Muscle Synergies for Motor Control

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A fundamental challenge in neuroscience is understanding how the central nervous system (CNS) controls the large number of degrees-of-freedom of the musculoskeletal apparatus to perform a wide repertoire of motor tasks and behaviors. A long-standing hypothesis is that the CNS relies on a modular architecture to simplify motor control and motor learning. In humans a large fraction of the variation in the muscle patterns recorded during reaching in different directions, with different speeds, and to targets whose location suddenly changes is captured by the linear combination of a small number of muscle synergies, coordinated recruitment of groups of muscles. These results suggest that muscle synergies are basic modules providing a low-dimensional representation of the motor commands implicitly incorporating knowledge of the dynamic behavior of the musculoskeletal system. More direct evidence for modularity would come from testing the prediction that a truly modular controller cannot easily adapt to perturbations which are incompatible with the modules. In an isometric reaching task performed in a virtual environment under myoelectric control subjects were exposed to “virtual surgeries” which modified the muscle-to-force mapping as in a complex rearrangement of the tendons. Subjects adapted faster to surgeries that could be compensated by recombining the muscle synergies identified in unperturbed force control (compatible) than to surgeries requiring new or modified synergies (incompatible). These results provide new evidence that the control of manipulation relies on muscle synergies and that the synergies are not merely low dimensional approximations to the data.

BioSketch:

Andrea d’Avella obtained a Laurea Degree (M.Sc.) in Physics at the University of Milan, Italy, in 1993, working in the ATLAS experiment at European Organization for Nuclear Research (CERN), and a Ph.D. in System and Computational Neuroscience at Massachusetts Institute of Technology, Cambridge, USA, in 2000, working on the modular organization of the frog motor system in the laboratory of Emilio Bizzi. In 2003, he joined the Laboratory Neuromotor Physiology at Santa Lucia Foundation, Rome, Italy, directed by Francesco Lacquaniti, as the head of the Computational Methods and Hand Biomechanics research team. His research focuses on the investigation of sensorimotor control of reaching and interceptive movements and on testing the role of modularity in human motor control. He has developed a novel computational technique to identify time-varying muscle synergies from multi- muscle EMG recordings. He is a member of the Boards of Directors of the Society for the Neural Control of Movements.