Basic Concepts

Localization

Hierarchy in Voluntary Movement Control
Planning
Execution
Feedback

Useful both as operational description of phases of voluntary control of movement, and as a conceptual principal for thinking about the location and function of the underlying neural circuits.

Sensory-motor integration within and between levels is critical.

Voluntary - Involuntary distinction

Motor Cortex Areas
Penfield’s brain stimulation studies showed that activation of small bits of primary motor cortex caused movements of specific muscles. The studies demonstrate Somatotopic Organization.

But this doesn’t work independently of a lot of processing going on in the spinal cord. We must consider SC circuitry; The best way to study SC circuitry and function is from the perspective of Spinal Reflexes.

Question? If the stretch reflex is as powerful as Kaplan says, then how does excitatory input from the cortex (or from anywhere else, for that matter) cause any movement at all??

The Gamma Loop: (‘gain setting’)
Study question: If the sensory nerve ends up stimulating both alpha and gamma motor neurons to the same muscle, then why does the knee jerk reflex work?

There's another problem for the motor system. The length of a muscle, in this case the extensor muscles for the knee (quadriceps), is "pre-set" by the gamma system. But also pre-set is the length of the knee's flexor muscles (hamstrings). So how does the knee ever extend? Shouldn't a contraction the hamstring muscle always fight the ability of quadriceps contraction to extend the knee?

Reciprocal inhibition of flexors and extensors that act on the same joint.
Illustrate using the elbow joint which is flexed by the biceps and extended by the triceps.

Coordinated movement of both legs, explored through study of the leg withdrawal reflex response to noxious (painful) stimulation of the bottom of one foot.

Review, time permitting
Also contributing to locomotory control are proprioceptors: in joints (reporting limb position) and in muscle (reporting muscle length or tension).

Clasp-knife reflex
Extreme case, protects muscle from overload. Normal: slow muscle contraction as contraction force increases. Thought to be important for fine motor acts, such as manipulation of fragile objects, which require steady but not too powerful grip.
Explore ingestive and taste responses in the Chronically Maintained Decerebrate

THE GAPE RESPONSE

Neurology of Taste-Driven Oral Motor Response

Normal
Anencephalic

Steiner, 1973

Taste Driven Oral Motor Responses

(From Video: Charlie Rose III ~27:00)
FEEDBACK
Voluntary movement without
Spinal sensory function:
Subject brings cup to mouth;
Tries to walk
(from Gazzaniga tex:

Left: following instructions to
Trace shapes, even in patient w/
Sensory neuropathy.
(a) Cognitive Neuroscience
(b) Cognitive Neuroscience
(c) Cognitive Neuroscience
(d) Cognitive Neuroscience
(e) Cognitive Neuroscience
Script w/ pen mounted in
Different places (e.g., wrist/toe)

PREDICTION
Waiter-Book example in video

Mirror Neurons/
Merging of Action/Perception
(Basketball example in video)

Observers with skill observing skilled performance

Fig. 7.26 – See accompanying text in Gazzaniga

Goal Directed Behavior: Requiring Brain
Cortex:
Premotor Cortex; (movement planning)
Primary Motor Cortex
Basal Gangla Loop
-- Cortex → BG → Thalamus → Cortex
Cerebellum Loop
-- Powerful reciprocal connections
with Motor Cortex
-- Integrates sensory information
(vestibular, proprioceptive, ++)
Cortical Regions Involved in Movement Planning and Execution

'Motor Cortex' generally refers to Areas 4 and 6.

"Primary Motor Cortex" (Area 4) often abbreviated "M1"
Primary Motor Cortex (M1) Electrophysiology: Movement Direction Representation

Cell's "Movement Tuning Curve"

This is a very broad tuning curve, as is typical across M1 neurons.

This came as a bit of a surprise given the earlier view that M1 contained a fine-grained movement map. Remember that electrical stimulation of specific M1 sites yielded very specific movement of individual muscles.

Yet movements are so accurate.

Current view: Movement direction in M1 is encoded by population coding

Tuning curves for 2 cells in primary motor ctx

"Population vectors" for those 2 cells, for right or left movements

"Population vectors" for many cells during accurate movement each of 8 directions.

Basal Ganglia and Cerebellum Loops

The Thalamus is a critical relay in both the Basal Ganglia and Cerebellar loops

Thalamus Overview
Basal Ganglia (basic loop)

- Caudate nucleus
- Putamen
- Globus pallidus
- Subthalamic nucleus
- Substantia nigra

Critical for proper execution of planned, voluntary, multi-joint movements.

Instructs primary motor cortex about movement direction, timing, and force. (For quick movements, instructions are based on prediction; too fast for feedback to be of use.)

Movement timing.

Learning

Cerebellum

Overview

Ataxic Gait Video, if time
Fig. 7.47 in Gazzaniga