At the highest levels of motor control, the brain represents actions as desired trajectories of end-effector

Normal condition, using fingers and wrist

Parkinon's diom Chinis

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Fr. Aprison's disease Chinic

Kings College Hospital

Using elbow as folcrum

Using shoulder as folcrum

(outstretched arm)

In reaching movements, hand trajectories are straight, while joint motions are complex.



1. Motivation: I will sign my name (prefrontal cortex, basal ganglia)

2. Posterior parietal cortex receives information from visual cortex and somatosensory cortex and localizes position of pen with respect to our body.

3. Premotor cortex localizes position of pen with respect to our hand and specifies a plan of action. (which pen, how fast?)

4. The cerebellum formulates details of the movement in terms of its dynamics.

5. Primary motor cortex sends info down to the spinal cord.

6. Brain stem centers ensure that we maintain stable posture as we reach for pen.



Descending tracts



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Corticospinal tract

- Origin: primary motor cortex (30%), Premotor (30%), somatosensory (30%)
- About 1 million fibers in humans.
- 90% cross at lower medulla
- All are excitatory
- Small diameter, slow conducting fibers



Corticospinal tract

- Right motor cortical areas control the left side of the body, specially distal muscles.
- Primarily slow conducting fibers.

How well can the right motor cortex control the right arm in humans?





Primary motor cortex micro-stimulation (15uA) at a single electrode location

Produces an excitatory response in many arm and hand muscles (both flexors and extensors).

Response is at short latency (around 10ms).

While both proximal and distal muscles are targets of M1 cells, the stimulation effect is more prominent for the distal muscles.



Supplementary Motor Area micro-stimulation (60uA) at a single electrode location

Produces an excitatory response in many arm and hand muscles (both flexors and extensors).

The earliest response is at around 15-20ms, 5-10ms longer than from M1.

The same stimulation from M1 produces effects that are 15 times stronger than from SMA.

Unlike M1, facilitation of distal muscles is not greater than from proximal muscles.

Output from SMA to motorneurons is markedly weaker compared with M1.

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Response in distal muscles

Response in proximal muscles

Motor control in split brain patients

A small number of individuals have had their corpus callosum sectioned to relieve intractable epilepsy.

In these individuals, information in the right visual field only goes to the left hemisphere.





Left hemisphere has

strong control over the contralateral arm and hand some control over the ipsilateral proximal arm muscle very little control over the ipsilateral hand muscle

Split brain patient studies:

1. Left hemisphere has good control over the left proximal arm muscles: Subject is shown a target in the right visual field. Information arrives in the left hemisphere. He is asked to reach with the left arm. He can reach with left arm normally.

2. Left hemisphere has very poor control over the left finger muscles: Subject is shown a hand posture in the right visual field and asked to copy it with the left hand. He cannot do so. Correct responses are seen for only the very basic gestures like making a fist.



The two hemispheres: alien hand

A split brain patient found that it often took her hours to get dressed in the morning because while her right hand would reach out and select an item to wear, her left hand would grab something else. She had trouble making the left hand follow her will.

The clothes selected by this woman's left hand were usually more colorful and flamboyant than those the woman hand "consciously" intended to wear.

N.G., a woman with sectioned corpus callosum

Experiment: she was asked to fixate her eyes on a small dot displayed on a screen. A pictures of a cup is briefly flashed to the right of the dot. Because the image is to the right, it falls on the left part of the retina of both eyes, and goes to the left hemisphere.

The left hemisphere houses the language centers.

She is now asked what did she see, and she says "a cup".



The two hemispheres: language center is usually in the left hemisphere

Now a picture of a spoon is shown to the left of the dot. The picture goes to the right hemisphere. She is asked what she saw, and she says "nothing". She says this because in nearly everyone, the language centers are in the left hemisphere. Because the left hemisphere has not been given the visual information, it says that it has seen nothing.

However, when N.G. is asked to reach under a table with her left hand and select, by touch only, from among a group of concealed items the one that was the same as the one she had just seen, she picks a spoon. While she is holding the spoon under the table, she is asked what she is holding, she says "a pencil". (R.W. Sperry 1968, American Psychologist 23:723-733)



Examination of the corticospinal tract

Stimulation is used to activate the motor cortex, and cervical spine.

Evoked EMG at biceps and hand muscle is recorded.



200

80



B Lateral brain stem pathways



Tectospinal tract

Terminates in the cervical spinal cord. Thought to be involved in turning the head in response to a light stimulus. Little is known about function.

Rubrospinal tract

Origin is in the midbrain region of brainstem.

Larger fibers than corticospinal tract.

Inputs: cerebral cortex and cerebellum.

Outputs: crosses and descends to cervical & lumbar spinal cord, mainly exciting arm and hand extensor muscles.



Stimulation of the red nucleus excites arm+hand extensors

Task: monkey reaches to a cylinder and retrieves food pellet. During the reach, RN is microstimulated. EMG from 11 arm/hand muscles are recorded and aligned to stimulus time and averaged. It is determined if the stimulation causes facilitation or inhibition of the muscle over the 40 ms post-stimulus period.



Reticulospinal tracts

Large fiber axons.

Control of posture and balance, acting on anti-gravity muscles.

Pontine reticulospinal tract

Excitatory synapses on leg extensors and arm flexors.

Medullary reticulospinal tract

Inhibitory synapses. Action is to reduce muscle tone for nearly all muscles of the upper and lower limbs.



Voluntary movements of our arm can have postural consequences.

The brain predicts postural consequences of planned movements and acts to prevent loss of balance.

Example of action of the pontine reticulospinal tract

Bell sounds to initiate the lift. Biceps is activated after gastrocnemius.



Postural consequences of voluntary acts depend on state of our body



The brain predicts postural consequences by taking into account the state of the body.

Cordo and Nashner, J Neurophysiol 1982

Vestibulospinal tract

Coordinate eye & head movements: Maintain gaze while head is rotating.

Keep head upright and body vertical using information from semi-circular canals.

Two main tracts: lateral and medial

Lateral VST: descending entire length of spinal cord and excites anti-gravity muscles of lower limbs.

Example: if floor suddenly shifts backwards, tilting body forward, LVST contracts leg extensors.

Medial VST: descending only to cervical spinal cord. Stabilizes head when body is moving.





Lesion at the internal capsule

Symptoms are due to loss of input to spinal cord and brainstem pathways.

Paralysis, followed by the Babinski sign at around 12 hours.

Spasticity: In the extensors of leg and flexors of arm (anti-gravity muscles). Passive movements of the limb encounters larger than normal resistance, due to increased activity of the stretch reflexes.

Recovery of some function after about 3 weeks. This is due to reduction of pressure caused by the blood vessel leakage, and increased function of the contralateral hemisphere.



Lesion at the internal capsule

Babinski sign.



Lesion of the corticospinal tract

Little effect on limb movements.

Substantial deficit in the control of fine finger movements.

No spasticity.

Lesion of the vestibulospinal and reticulospinal tracts

Severe postural deficits. Cannot right oneself or keep oneself upright.

No problems making arm movements. No problems with fine manipulation.

Lesion of the spinal cord

Loss of all descending input, areflexia, followed by spasticity.



Recovery from corticospinal lesion

Lesion is place along the left pyramidal tract in the medulla, rostral to the decussation.

Task: use right arm to pick up food pellets placed on small holes on a board.





Recovery from corticospinal lesion: a role for the rubrospinal tract

Before lesion, stimulation of red nucleus tended to produce post-stimulus facilitation of arm extensors and inhibition of flexors. After recovery from corticospinal lesion, stimulation of the red nucleus now produces a more balanced pattern of post-stimulus facilitation of flexors as well as extensors.

Task: reach to a cylinder to get food. During reach, RN is stimulated.



lesion animal

control animals