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

Cortical Motor Systems

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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