
Plasticity of CNS and Motor Relearning

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Especially confusing and fragmentary are theories on the influences of various cortical and subcortical areas on spinal motor neurons and motor units in man. It was therefore refreshing to be able to develop and advocate a technique that not only proved to be quite simple but also promised to reveal considerable fundamental information. Ironically, the technique was only a modification of ordinary electromyography. This modification consists of regarding EMG signals not for their own intrinsic value but as the direct mirroring of the activity of spinal motor neurons. Thus the group of muscle fibers in a motor unit is considered only as a convenient transducer that reveals the function of the nerve cell.

Following up the generally ignored pioneer work that neurophysiologists performed in the 1930's, my students and I systematically studied the factors that influenced the fine control of motor units.

Using special indwelling wire electrodes we developed methods for studying the fine control of the spinal motor neurons especially their training, and the effects of volition. Later, in a series of studies, this group further developed and described a system of testing and of motor unit training. We demonstrated the existence of a very fine conscious control of pathways to single spinal motor neurons. Not only can human subjects fire single neurons with no overflow (or perhaps more correctly, with an active suppression or inhibition of neighbours), but also they can produce deliberate changes in the range of firing. Most persons can do this if they are provided with aural (and visual) cues from their muscles. Many investigators have documented the qualitative and quantitative aspects.

Subjects are invariably amazed at the responsiveness of the loudspeaker and cathode ray tube to their slightest efforts, and they accept these as a new form of "proprioception" without difficulty. It is not necessary for subjects to have any knowledge of EMG. After getting a general explanation they need only to concentrate their attention. With encouragement and guidance, even the most naive subject is soon able to maintain various

levels of activity in a muscle on the sensory basis provided by the monitors. Indeed, most of the procedures he carried out involve such gentle contractions that his only awareness of them is through the apparatus. Following a period of orientation, the subject can be put through a series of tests for many hours.

Once a person has gained control of a spinal motor neuron, it is possible for him to learn to vary its rate of firing. This rate can be deliberately changed in immediate response to a command. The lowest limit of the range of frequencies is zero, *i.e.*, one can start from neuro-muscular silence and then give single isolated contractions at regular rates as low as 1/2 and at increasingly faster rates. When the more able subjects are asked to produce special repetitive rhythms and imitations of drum beats, almost **all** are successful (some strikingly so) in producing subtle shades and coloring of internal rhythms. When tape-recorded and replayed, these rhythms provide striking proof of the fineness of the control.