Organization of Motor Functions 3. The Cortex

Prof. Szabolcs Kéri

University of Szeged, Faculty of Medicine
2019
Primary motor area (BA 4)
Premotor area (PMA, BA 6)
Supplementary motor area (SMA)
Cingular motor area (CMA)
Frontal eye movement field (FEF, BA8)
Somatosensory cortex (BA 3,1,2)
Posterior parietal cortex (BA 5, 7)
I. The pyramid tract and the primary motor cortex
The pyramid tract

**Origin:** *all motor cortices* + BA 3,1,2,5,7 (~ 1 million fibers, 50% BA 4, <5% Betz giant neurons in layer V)

↓

*Posterior capsula interna*/pedunculus cerebri

↓

Corticomesencephalic

Corticopontin

Corticomedullar (bulbar)

↓

*Decussatio pyramidum* (medulla)

80-90% crossed: *lateral corticospinal tract*

10-20% non-crossed: *anterior corticospinal tract*

↓

**Termination:** *ventral horn* in spinal cord, motoneuron or interneuron

*Corticomotoneuron:* monosynaptic connection with spinal motoneuron

(most refined movements)
Cortex

Capsula interna

Fibers terminating on brainstem nuclei

Decussatio pyramidal

Anterior and lateral corticospinal tract

Ventral motor nerves
Upper and lower motoneurons

Cortico-motoneurons (BA4)

Extensor motoneurons

Inhibitory interneurons

Flexor motoneurons

Kandel & Schwartz et al., 2012
Somatotopy: the motor homunculus (body map)

- Agranular cortex
- Area of body part representation is determined by function
- Columns are less strictly organized, strong lateral connections
- Plasticity

Kandel & Schwartz et al., 2012
Mapping of human cortex via stimulation during neurosurgical intervention

Wilder Penfield

Foerster & Penfield, 1930

Penfield in Sherrington’s lab
The action map of the motor cortex

Body map: the first (classic) organizing principle - a map of the body parts (somatotopy) - overlapping and fractured representation

Action map: the second (new) organizing principle - a map of complex, meaningful movements
Function of the primary motor cortex

Features of movements encoded by cells:

- speed
- direction
- strength
- coordination of muscle groups regulating multiple joints (together with the spinal cord)

Egocentric reference frame: determining the spatial localization of the point and the movement trajectory relative to our own body

Re-coding movement trajectory to muscle groups and joints
Representation of the upper limb is determined by the functional interaction of proximal and distal muscles

PROXIMAL
PROXIMAL-DISTAL COFACILITATION
DISTAL

Primary motor cortex
Trunk and hindlimb
Face

Sulcus centralis

Kandel & Schwartz et al., 2012
Training of finger movements increases the area of fingers’ representation in the cortex

Lesion of the pyramid tract:
- Disorder of fine goal-oriented movements (fingers)
- Babinski sign
- More extended lesion: full upper neuron syndrome, paresis
II. Long-loop reflex of the motor cortex
Structural basis and electrophysiology of long-loop reflexes

Motor cortex

Long-loop pathway

Spinal reflex pathway

Stretch receptor

Spinal cord

Electromyography

M1 M2

Long-loop, late response
Long-loop reflexes of the motor cortex

Reflexes related to posture
- **Righting** reflex (visual reaction to establish upright position)
- **Placing** reaction
- **Hopping** reaction

Involuntary hand reflexes (observable after cortical lesions - deliberation)
- **Grasping** reflex
- **Protective** reflex
III. Higher-order motor control: premotor and supplementary motor area
Premotor cortex
- Multisensory information from posterior parietal cortex: *grasping objects*
- Stabilizing *posture* before goal-oriented movements
- **Mirror neurons**: active during execution and observation of movements (imitation)

Supplementary motor area
- *Planning* and *imagining* complex movements
- Bilateral *coordination* of two hands and fingers
- Coordination of *posture* and goal-oriented *voluntary movements*
Neurons in the premotor-posterior parietal system encode the purpose of the movement.

Internally generated, planned action (e.g., looking for a cup to make coffee)

Stimulus-driven action (e.g., grasping a cup in front of you)

SMA – supplementary motor area
M1 – primary motor cortex
S1 – primary somatosensory area
Action without intention („alien hand” syndrome): preSMA lesion

Box 2 | The preSMA: a key structure for voluntary action

a Conscious intention

b Action inhibition

While being tested, patient CU spotted an apple and a knife left on purpose on a corner of the testing desk.

He peeled the apple and ate it. The examiner asked why he was eating the apple.

He replied: “Well ... it was there.” “Are you hungry?” “No, well a bit.” “Have you not just finished eating?” “Yes.” “Is this apple yours?” “No.” “And whose apple is it?” “Yours, I think.” “So why are you eating it?” “Because it is here.”

preSMA: pre-supplementary motor area, an inhibitory gate of motion patterns

Haggard P. Nat Rev Neurosci 2008;9:934.
IV. Summary and overview: function via clinical examples
Symptoms following the lesion of the motor cortex and related structures

1. **Upper motoneuron syndrome:** spastic paresis, hemiplegia; in milder cases: disorder of finely coordinated *finger movements* - *primary motor cortex*

2. Disorder of **initiation** of movements (akinesia/mutism), or **inhibition** of movements (e.g., grasping objects aimlessly), **alien hand** – *premotor, supplementary motor*

3. **Apraxia:** loss of complex motor patterns without paresis (e.g., brushing teeth) - *supplementary motor, posterior parietal*

4. **Neglect:** loss of attention and orientation to one side of the body and visual field (e.g., no socks on the left foot, no detection of stimuli appearing in left visual field) - *right posterior parietal*

5. **Increased visual and intentional control:** hand movements must be followed and controlled by vision - *somatosensory*, disorder of proprioception
Loss of proprioceptive input disrupts movement coordination: connecting two dots

A  Movement Paths

Arm Vision  0-1min  1-2 min  5-7 min

Hiding the arm from vision

Drawing of a patient with neglect
Practical implication of neurophysiology: brain-computer interfaces

Neuromedical Control Systems Lab (NCSL)