of muscle activation (a synergy).

Recently, we have tested the hypothesis that linear combinations of muscle synergies represent a general mechanism for the construction of motor behavior. To this end, we have examined several motor behaviors in intact, freely moving frogs. We recorded simultaneously from a large number of hindlimb muscles during locomotion, swimming, jumping, and defense reflexes, like wiping and kicking. We found that muscle activity patterns in each behavior could be reconstructed as linear combinations of a small number of muscle synergies. Moreover, some of the synergies were similar across different behaviors. Currently, we are investigating the way in which the CNS controls the hand movements of the monkey. The large number of muscles involved in the control of hand and finger movements and the variety of complex motor behavior of the hand make the hand an ideal model system for testing the validity of the modularity hypothesis.

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