Motor Systems

The perception-action hierarchy

Perception (Somatosensory)  Action (Motor)

Brain

Spine

Motor Areas of the Brain

• Subcortical and Cortical
• Hierarchical control
  - Connection between areas with multiple levels of control
  - Higher levels: planning based on experiences and perceptions
    (lower level isolation leads to simple reflex reactions)

Motor areas of the brain

Subcortical
  - Cerebellum
  - Basal Ganglia

Cortical
  - Motor cortex
  - Premotor cortex
  - Parietal cortex
  - Supplementary motor area (SMA)
Subcortical Areas: Cerebellum

• 10% of brain mass, more that 50% of neurons
• Input from primary & secondary motor cortex
  – Motor feedback from vestibular and somatosensory systems
• Evaluates and corrects input for ongoing movements
• Major role in motor learning

Damage to the cerebellum

• Trouble with rapid, ballistic movement sequences that require accurate aim and timing
  – e.g., tapping a rhythm, pointing to a moving object, typing, speaking, writing, playing a musical instrument
• Strength is preserved
  – e.g., grasping, lifting
• Difficulty in controlling the angle and distance of eye movements
  – executing saccades to particular location
• Symptoms resemble alcohol intoxication
  – clumsiness, slurred speech, inaccurate eye movements

The finger-to-nose test

• Instructions:
  “Hold one arm straight out and then, at a command, touch your nose.”
• Normally executed in 3 steps
  1. ballistic movement towards the nose
  2. hold (stop) finger just in front of nose
  3. slower movement to touch nose
• Diagnostic of cerebellar damage

Subcortical: Basal Ganglia

• Consists of
  – Putamen
  – Caudate nucleus
  – Globus pallidus (GP)
  – Substantia nigra
  – Subthalamic nuclei (SN)
• Receives input from cortex and transmits back via thalamus
• Nuclei are not a single entity, but interconnected network
Basal Ganglia Pathways

- Striatum = caudate + putamen
- Two pathways: Direct and Indirect
- Direct pathway: Increase thalamic activity through direct inhibition of GPi
- Indirect pathway: can increase thalamic activation (through GPe) or decrease it (through STN)

Parkinson’s Disease

- Neurodegenerative disease
  - basal ganglia affected
  - gradual progressive death of neurons in substantia nigra
  - decreased dopamine release into the caudate and putamen

- Symptoms include
  - rigidity
  - muscle tremors
  - slow movements
  - difficulties initiating physical and mental activity

Effect of Parkinson’s Disease

- Loss of dopaminergic fibers of substantia nigra (SNc)
- Reduces inhibitory activity along the direct pathway
- Increased inhibition from the globus pallidus (GPi/SNr) to the thalamus
- Decrease in cortical activation and movement

Pathology and treatment

- Treatment with L-Dopa, a precursor to dopamine (can cross the blood-brain barrier)
- L-Dopa does not prevent loss of neurons
- Produces side effects, including restlessness, sleep problems, delusions

Huntington’s Disease

- Progressive degenerative disorder
- Clumsiness, balance problems and general restlessness (onset)
- Involuntary movements (chorea) gradually take over normal motor function
  - Contorted positions
- Patients develop apraxia, aphasia or agnosia
Effects of Huntington’s Disease

- **Atrophy**: cell death
  - Basal ganglia: as high as 90% in striatum
- Atrophy leads to pathway changes in striatum
  - Affects inhibitory neurons of indired pathway
  - Leads to reduced output from basal ganglia -> excessive excitation of thalamus -> uncontrollable movements

Changing view on Basal Ganglia and Cerebellum

- **Traditional view**: Both areas involved in motor control and motor learning
- **Emerging view**: Both areas are involved in motor and non-motor control functions (i.e. cognitive functions)