Organization of the Motor System

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Outline

- Hierarchical organization of movements
- Feed-back and Feed-forward control of movements
- Hierarchical organization of motor systems
The Motor Systems Generate movements that are hierarchically organized

- Rapid (reflexive) response to harmful stimuli
- Maintain posture with respect to gravity
- Voluntary, purposeful movements

Overview - organization of motor systems
Reflex

- Involuntary movement, mediated by motor circuitry in the spinal cord
- Coordinated patterns of muscle contraction and relaxation
- Movement governed by the type of sensory receptors stimulated
  - Stretch receptors produce stretch reflexes
  - Cutaneous receptors produce withdrawal reflex

Voluntary Movement

- Initiated to accomplish a specific goal
- Triggered by external stimuli
- Improve with practice
Voluntary Movement

- Responds to feedback mechanisms to correct for internal and external changes
- Two types of feedback mechanisms
  - Feed forward
  - Feed back

Feed-back Control

- Reactive
  - Responds to the current state of affairs
- Depends on sensory signals
  - To detect changes and perturbations in the state of affairs
- Characterized by gain
  - Gain is kept relatively low so as to be sensitive to changes in the state of affairs
Feedback control: command specifies desired state

Feed-forward Control

- Anticipatory
- Depends on experience, senses
- Essential for rapid action
- Can modify the operation of feedback mechanisms
Feed-forward control: command specifies response

Catching a ball requires feed-forward and feedback controls

The anticipatory responses, before the impact of the ball, consist of coactivation of biceps and triceps muscles.

After impact there is a transient activation of the stretch reflex with further co-activation of flexor and extensors.
Feedforward and feedback mechanisms of postural control

Hierarchical Organization of Motor Systems

- Level 1: The spinal cord
- Level 2: The brain stem
- Level 3: The cortex
Hierarchical Organization of Motor Systems

Level 1: The spinal cord

- Mediates reflexes, automatic movement
- Motor neurons and interneurons in spinal cord receive projections from higher centers that modulate these movements
Hierarchical Organization of Motor Systems

Level 2: The Brain Stem

Two Systems:

- **Medial Descending Systems**
  - Integrate visual, vestibular, somatic information
  - For control of posture

- **Lateral Descending System**
  - Controls distal muscles (e.g., arm & hand)

The Medial Descending Systems

Superior colliculus (Receive visual information)

Tectospinal tract

Vestibular nuclei

Vestibulospinal tract

Reticular formation

Reticulospinal tract

Controls the head balanced on the shoulders as the body moves through space

Controls the antigravity reflexes
The Lateral Descending Systems - from brain stem nucleus

Rubrospinal tract controls goal-directed limb movements such as reaching and manipulating.

Hierarchical Organization of Motor Systems

Level 3: The Cortex

- Motor Cortex (primary motor cortex, premotor and supplementary motor cortex)
- Projects directly
  - to the spinal cord to regulate movement
  - Via the Corticospinal Tract
- Projects indirectly
  - Via the Brain stem to regulate movement
The Motor Cortex

- Primary motor cortex
- Premotor area
- Supplementary motor cortex

The Lateral Descending Systems
- from cortex

Corticospinal tract
Effects of the lateral pathway lesions

- Late 1960s, done by Lawrence and Kuypers.
- Lesions in both corticospinal and rubrospinal tracts in monkeys.
- Unable to make fractionated movements of the arms and hands. Unable to move shoulders, elbows, wrists and fingers independently.
- Voluntary movements were slower and less accurate.
- Able to maintain normal posture.

Babinski reflex and corticospinal tract lesion