Lecture 26 -- Voluntary Movement I -- Ghez

Psychophysical Principles and Neural Control

Introduction

Previous lectures stressed the importance of sensory information in the control of motor action. All movements effectively involve sensorimotor transformations. Previous topics, however, focused mainly on the reflexes and relatively automatic behaviors. This lecture and the next examine voluntary movements. We begin by describing key psychophysical principles that govern voluntary movements, focusing primarily on reaching and grasping. Then, we consider the organization of motor areas. The next lecture examines the role of cortical motor areas in movement control.

Reaction Time is longer than reflex latency but is reduced by practice (pp. 661-665)

- Reaction time (RT) is longer than reflex latency but also varies with the neural conduction distance and the modality of the stimulus: 80 ms for somatosensory to 150 ms for visual (arm movements) vs. 20- 40 ms for reflexes.
- RT varies with amount of information processing: <u>choice effect</u>.
- Stage theory suggests that information is processed serially during RT.
- Parallel processing does occur
- Choice effect is abolished with practice and learning. Automatization.

Voluntary Movements Trade Speed for Accuracy (p. 662)

- Inaccuracy reflects uncertainty about the forces and loads that oppose movement and time available to correct errors.
- Speed-accuracy tradeoffs mean that faster movements tend to be less accurate than slower movements.
- Speed-accuracy tradeoffs reflect reduced time available to correct movements and increased variability of muscle contractions with increased rate of change of force during recruitment.
- Speed-accuracy tradeoffs vary with practice.

Reaching movements: 'Invariant Features' regulated by motor programs (pp. 658-659)

Reaching to grasp is a model system for studying sensorimotor transformations.

- Two invariant features: movements are straight and have stereotyped bell-shaped speed profiles despite variable joint motions.
- Implies entire movement is planned in advance and carried out feedforward. Scaled force impulse matches velocity profile to distance.
- Reaching movements are initially planned and represented in the brain in a simplified abstract form as vectors in which extent and direction is specified.
- Transformation from retinotopic coordinates to hand vector involves learning a spatial scaling factor and a reference frame through practice and using visual errors.
- During reaching to grasp, separate program governs the hand motion and is instantiated in parallel to control of fingers: Preshaping.

Accuracy also requires knowledge of musculoskeletal biomechanics obtained through proprioception. (Not in text book)

Moving the hand accurately to a target requires translating extent and direction information — the hand kinematic plan — into muscle commands that rotate joints. These commands have to take account of the biomechanical properties of the limb.

Insight from studies of patients with large fiber sensory neuropathy ("deafferented patients").

- Deafferented patients make large errors in extent and direction that vary with movement direction. (Movements in directions with low inertia are hypermetric.) Errors are due to failure to adapt muscle commands to directional differences in inertial resistance.
- Deafferented patients are also unable to counter interjoint interactions through feedforward control.
- Reaching is controlled using an internal representation of the mechanical properties of the limb and requires fine spatio-temporal control of muscle contractions.

Reaching is controlled by transferring visual information from visual cortex to posterior parietal, premotor and primary motor cortices. (pp. 756-759)

How does the brain achieve the precise spatio-temporal control of muscles necessary to move limbs and produce the fine control of individual joints for finger movements during grasping and manipulation? Insights first came through applying local electrical stimulation to brain regions. More recently, magnetic stimulation, single neuron recordings and neuroimaging.

- Somatotopic maps of contralateral limb and body muscles in primary motor cortex
- Somatotopic maps of limb movements in premotor areas and suppressor maps in SMA
- Explains: focal epileptic seizures, paresis from stroke
- However, representation of individual muscles is distributed over a relatively broad area with multiple low threshold points (Convergence). There is also divergence, such that individual corticospinal neurons diverge to multiple spinal motor nuclei.

Conclusions

- Reaching and grasping movements involve three complex sensorimotor transformations responsible for controlling hand kinematics, limb dynamics and for adapting finger movements to objects for grasping.
- Visual and proprioceptive information have different funtions: visual for kinematic planning, error monitoring, learning visuomotor mapping and preshaping. Proprioceptive information for generating internal models of peripheral plant.
- Neurons controlling individual muscles are distributed in hierarchies of premotor and motor areas which receive visuospatial information from the posterior parietal cortex.

Relevant reading: chapters 33 and 38 in "Principles"