【Grant-in-Aid for Scientific Research (S)】

Neuronal mechanism of skillful hand movement of non-human primates

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Purpose and Background of the Research

●Outline of the Research

Hand dexterity is an ability that only primates, including humans, have acquired during evolution, and understanding the neural basis of this ability will lead to an understanding of humans themselves. However, the neural mechanisms of fine motor control of hands and fingers remain largely unknown. This is because, while research has been conducted on the movement control from the viewpoint of signal transduction, there has been little research on how the nervous system processes sensory feedback from the fingers. We have previously elucidated the neural mechanisms by which hand dexterity movements are controlled by "muscle synergies," or functional units of muscle activity regulation. In this study, we consider the sensory feedback signals from the fingers generated by this muscle synergy as "sensory synergy" and elucidate the neural entities, circuit architecture, and formation patterns of "sensory synergy" in monkeys. We will also propose a new principle of biological motor control by modeling the coupling mechanism between "sensory synergy" and "muscle synergy" using the results of this experiment.

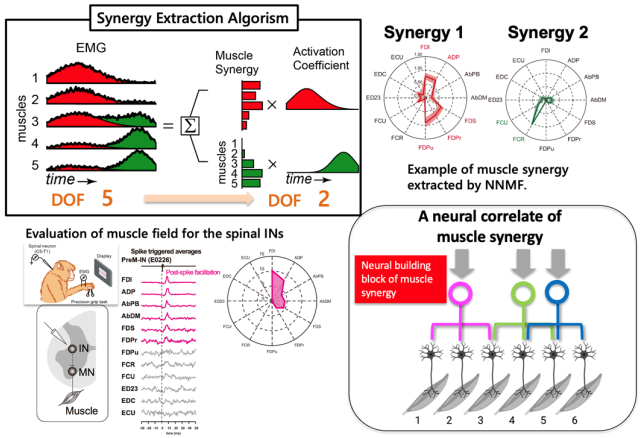

Figure 1. Neural representation of muscle synergy.

●Neural mechanism of hand muscle synergy

"Muscle synergy" is the idea that "the brain does not control each muscle individually; the brain controls sets of multiple muscles as a unit. The idea is that there are multiple functional modules in the central nervous system that is responsible for the control of multiple muscles and that the brain controls movement by combining these basic units. When we first began our research, this muscle synergy hypothesis was no more than a concept to avoid the combinatorial explosion in muscle control. However, we have demonstrated that the muscle synergies involved in hand movements are represented in the spinal cord and that their abnormalities make normal movement impossible.

●Sensory synergy: New concept.

The fingers have different modalities of sensory organs. The cutaneous receptors receive tactile sensations on the skin surface, while the deep receptors receive the posture and position of the fingers, which are then transmitted to the central nervous system. However, the neural mechanism of how the central nervous system processes this information and extracts the functional somatosensory information during hand dexterity movements has not been clarified to date.

Here, we attempt to elucidate this problem by proposing a new concept of "sensory synergy". In this concept, the brain does not receive sensory signals from individual receptors separately, but there are multiple functional units (sensory synergies) in the central nervous system that represent multisensory information with multiple receptors, multiple modalities, and multiple receptive fields, which are stimulated simultaneously during hand movements.

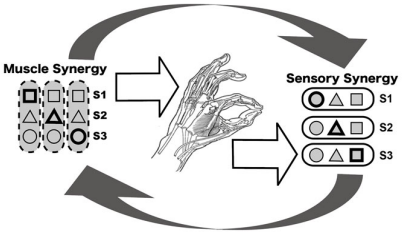

Figure 2. Muscle and sensory synergy.

Expected Research Achievements

●A neural mechanism of sensory synergy

First, we will develop a technique for recording of neuronal activity in the macaque monkey's primary sensory nucleus (medulla oblongata and spinal cord). Hand movements stimulate muscle spindles, tendon spindles, and cutaneous receptors, which are transmitted via afferents (mainly group I) to higher centers in the CNS. The initial relay nuclei of this ascending tract are the spinal cord and medulla oblongata. Here, we develop a method to record the multi neuronal activity of neurons relaying somatosensory signals in these nuclei in awake monkeys. We then record the neuronal activity and mathematically extract the sensory synergy structure. Then, taking into account the physiological characteristics of individual neurons, the neural representation of sensory synergy is elucidated. We will then use optogenetics and animal models to elucidate the central control mechanisms of the sensory synergies, their formation mechanisms, and their relationship to sensory-motor abnormalities, as well as to model the linkage between muscle synergy and sensory synergy.

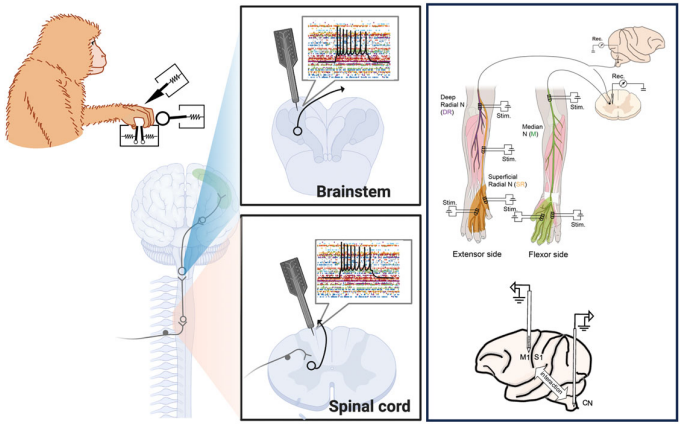

Figure 3. Research plan

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