Lecture 27 – Voluntary movement II -- Ghez

Representation of movement parameters and motor planning

We have seen that voluntary movements differ from reflexes in that (1) their form, i.e. the muscles that are contracted and joints that are rotated, is adapted to the kinematic and dynamic demands of specific behavioral tasks, (2) their effectiveness improves with practice, (3) their latency, or RT, is influenced by the processing demands of the task. We saw how motor cortical regions are somatotopically organized. In this lecture, we examine first how the somatotopic organization may change over time or practice in motor tasks, then we examine how primary motor cortex codes for motor behavior. Finally, we examine how different regions of premotor cortex specify more global aspects of reaching and grasping.

The somatotopic organization of the motor cortex is plastic. (pp 761-764)

- Small cortical lesions result in reorganization of muscle representation with expansion in representation of major undamaged muscle territories and dedifferentiation of more sparsely represented territories.
- Reorganization is altered and residual fragmentary representations expand with increased usage. Implications for rehabilitation.
- Representations also expand in normals with extended practice making specific sequences of finger movements.

The discharges of motor cortex neurons encode movement parameters during execution. (pp 764-770)

- Corticospinal neuron activity varies with force exerted in particular muscle groups rather than the displacement of joints or hand during movements.
- Some neurons are phasic and encode rate of change of force, other neurons encode decrements in force, presumably by inhibiting specific spinal motor nuclei.
- Movement direction is encoded by populations of broadly tuned directional neurons.
- Neurons controlling individual digits and the wrist are distributed spatially within hand region of motor cortex.
- Corticomotorneuronal (CM) cells are recruited preferentially during precision grip rather than power grip.

The frontal cortex contains 4 premotor areas that organize different aspects of voluntary motor behavior. (Pp 770)

- Four premotor areas are defined by having dual projections: to primary motor cortex and to spinal cord and include supplementary motor area (SMA), cingulate motor area (CMA), dorsal premotor and ventral premotor areas.
- Stimulation frequently produces motor effects that more closely resemble natural movements, are frequently bilateral, but require greater stimulating currents.

Internally paced movements and motor sequences are organized in the supplementary and pre-supplementary motor areas. (Pp 771-774)

An important feature of voluntary behavior is that the component movements can be prepared in advance of their being made. They can also be rehearsed in their entirety in our mind without being actually performed.

- Premovement ('bereitshaft') potentials can be recorded up to one second before an 'internally generated' voluntary movement.
- Neuroimaging (measuring oxygen usage by local brain regions) shows activation of premotor and motor cortex during internally rehearsed movements. Implications for skill development.
- Single neuron recordings show that specific sequences of planned movements are represented in discharge of SMA neurons.
- Other neurons are specific to individual movements, however, with extended practice, such SMA neurons are no longer recruited and the task is left entirely to the motor cortex.

Reaching and grasping involve separate visuomotor channels. (Pp 774-779)

- Visual information for reaching and grasping is processed in distinct parieto-frontal pathways.
- Reaching involves transferring information from posterior parietal to dorsal premotor regions.
- Premotor and posterior parietal neurons show "set-related" activity and fire selectively during reaching. Dorsal premotor for reaching, ventral premotor for grasping.
- Different modes of grasping are represented in different types of set-related and movement-related patterns of activity.
- The presence of mirror neurons indicates that the brain develops a vocabulary of motor behaviors that are represented abstractly. Implications for skill development and rehabilitation.

Conclusions

- The primary motor cortex is not a keyboard of upwardly-displaced motor neurons! Instead it is a complex mosaic of control elements capable of playing entire chords of muscle contractions, orchestrating sequential synergies and even controlling muscle relaxation precisely (decrementing neurons).
- Premotor neurons encode global aspects of task performance by their set- and movement-related patterns of discharge.
- No longer interested in which muscle groups are to be contracted, separate populations of neurons in different premotor areas encode entire motor sequences, upcoming sensorimotor transformations or limb configurations appropriate to different tasks in conjunction with the posterior parietal cortex receiving visual input directly.
- Cortical motor areas are continously being remodeled with the performance history of the individual so that processing becomes more efficient.

Relevant reading: chapter 38 in “Principles”