Cortical motor systems

Motor areas of the brain

Subcortical
- Cerebellum
- Basal Ganglia

Cortical
- Motor cortex
- Premotor cortex
- Supplementary motor area (SMA)
- Parietal cortex

Primary motor cortex

- The pre-central gyrus (area 4)
- Part of the frontal lobe
- Left motor cortex controls right side of body and vice versa

Motor cortex: Homunculus

- Somatotopic organization
  - Upside down
- Areas of elaborate control (i.e., hands, and lips) have larger cortical area
- Stimulating each location of the somatotopic map causes increase in tension in the corresponding muscle

Mapping the Motor Cortex

- Penfield, a Canadian surgeon
- Applied electric currents to the brain’s surface, while operating on epileptic patients
- Patients awake, could tell what they were experiencing
- Movement of the patients’ bodies revealed motor cortex map
Duration of stimulation

- Penfield and many other studies
  - brief trains of electrical impulses (20 ms)
  - evoke muscle twitches

- Graziano et al. (2002)
  - longer train of impulses (500 ms)
  - closer to behaviorally relevant timescale
  - evoked more complex, coordinated movements (e.g., reaching, grasping)
  - the twitch evoked by a short stimulation could be the beginning of longer movement

Longer electrical stimulation

- Causes joints to move into a specific final posture, regardless of initial position
- Joints remained in final configuration until stimulation ended
- Evoked postures have behavioral significance (e.g., putting food in mouth, defending side of the head from threat)

TMS

- Transcranial Magnetic Stimulation

- Slow TMS (1 Hz) produces activation

- Rapid TMS (>10 Hz) results in suppression ("temporary lesion")

- Frequency of stimulation matters

Control of Movement Revisited

- Traditional view
  - motor cortex contains a map of body’s musculature
  - activity in each location of the somatotopic map, causes the corresponding muscle to move

- More recent view
  - complex relationship between cortex and muscles
  - organized in terms of behaviorally useful actions, aimed towards a goal posture

The Supplementary Motor Area (SMA)

- Activated, in addition to motor cortex, during movement sequences

- Bilateral activation

- Activated during the preparatory phase of a delayed movement task
The Supplementary Motor Area (SMA)

- Activated during *imagined* movement
- No motor cortex activation
- SMA controls movement at a more abstract level

SMA vs Premotor cortex (PMC)

- Both are in Brodmann Area 6
- Location within area 6
  - SMA: medial and superior
  - PMC: lateral and dorsal
- Functionally different

Internal vs External Guidance of Movement

- Externally-guided movements
  - task depends on external clues
  - e.g., movements under the guidance of visual, auditory, or somatosensory feedback
  - supported by PMC
- Internally-guided movements
  - task performed without visual (or other sensory) guidance
  - e.g., sequential finger tapping
  - supported by SMA

Externally guided movement

Information from vision, touch, etc

Internally guided movement

Information related to internal goals and motivational states
Apraxia

- Literally, “no action”
- Problem in coordination of movement
- Control of muscles preserved
- Associated with left hemisphere lesions
- Most frequent when lesion includes parietal cortex
- Often accompanied by aphasia
- Assessed by asking patients to produce goal-directed gestures

Apraxia

- Patients most impaired when trying to pantomime an action
- For example: “show me how you slice a loaf of bred”
- Patent may form a fist and pound the table

Apraxia

- When given the object, the performance improves
- Some clumsiness and inappropriate movements remains