Voluntary Motor Control

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Motor Control:

- Voluntary
  - reading, writing, playing piano
  - purposeful, goal-oriented actions
  - Learned movements
    - improve with practice

- Reflexes
  - involuntary, rapid, stereotyped
    - eye-blink, coughing, knee jerk
  - graded control by eliciting stimulus

- Rhythmic motor patterns
  - voluntary & reflexive aspects
    - chewing, walking, running
  - initiation & termination voluntary
  - once initiated, repetitive & reflexive
Summary: Control of voluntary action

- Motor System
  - cortical, sub-cortical, descending tracts
- Movement Coding
- Making a Movement
  - planning, execution, prediction

Revision: Subdivisions of the Brain

1. Forebrain
   - Cerebrum
     - cerebral cortex
     - basal nuclei
   - Diencephalon
     - Thalamus
     - Hypothalamus

2. Cerebellum

3. Brainstem
   - Midbrain
   - Pons
   - Medulla
Revision:
External View of Divisions of the Brain

Germann and Stanfield

(a) External anterior view
(b) External lateral view (left hemisphere)

Basic Brain Lateralization

- Sensory pathways cross
  - Right brain perceives left input
  - Left brain perceives right input

- Motor pathways cross
  - Right brain controls muscles on left
  - Left brain controls muscles on right

But, a bit more complicated..
Organization of Motor Control

- Hierarchical & Parallel
- Parallel
  - pathways active simultaneously
  - e.g. moving arm
    1. muscles producing movement
    2. postural adjustments during movement
- Recovery of function after lesion
  - overlapping functions

Sensory Motor System

Cortical Areas:
- Primary motor cortex M1
- Premotor cortex
- Supplementary motor area
- S-I and S-II
- PPC

Sub-cortical Areas:
- Cerebellum
- Basal Ganglia

Muscles
Organization of M1

- Regions of M1 relate to regions in the body (muscle groups)
- Somatotopy
- Cortical Magnification
- Motor Homunculus
- Codes for Action

Making a Movement

**Intention to move:**
Sensory event (S-I & S-II)
Behavioural Relevance

**Planning:**
Locate Goal in Space (PPC)?
Inform motor areas

**Co-ordination:**
Formulate movement sequence
SMA and premotor area

**Execution:**
Send motor command M1
Use sensory feedback
Descending Tracts

Hans Kuypers: classification of descending tracts

Parallel processing

- Simultaneous transmission along separate pathways: pyramidal/ extrapyramidal tracts.

- Tracts process information separately. A backup circuit if one of the pathways fails.

- For example, if a pyramidal pathway was damaged (i.e. distal limb movement), the extrapyramidal system can partially compensate so that distal movements are not entirely lost.
Hierarchical Control: Spinal Cord

- Automatic & stereotyped responses
  - reflexes
  - rhythmic motor patterns
- Can function without brain
- Spinal interneurons
  - same circuits as voluntary movement
- Pathways converge on a motor neuron
  - final common path

Motor neurons

To execute a motor program need to activate efferent neurons that innervate skeletal muscle. These neurons originate in the ventral horn of the spinal cord and are called (lower) motor neurons.

These motor neurons can be influenced by afferent neurons (i.e. reflexes) or by input descending from the brain or descending pathways.
Upper and Lower Motoneurons

- Widely used terms that originate from clinical neurology describing differing pathologies
- Lower motoneuron: Spinal, Motor unit
- Upper motoneuron: Corticospinal
- Move away from using these terms—there is little physiological justification

Movement & Muscles

- Movement control more than contraction & relaxation
  - Accurately time control of many muscles
  - Make postural adjustment during movement
  - Adjust for mechanical properties of joints & muscles
    - inertia, changing positions
Movement Parameters

- Direction
- Force
- Acceleration
- Velocity
- Position / Displacement

Cortical Coding: Force

Evarts 1968:
single units code force

![Diagram of cortical coding for force](image)
M1 and perturbed move

Reaching movements

- Georgopoulos, 82
- monkey
- hand movement
- many single M1 units
Single Cell Directional Tuning

Movement task for monkey

Record activity of individual M1 cell

Directional selectivity

Population Vector Coding
Feedforward control: Anticipatory control of grip force

- Grip force anticipates self-generated load force
- Reflexive grip response to externally generated loading
- Corticospinal tract crucial in both situations

Feedforward posture control

- Once the intention to pull the handle is realized, predictive contraction of the gastrocnemius muscle, faster than the signal to contract the bicep.
Brain and movement

- Execution
- Advance planning

Motor disorders

- Cortical stroke
  - Hemiparesis
  - Apraxia
  - Visuo-motor ataxia

- Cerebellar
  - Ataxia

- Basal ganglia
  - Parkinson's disease
  - Lack of dopamine in substantia nigra:
    - Rigidity - slow stiff movements
    - Involuntary movements or tremors
    - Difficulty initiating/stopping movements
Summary

• Anatomy and Organisation of motor areas
• Planning, co-ordination and execution of movement
• Movement parameters in the brain (force and direction)
• Disorders of movement

Reading