33 The Organization of Movement

Kandel: Principles of Neural Science
2006/11/14
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In this Chapter,

- Review the Principles govern Movement
- Motor Psychophysical studies
  -> Lawful Relationship
- Anatomical Organization of Motor System
  ~ Spinal cord, Brain stem, & Cerebral cor.
3 Categories of Movement

- Reflexive (involuntary) -> Chap.35
- Rhythmic
  ~ pattern of muscle contraction & relaxation elicited by stimuli
- Voluntary
  ~ Goal-Directed Movement
Voluntary Movements

~Improvement with Practice

How to control posture & movement?

The Nervous System Learns to Correct for External Perturbations in 2 ways:

(i) Feedback control,
(ii) Feed-forward control.
Feedback

A Feedback control: command specifies desired state

Desired state

Reference signal (command)

Comparator (ie, subtraction)

Feedback signal

Error signal

Controller (ie, filtering, amplification)

Actuator (eg, muscle)

Input processing (ie, filtering, amplification)

Sensor (eg, muscle spindle)

Disturbance (eg, ball)

Fig. 33-1 A
Feed-forward control: command specifies response

Fig. 33-1 B
Catching a ball

Fig. 33-2 A

Both Feed-forward & Feedback control are needed.
Fig. 33-2 B
3 key principles in Feed-forward control

• Essential for Rapid action
• Prediction of sensory events
• Modifying feedback mechanism
Voluntary Movement obey Psychophysical Principles

Motor system = reverse of Sensory system

3 laws of Voluntary Movements

1. Brain represents the result of Motor action independently of the specific effector or the way.
2. RT depends on the amount of information.
3. Trade-off @ Speed & Acuracy of Movement
Invariant Feature in Voluntary

A  Able was I ere I saw Elba
B  Able was I ere I saw Elba
C  Able was I ere I saw Elba
D  Able was I ere I saw Elba
E  Able was I ere I saw Elba

Fig. 33-3  Motor Equivalence
Complex Motion of the Joints

Fig. 33-4 A, B
Planning Reaching Movement

Fig. 33-4 C
Acceleration & Velocity of Reaching

Fig. 33-5
Motor Planning

• Brain forms a representation of a Movement before its execution. = Motor Planning
Ex) Movement Kinematics
    Movement Dynamics
How to respond to Sensory Information
-> Experiment of Slippery object
Lifting Slippery Objects

A Lifting task

Movement

Load force

Grip force

Fig. 33-6 A
B Correctly anticipated weights

Fig. 33-6 B
C Correction to unanticipated slippage

- Load force
- Grip force
- Position
- Load force rate
- Grip force rate

Afferent response, single FA II

400 g

800 g

0.2 s

Time of expected sensory event
Time of actual sensory event

Fig. 33-6 C
Drawing of Figure 8

Fig. 33-7 A
Movement Primitives (Schemas)

Fig. 33-7 B
RT Varies with the Amount of Info.

Reaction Time = Time betw. Stimuli & Response

Time scale of various response:

• Voluntary Response to proprioceptive stimuli ~ 80 – 120ms
• Shortest Monosynaptic Reflex response ~ 40ms
• Reaction to Visual Stimuli ~ 150-180ms

RT is shorter when subjects know which response to do, is prolonged when they must choose one of responses.
Choice Effect

Fig. 33-8 A
Model of Info. Processing

Fig. 33-8 B
RT decrease with Learning

Fig. 33-8 C
Timed Response Paradigm

Fig. 33-9 A
Parallel Processing in Movement

Fig. 33-9 B
Accuracy of Movement varies in proportion to Speed of Movement

Fig. 33-10
Learning Improves the Accuracy

Fig. 33-11
Hierarchical Organization of the Motor System

Fig. 33-12
The Cerebellum & Basal Ganglia are Both Necessary for Motor Action

- Parkinson/Huntington disease @ Basal Ganglia
  -> involuntary movement, abnormal posture, etc…
  -> Motivation & Selection of Adaptive Behavioral Plan
     (Chap. 43)

- Vascular lesions & Familial Degenerative @ Cerebellum
  -> Loss of coordination & Accuracy of Limb Movement
  -> Timing & Coordination of Movements
  & with Learning of Motor Skills (Chap. 42)
Lesions of the Motor Pathway
- Positive/Negative Signs

- Negative Signs = Loss of particular capacities controlled by the damaged system
- Positive Signs = Withdrawal of Tonic Inhibition from neural circuits mediating behavior

In human, Lesions of the pathway or Brain stem
- Weakness of Voluntary Movements
  & Increase of Muscle Tone
Diagnosis of Motor Impairment

3 important differences separate diseases of the descending pathway and motor neuron:

i) spasticity in the former

ii) denervation atrophy & reduce of muscle volume in the latter

iii) more diffusely in limb or face muscle/a patchy way & limitation to single muscle
4 Types of Neurons in the Spinal Gray Matter

1. Local Interneurons -> the same/adjacent segment
2. Propriospinal neurons -> distant spinal segment
3. Projection Neurons -> ascend to higher centers
4. Motor Neurons -> innervate muscles

(Right sites of arrows, “->” show axons terminal.)
The Motor Nuclei @ Spinal code

Fig. 33-13
Medial & Lateral Descending Pathways

Fig. 33-14
The Cortex Control Motor neurons through desending pathways

Fig. 33-15
Overall View

• Motor commands are organized Hierarchically.
• The cortex can control the Motor neurons by Corticospinal & Corticobulbar pathways.
• The inputs to each component of motor hierarchy create somatotopic map. Then, each level of motor control receives sensory info, modifying the motor output. Finally, motor program refined continuously by learning.