Lecture 23. Motor Cortex and Free Will

Dr. Jesse Goldberg

Pre lecture materials (you will be tested on this content)

1. Panopto video: How to analyze neural activity: spike rasters and rate histograms
2. Panopto video on Primary Motor Cortex
3. Panopto video on Parietal Cortex and Affordances

Additional Reading Research Article in Science Magazine (Optional):

Stimulating the primary motor cortex in monkeys can make them move their arms in seemingly natural ways. How do you think you would feel if somebody did this to you, or if they stimulated your parietal cortex instead? If you are curious, check out this article:

Movement intention after parietal cortex stimulation in humans.
Desmurget M, Reilly KT, Richard N, Szathmari A, Mottolese C, Sirigu A.
Science. 2009 May 8;324(5928):811-3

Learning Objectives:

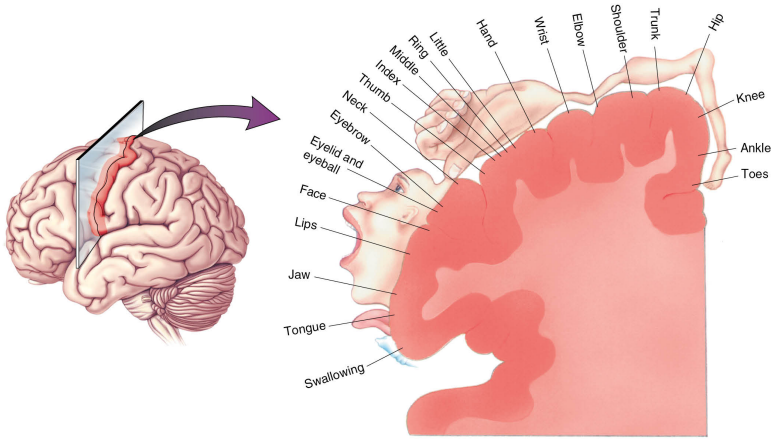
1. Be able to describe the 'homunculus,' the topographic organization in the motor cortex and how it gives rise to the cortico-spinal tract.
2. Be able to interpret data which suggest that the parietal cortex is involved in intentionality. Be able to apply your knowledge of the parietal cortex in intentionality towards disorders such as neglect and alien hand syndrome.
3. Understand how you get from a motor plan to its execution. Specifically, know the difference between kinetics and kinematics for motor control.
4. Understand the concepts of *object affordances* and *mirror neurons,* and how they are encoded in parietal cortical areas.
5. Know how to analyze neural activity with respect to behavior. Specifically, be able to interpret a spike raster plot and a corresponding rate histogram.

Lecture Outline

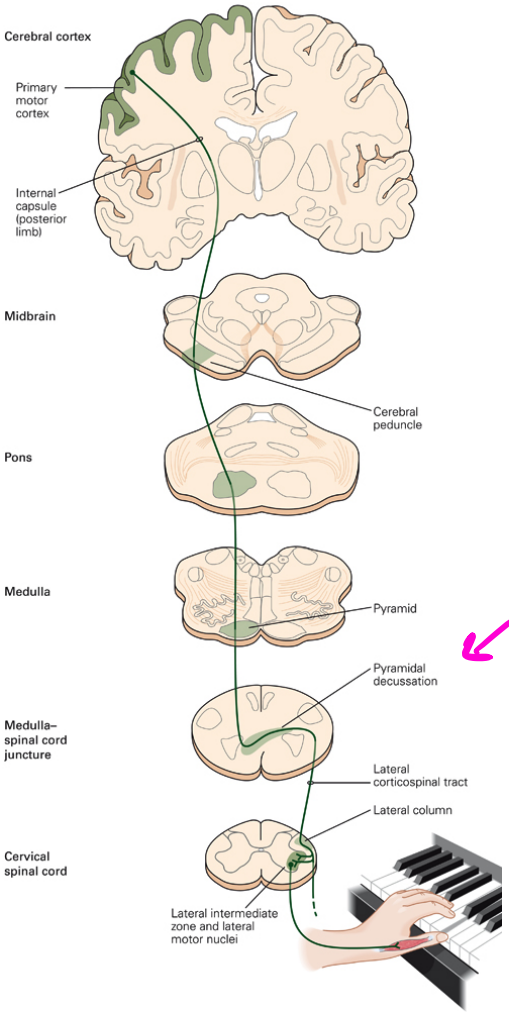
A PDF of the powerpoint slides from this lecture will be made available on the class website and will contain all key figures and concepts you need to know for this unit.

I. Motor Cortex, the body map and the Homonculus

A. Topographic organization of motor cortex (Fig. 14.8)



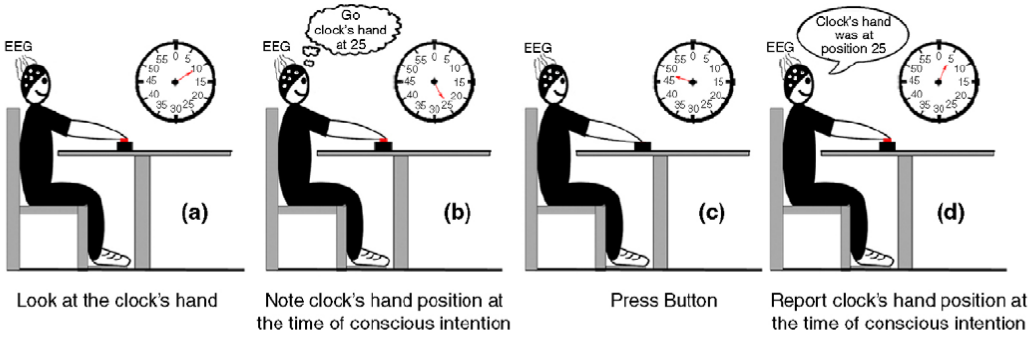
B. Motor Cortex projects to the ***contralateral*** spinal cord via the cortico-spinal tract (Fig. 14.3), i.e. ***left*** cortical lesion will impair function of ***right*** side.



where crosses over

II. Where does intentionality come from?

A. The Libet experiments reveal that a 'Readiness Potential' precedes awareness of movement initiation.



B. Human microstimulation studies reveal different effects of stimulating motor versus parietal cortical areas.

i) *Intentionality* results from microstimulation of human parietal, but not primary motor cortex.

ii) *Movement* results from stimulation of motor, but not parietal areas.

III. The parieto-frontal hierarchy for motor planning and execution

A. Kinetic to kinematic transformations in motor cortex

a. *Kinematics* refers to the 'goal' of the movement, e.g. "lift the pen."
b. *Kinetics* refers to the commands that are sent to muscles, e.g. "Flex my biceps."
c. *Kinematic – kinetic coordinate transformation:* Of course, what muscles you use to lift the pen depends on the current state of your arm! So during motor planning, the current posture must be taken into account to transform kinematic coordinates into kinetic ones.

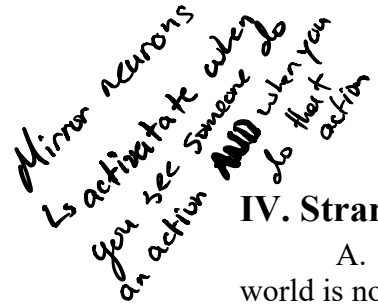
B. Parietal cortex encodes affordances, i.e. *what's actionable* in the world

a. When you look at an object, parts of your parietal lobe are encoding that object in terms of *how it can be grasped*. Affordances are not the visual feature of an object, but rather *pragmatic opportunities that the object affords for action.*

Kinematics → Goal

affordances – opportunities the object affords for action

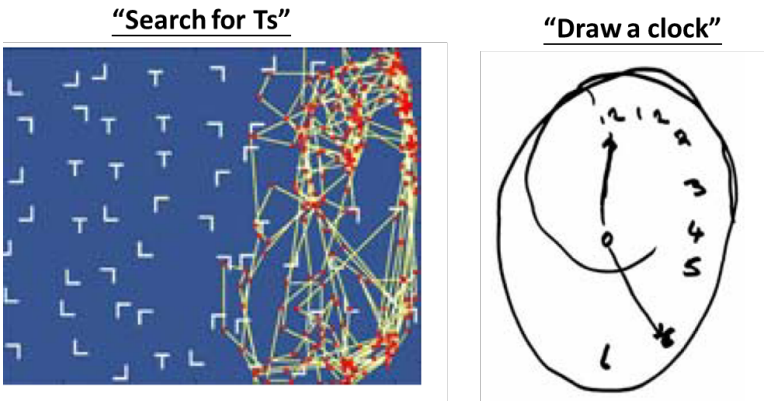
Kinetics → Command sent to muscles



b. *Mirror neurons* are neurons also found in parietal cortex whose activity is modulated both by performing an act AND by watching someone else perform the act (Fig. 14.10). They have been proposed to be important for imitation and even for empathy.

IV. Strange neurological conditions result from parietal lesions

A. Unilateral parietal stroke results in ***hemi-neglect syndrome,*** as if half of the world is not actionable.

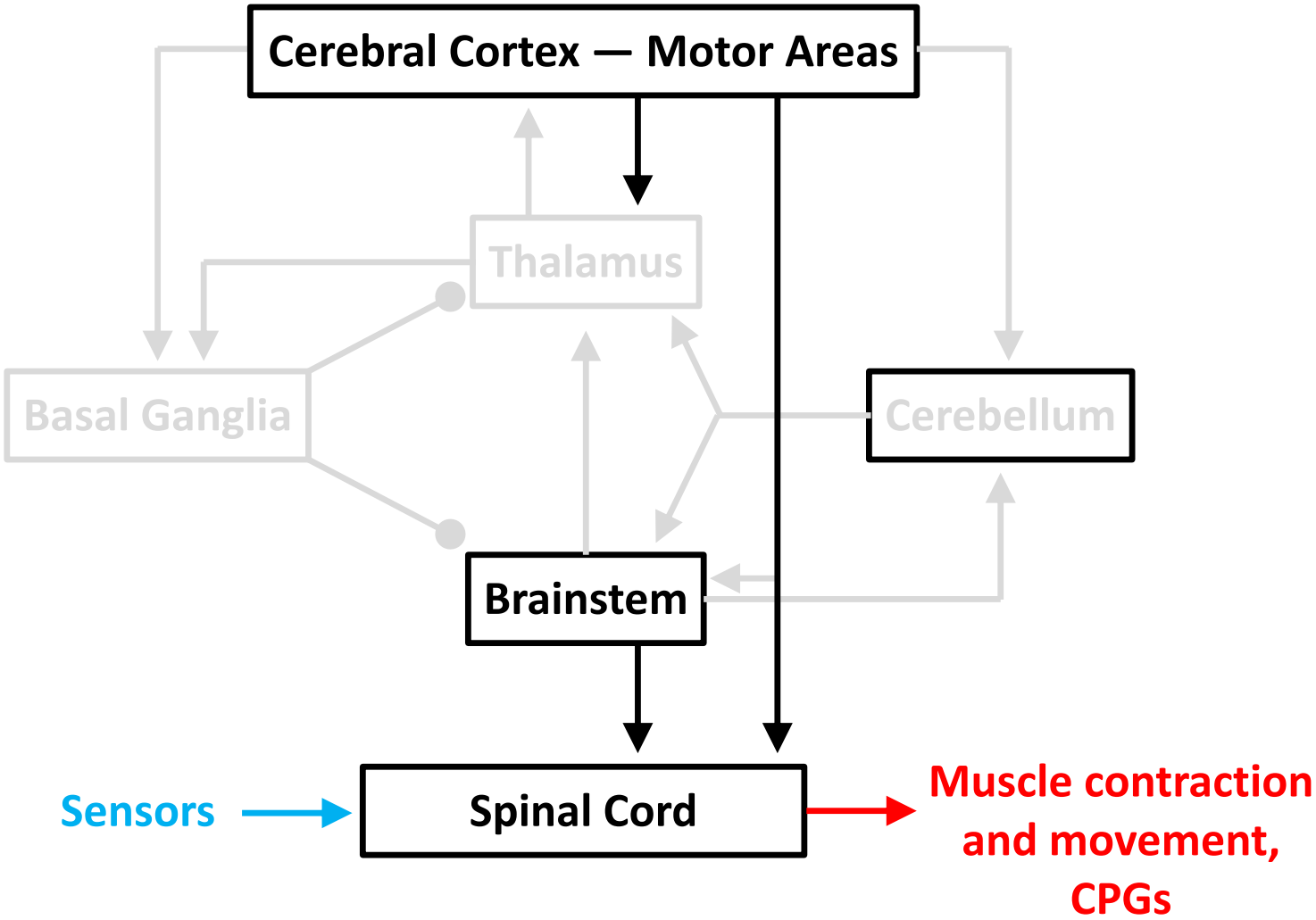


B. Unilateral lesion to some frontal cortical areas result ***Alien Hand Syndrome***

Study Questions

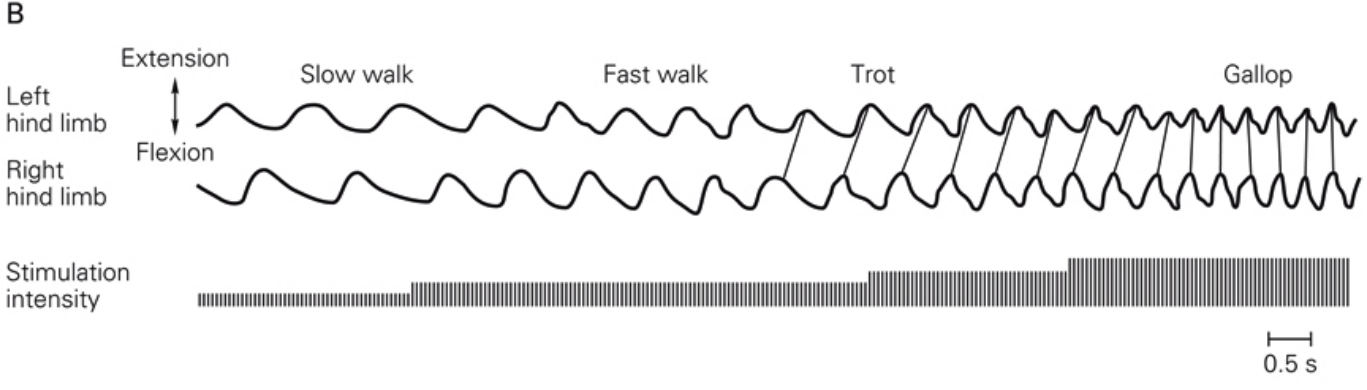
1. You look at a pen on the desk in front of you. Pick it up. Watch your hand as it goes. At what angle and velocity does your hand approach the pen? What do your fingers do in the instant before they grasp then pen, and what do they do during the grasp? How might this simple reach and grasp emerge from a kinematic to kintic coordinate transformation? What brain areas participate in this simple action?
2. What are an object's *affordances*?
3. What are *mirror* neurons?
4. Can you design experiments to test the neural correlates of free will?

Descending inputs to spinal cord can turn on CPGs



Stimulation of the Midbrain locomotor region (MLR) in the brainstem triggers locomotion

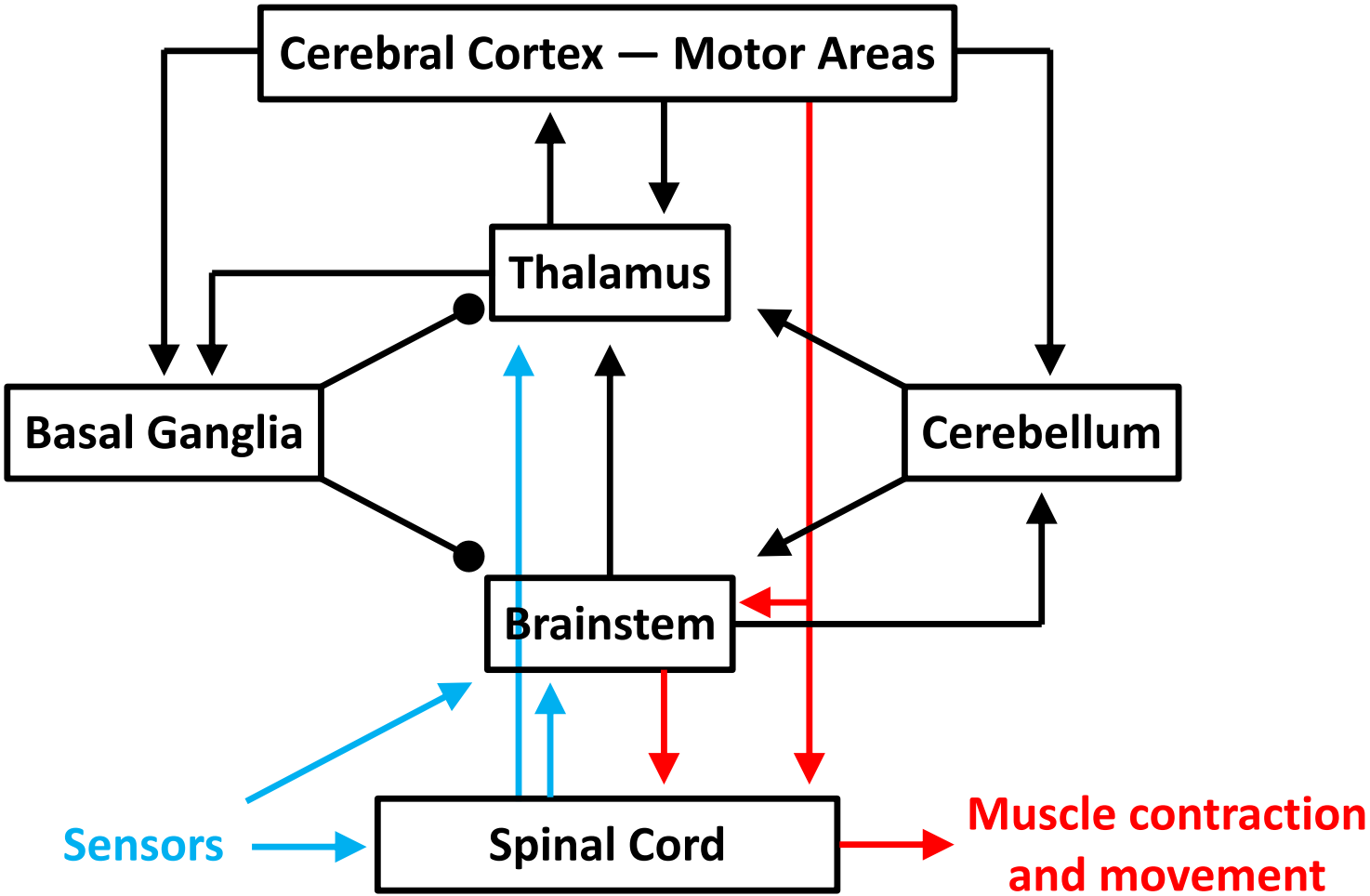
http://www.youtube.com/watch?v=wPiLLplofYw



Goals of lecture 1

1. Neuromuscular Junction
2. Motor neurons and motor units
3. Simple Reflexes
4. Central Pattern Generators (CPGs)

Motor Cortex and Free Will



Where – if anywhere – in this motor hierarchy does 'intentionality reside?"

Today's main points

(1) FROM GOAL TO ACTION: Kinematic→Kinetic coordinate transformations in cortical circuits

(2) WHAT TO DO? Parietal encoding of object AFFORDANCES

(3) TO DO, OR NOT TO DO? Intentionality emerges from brain activity

(4) WHEN THE SYSTEM BREAKS: Clinical signs from parietal and frontal cortical damage

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Clicker Question: A patient comes with a paralyzed left arm. This presentation is NOT consistent with a lesion in which of the following areas?

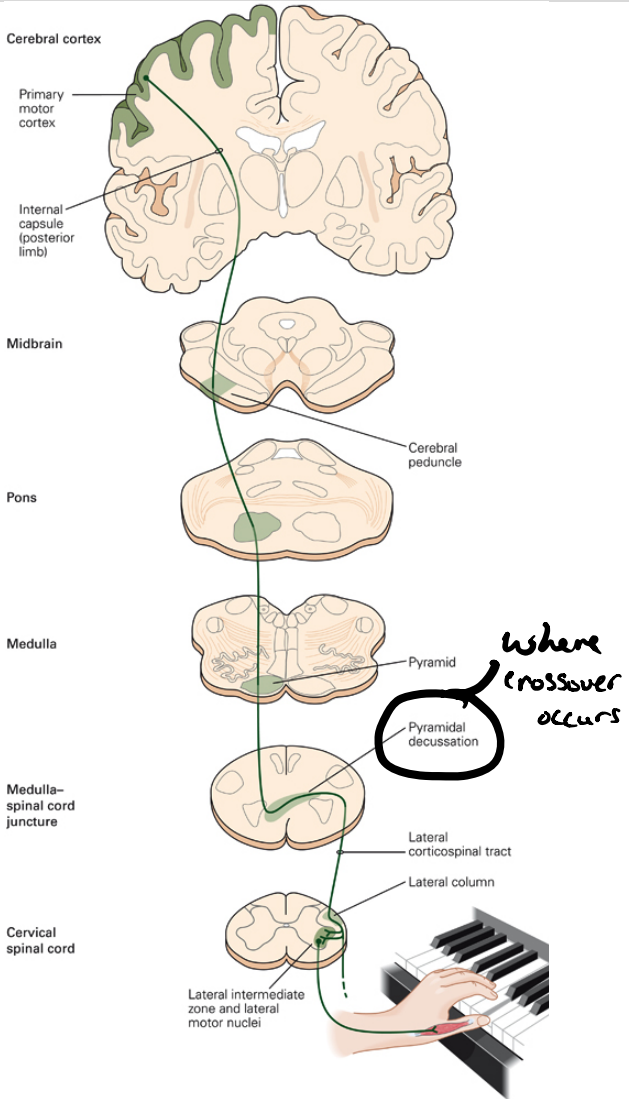
A. Left cervical spinal cord below the pyramidal decussation. – paralyze left

B. Right brainstem above the pyramidal decussation. – paralyze left

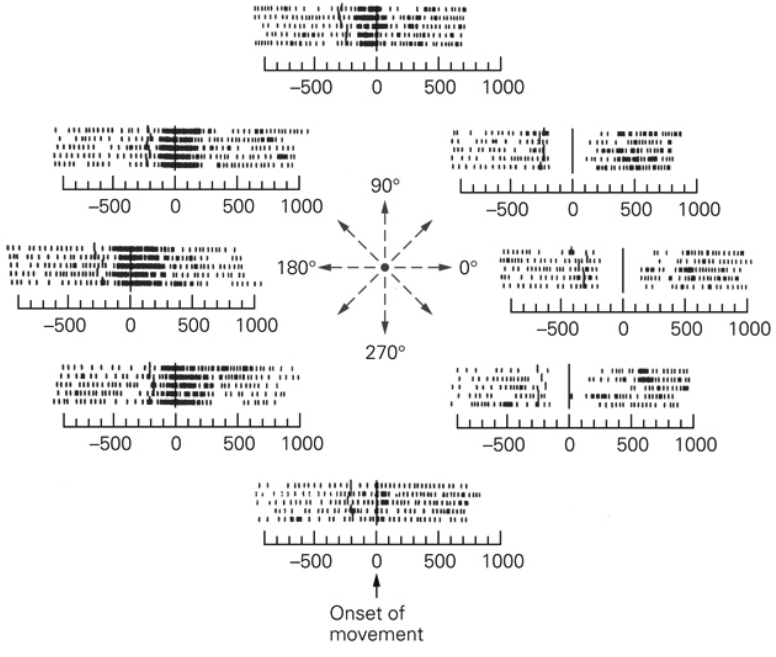
C. Right motor cortex – paralyze left

D. Ventral roots on the left side of the cervical spinal cord – paralyze left

E. All of the above are consistent with left limb paralysis.



Clicker Question: What does this neuron encode in the center out task?



(A) Neurons are encoding kinematic parameters of movement (endpoint)

(B) Neurons are encoding kinetic parameters of movement (which muscles to activate)

(C) Neurons are encoding both kinetic and kinematic parameters

(D) Impossible to tell with this dataset (could be either one)

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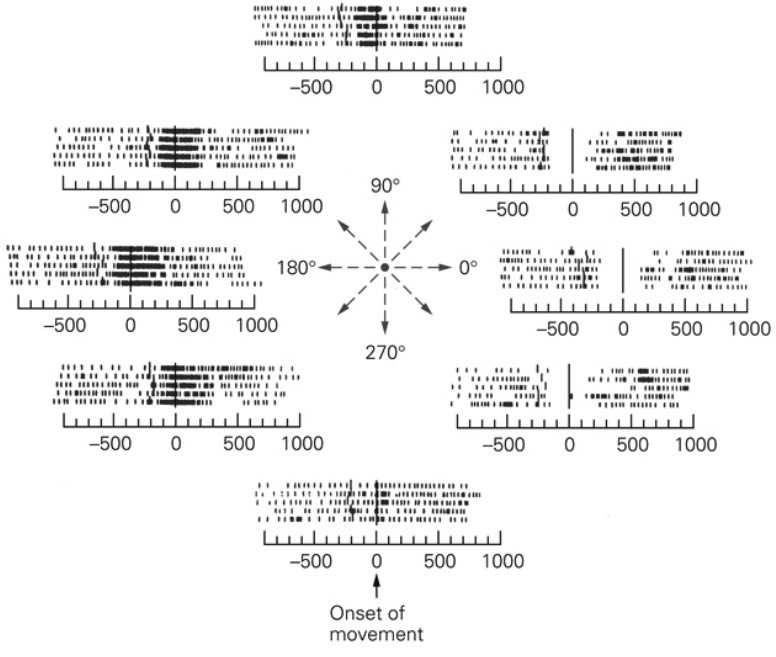

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Clicker Question: Which experiment could disentangle kinematics from kinetics?

thinking of movement

doing movement

(A) Repeat reach task while varying the starting posture/position

(B) Repeat reach task but make monkey do specific Left-Right sequences

(C) Test how motor cortex lesion affects performance in reach task

(D) All of the above

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Clicker question: This data suggests that the neurons recorded here are coding for…

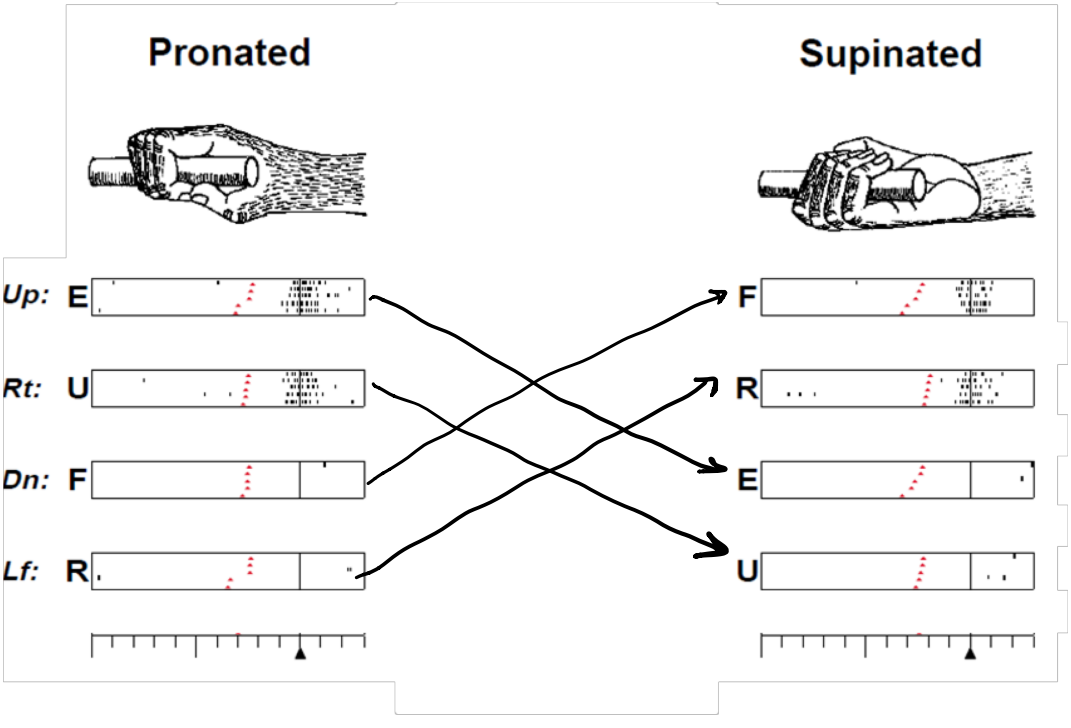
A. Kinetics

B. Kinematics

C. Affordances

D. Force

E. None of the above



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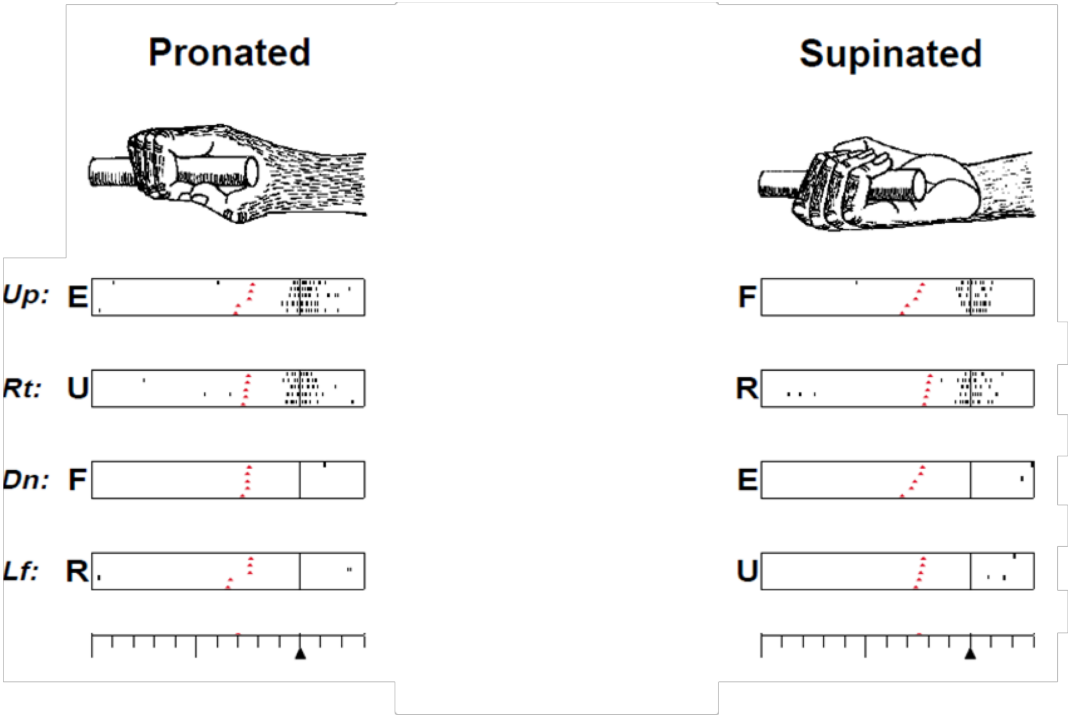
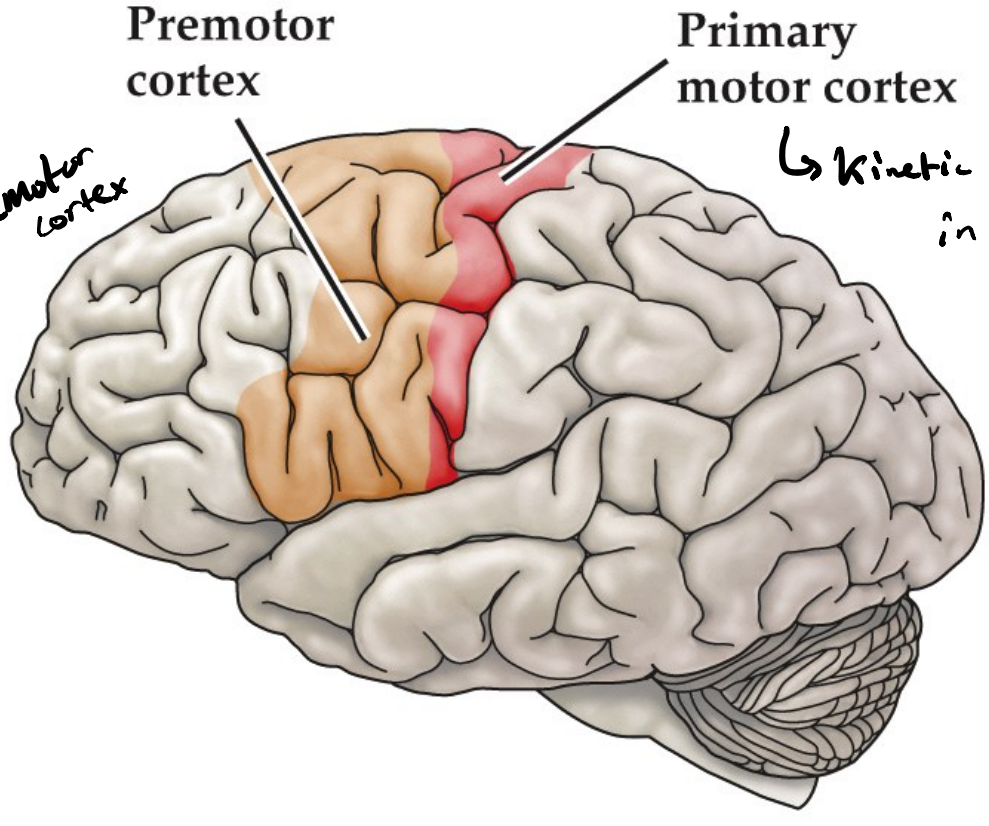


Hierarchical processing in motor cortical areas: Kinematic-to-kinetic coordinate transformation in Premotor→Motor cortex

Kinematic neurons – Goals

Kinetic neurons – Muscles



Kinematics stored in premotor cortex

↳ Kinetic neurons stored in primary motor cortex

What piece of information is necessary to implement this transformation?

-POSTURAL INFORMATION (So you need some sensory processing in motor cortex)-

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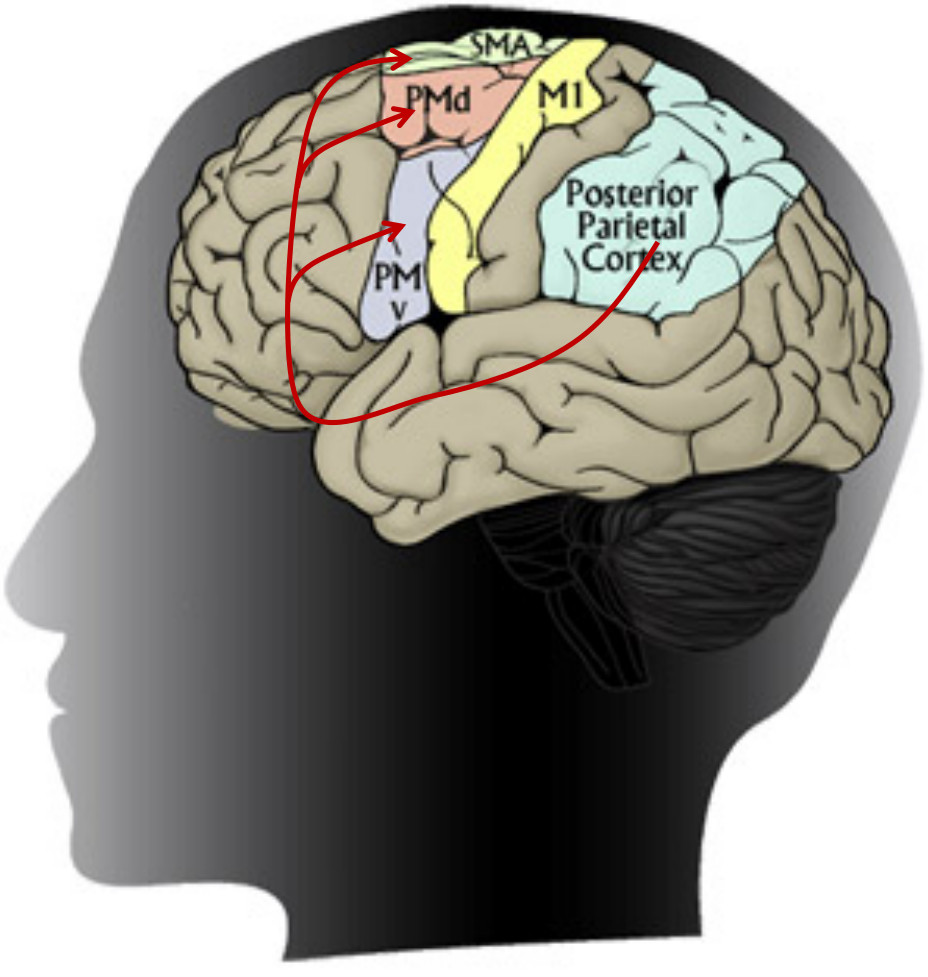
(3) TO DO, OR NOT TO DO? Intentionality emerges from brain activity

(4) WHEN THE SYSTEM BREAKS: Clinical signs from parietal and frontal cortical damage

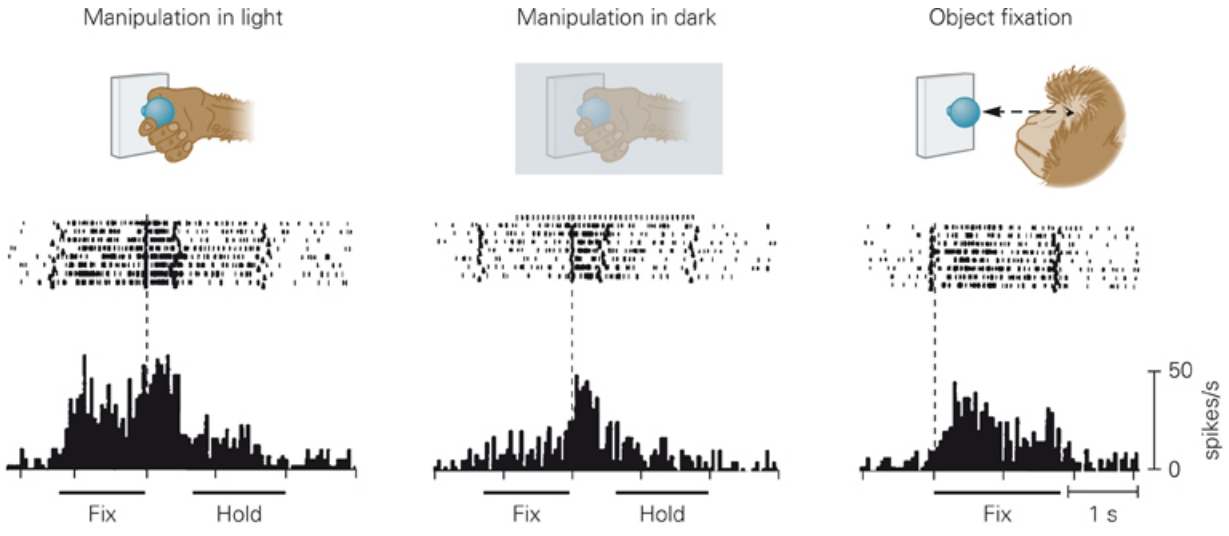
Parietal Cortex: More complex motor planning for goals (e.g. affordances)



Parietal lobe gets sensory inputs and projects to motor cortical regions

Parietal lobe gets sensory inputs & projects to motor cortical regions

Clicker question: What is this parietal neuron encoding?



A. The kinematics of the reach

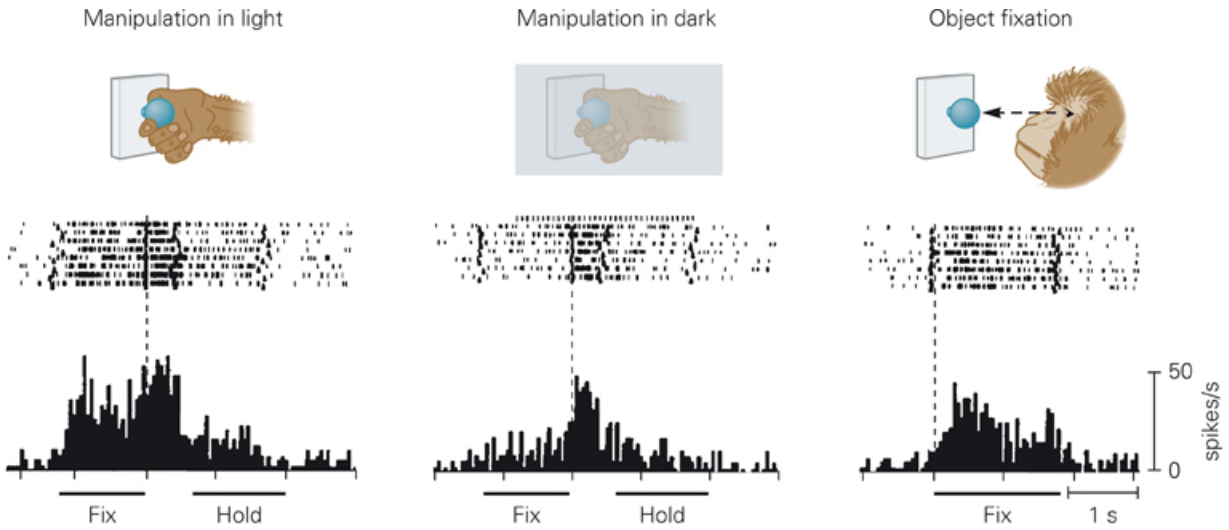
B. A precise location of the knob being grasped

C. The action of grabbing a knob

D. The visual percept of the knob

E. C and D

Clicker question: What is this parietal neuron encoding?



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E. C and D

Just seeing an object can activate motor-accessing circuits on how to grab it!


IN GOD WE TRUST
LIBERTY
240
S O N D J F M A

Fresh Promotions


IN GOD WE TRUST
LIBERTY
240
S O N D J F M A

Fresh Promotions

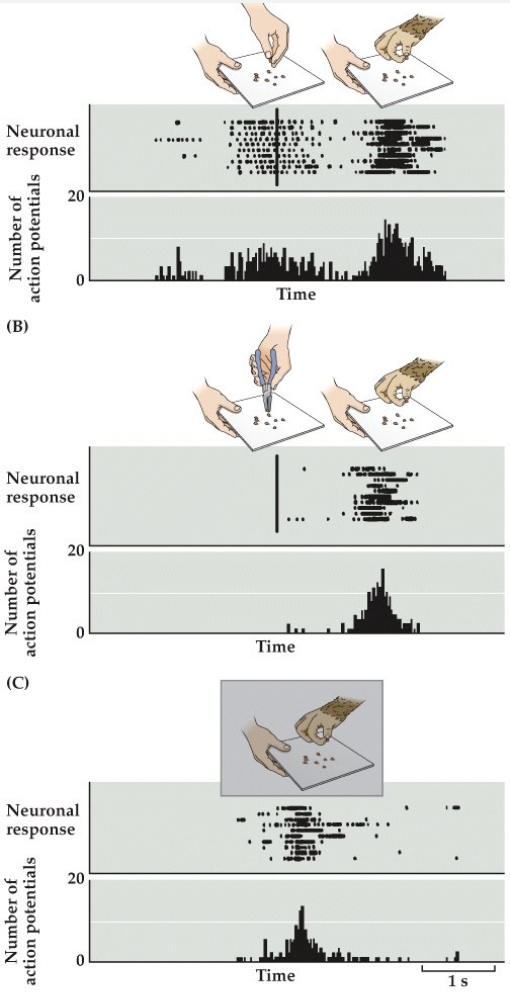
An affordance neuron in parietal cortex is active during

(1) Perception of an object
(2) When acting on the object

Affordance neuron is active both when perceiving the object as well as acting on the object.

The motor theory of perception

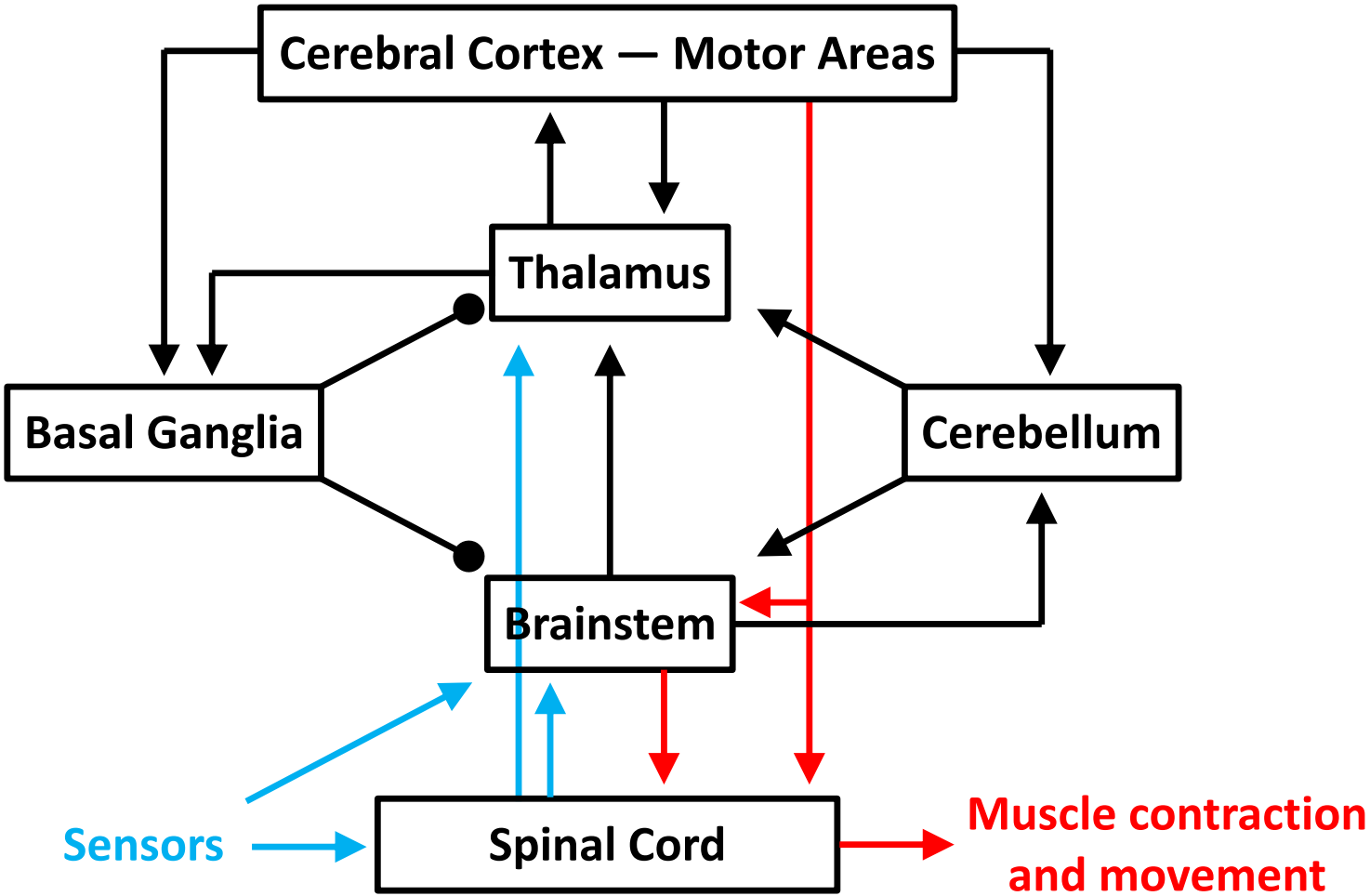
Mirror neurons encode an *action* either performed or observed



Affordance: Just seeing an object can activate motor-accessing circuits on how to grab it!

Mirror neuron: Just ~~seeing~~ an object action can activate motor-accessing circuits on how ~~to grab~~ do it!

Lecture 21 – Motor Cortex and Free Will



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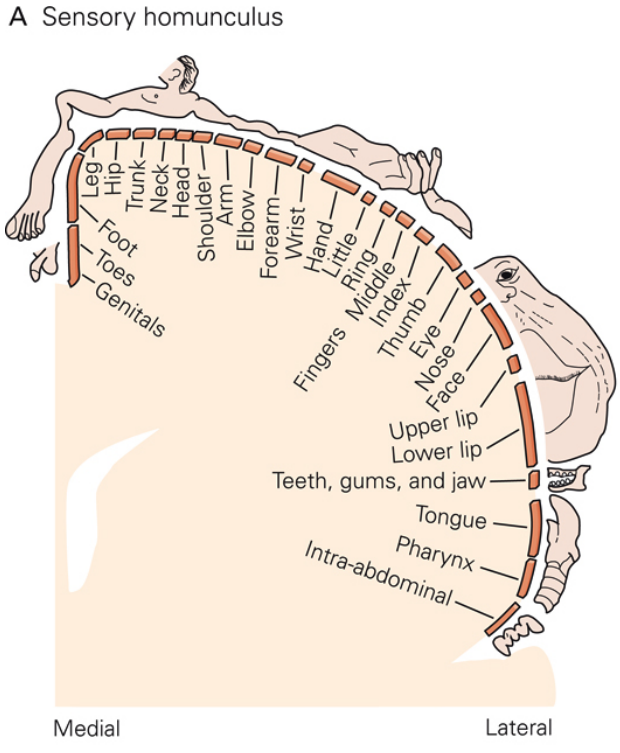
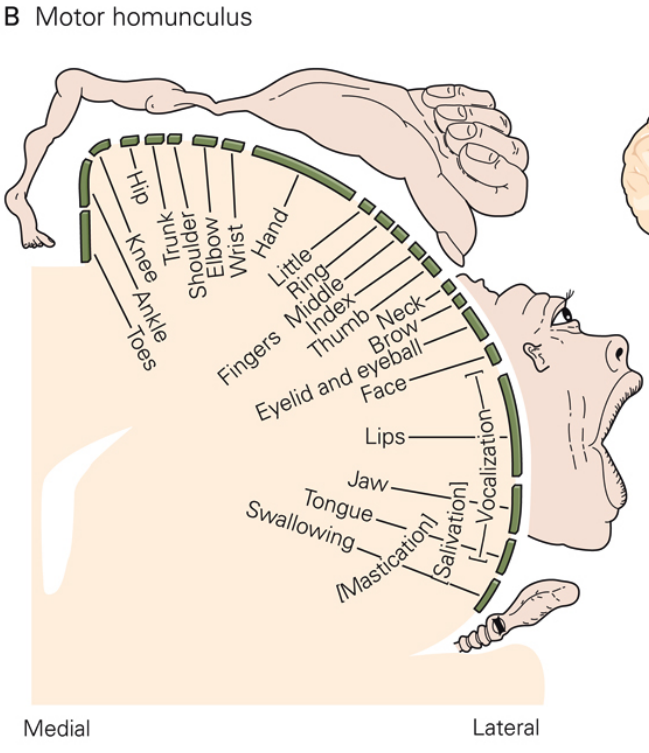
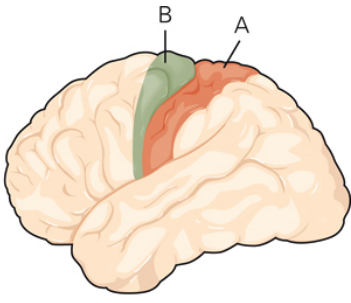
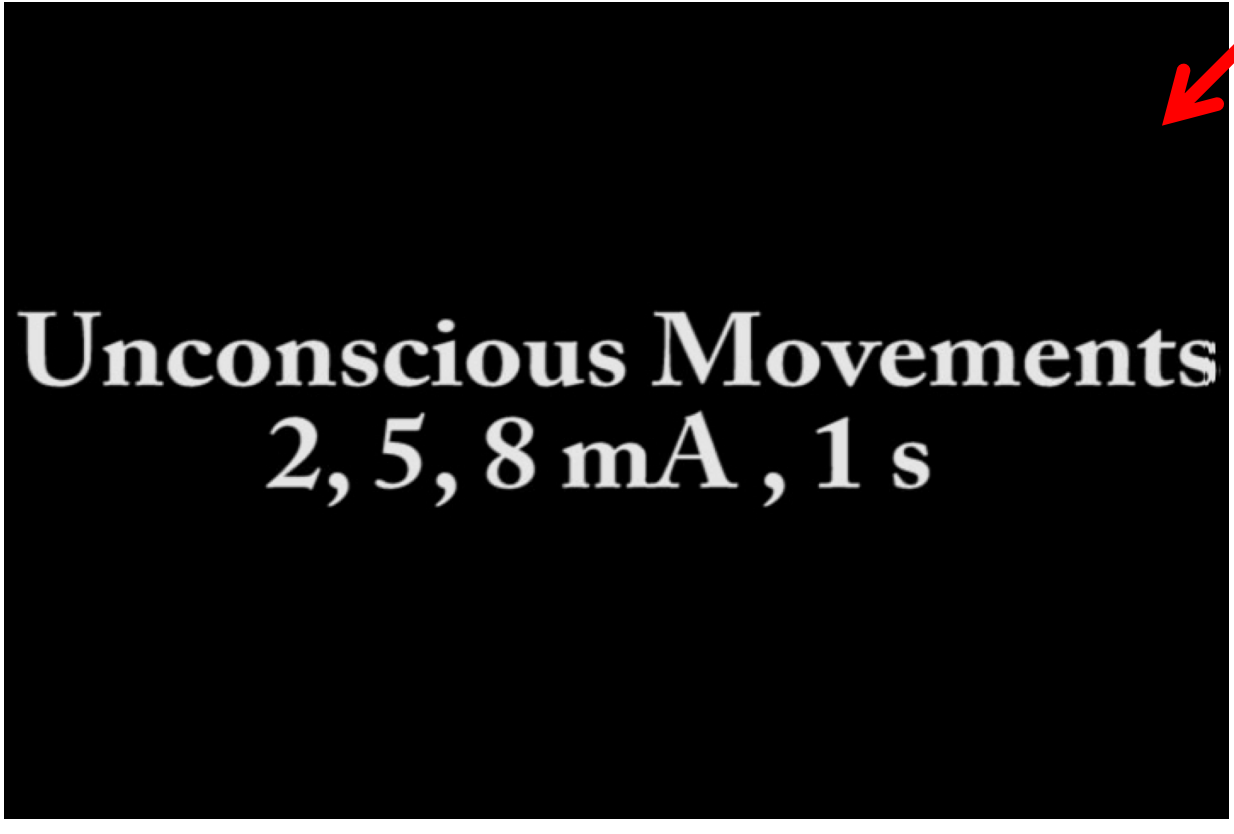
Microstimulation experiments reveal the ‘homonculus’ in sensory and motor cortex





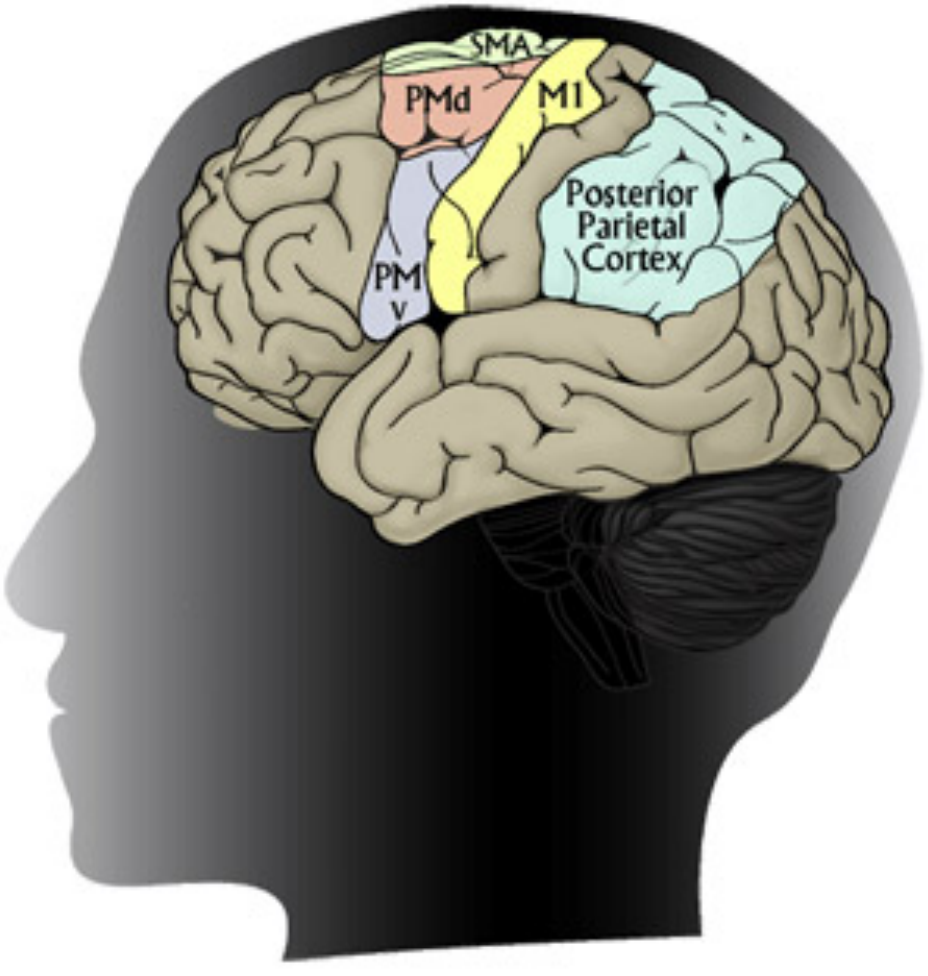


Is motor cortical activation and execution of subsequent movement sufficient to give the sense that the movement was *willed*?

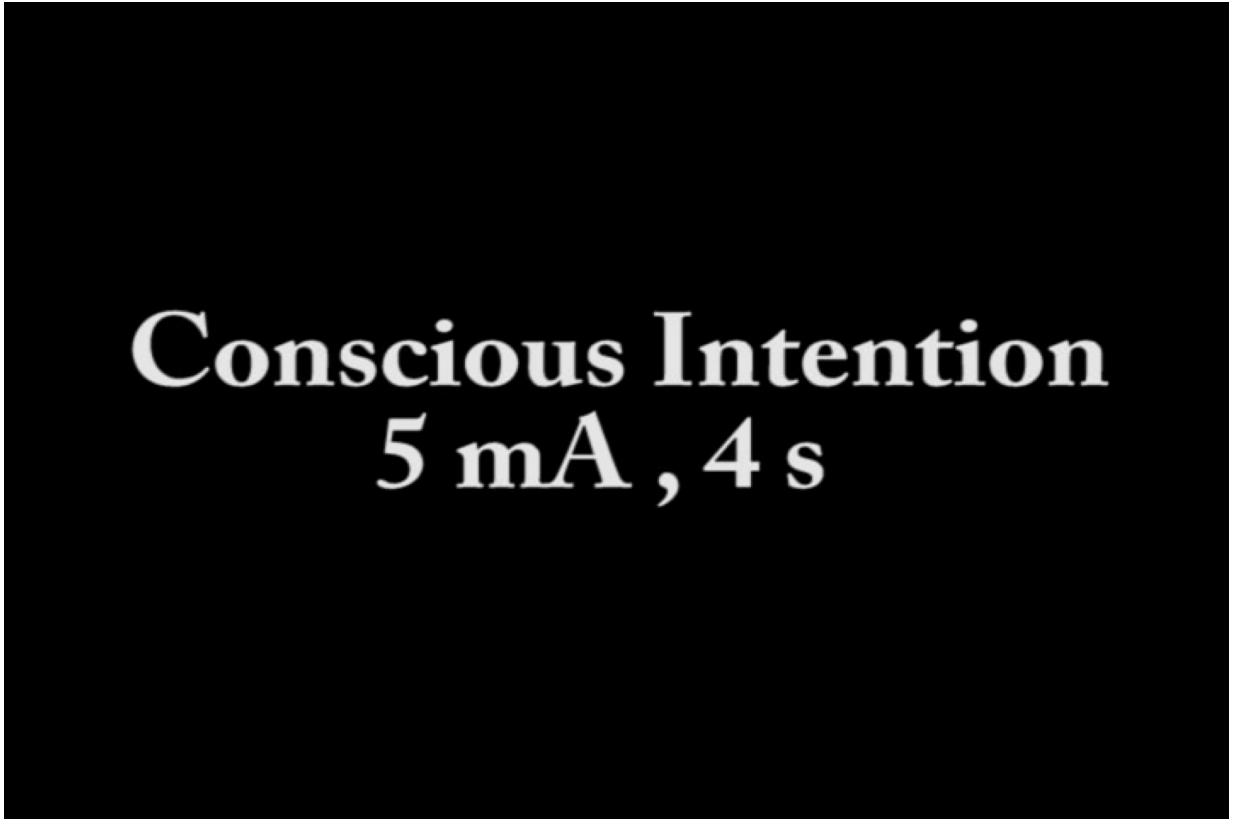


Stimulation of motor cortex produces UNCONSCIOUS/UNPERCEIVED movements

What happens when you stimulate parietal cortex?



Does parietal stimulation trigger movement?
Does it trigger the will to move?
Does it trigger the sense that you just moved?

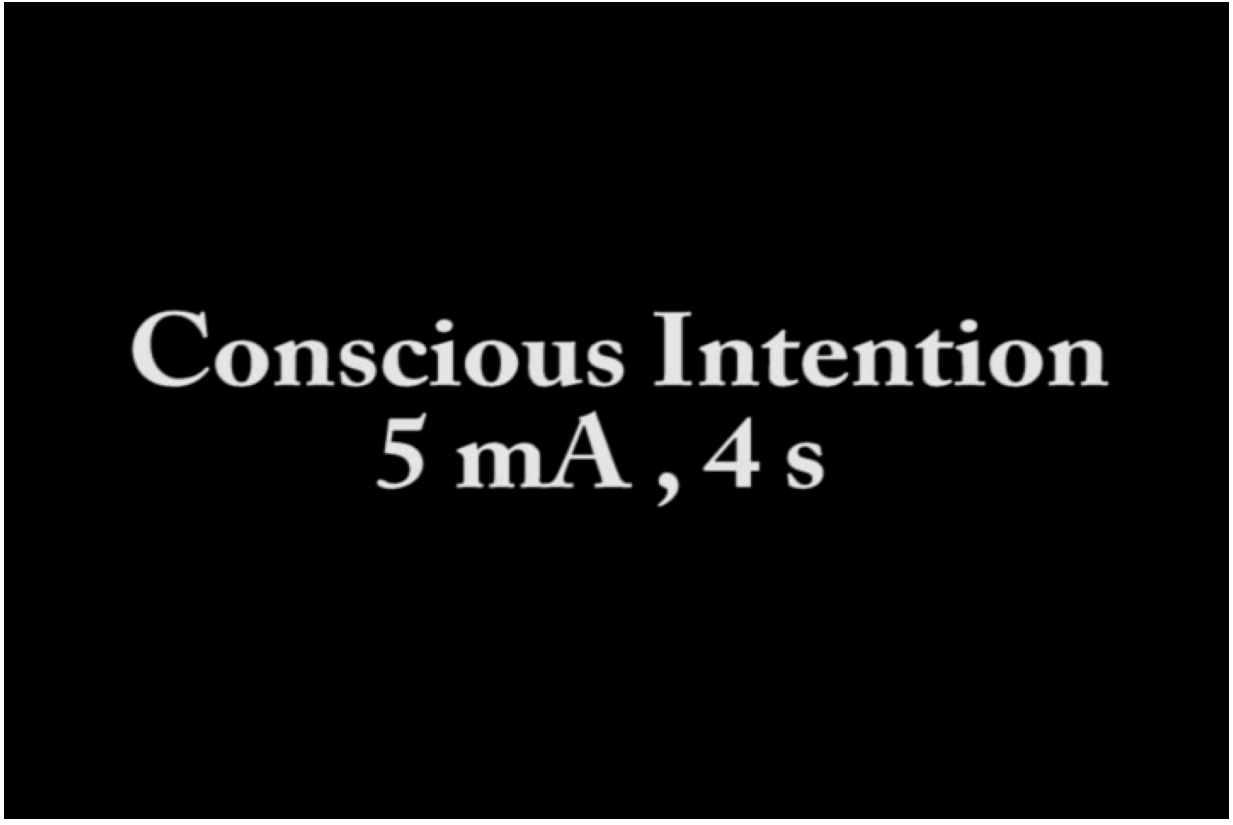


Parietal stimulation produces THE WILL TO MOVE
Higher stimulation intensities give patients the ILLUSION THAT THEY MOVED

Does parietal stimulation trigger movement? No

Can it trigger the will to move? YES

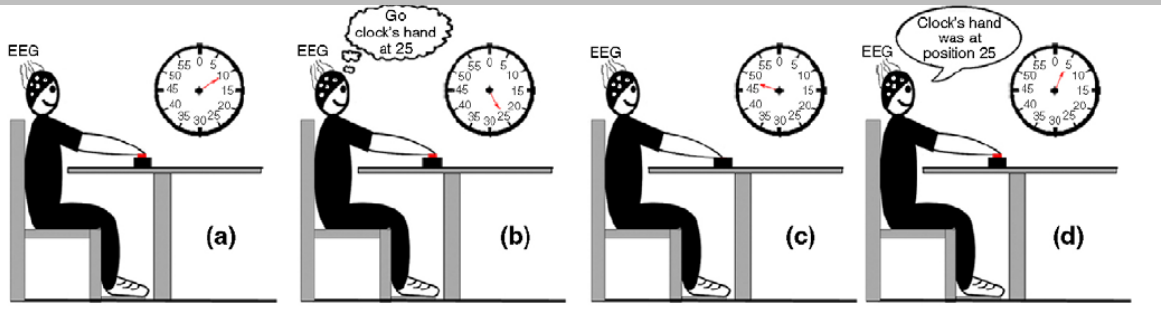
Can it trigger the sense that you just moved? YES



Parietal stimulation produces THE WILL TO MOVE

Higher stimulation intensities give patients the ILLUSION THAT THEY MOVED

The Libet experiments: An exercise in 'Free Will'



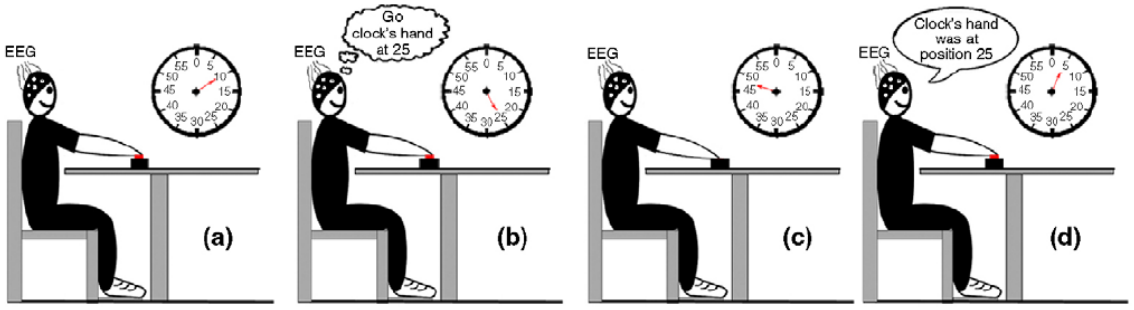
Look at the clock's hand

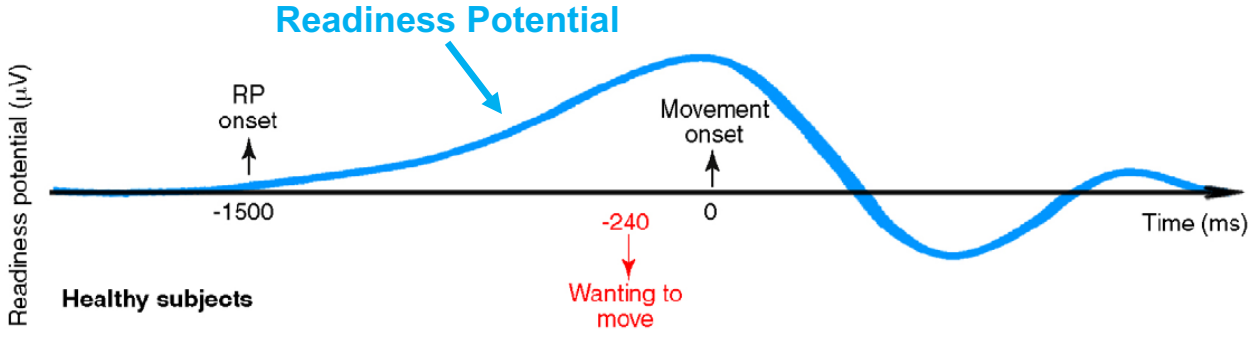
Note clock's hand position at the time of conscious intention

Press Button

Report clock's hand position at the time of conscious intention

Perceived conscious intention appears *during* motor planning





Recap

Parietal Stimulation → will/perception of movement

Motor Cortex Stimulation → unconscious movements

Discussion question: What do the Libet experiments definitely show?

A. The readiness potential begins before awareness of movement

B. The sense that you are 'about to move' can actually begin after specific parts of your brain have begun to initiate the movement

C. Free will does not exist

D. There is no such thing as justice, but it is a convenient concept for a functioning society and legal system

E. A and B

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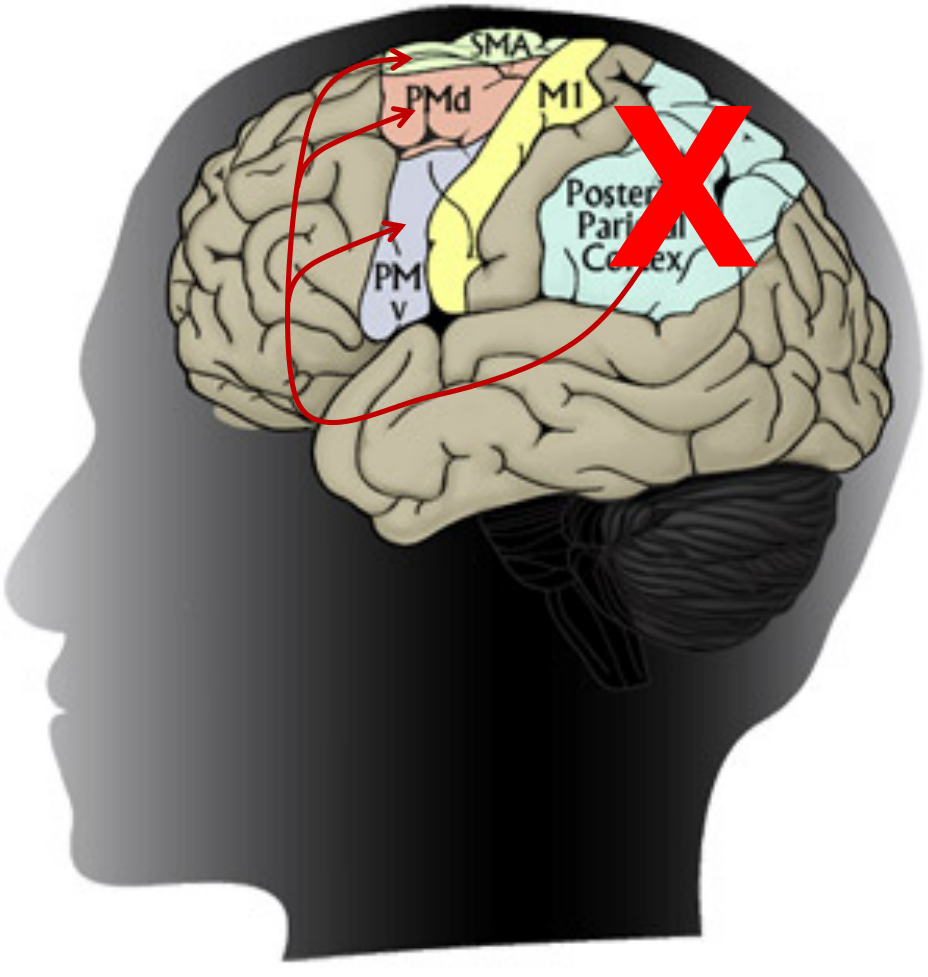
(4) WHEN THE SYSTEM BREAKS: Clinical signs from parietal and frontal cortical damage

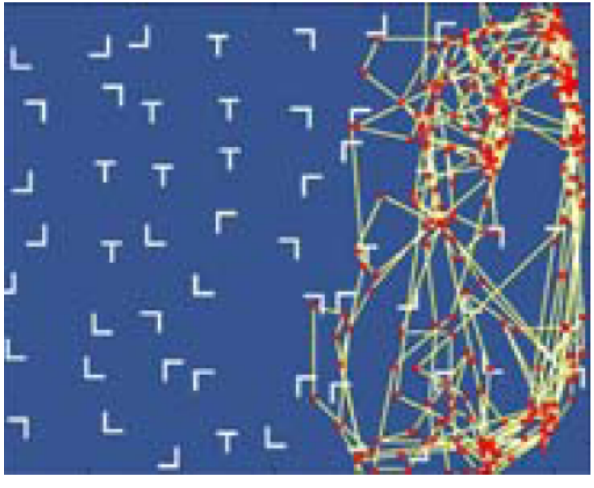
Parietal lobe and *sensory guided motor behavior*



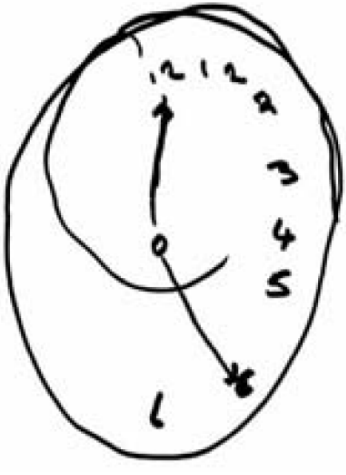
Unilateral parietal strokes result in contralateral 'hemineglect'

Symptoms after RIGHT PARIETAL STROKE

"Search for Ts"



"Draw a clock"



Hemineglect → Hemi = half, Neglect = ignore i.e ignore-half (the world)

As if half of the world is not *actionable*

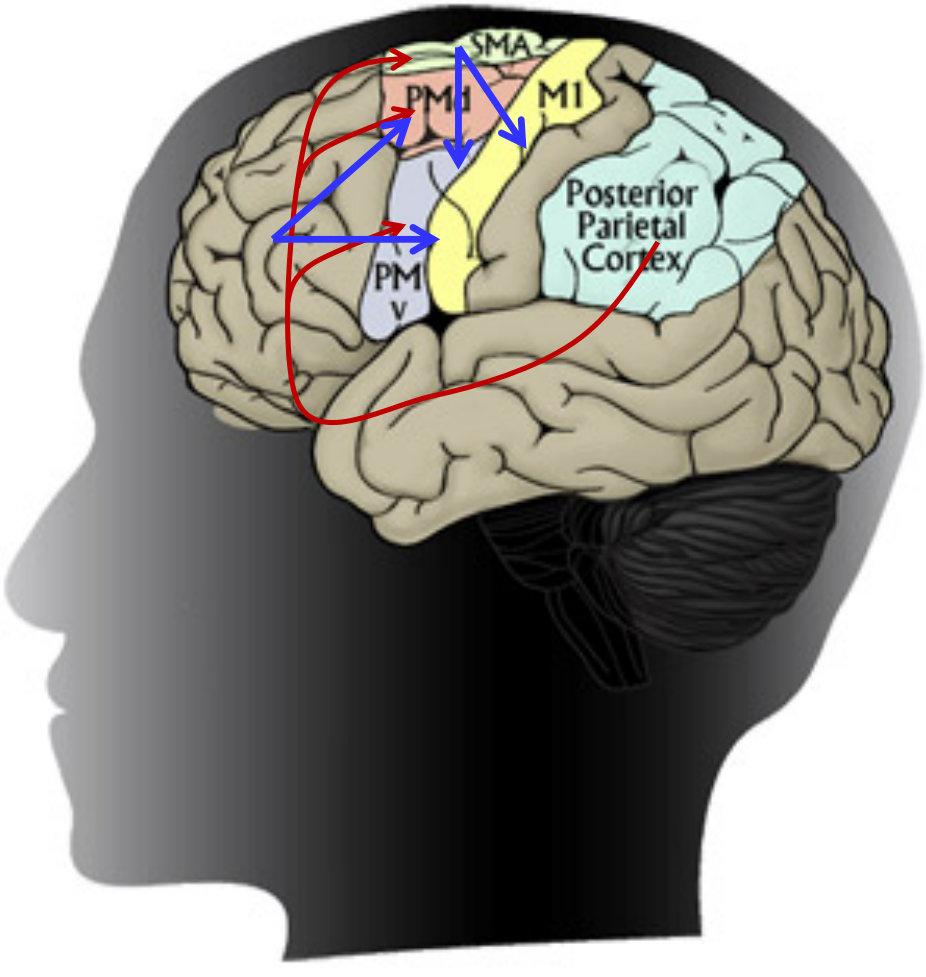
An affordance neuron in parietal cortex is active during

(1) Perception of an object
(2) Handling the object

So what prevents us from grabbing all objects we see?


gettyimages
Dorling Kindersley
125158471

Frontal and supplementary motor areas also regulate movement



The SMA controls movements that are internally generated (rather than sensory driven)

Supplemental Motor Area Lesions → ALIEN HAND SYNDROME

From the onset of his disease, CU displayed non requested but coherent activities whenever the environment presented him with the opportunity to carry them out. For instance, while tested, 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".

CU, to his dismay, was unable to halt his grasping, and often required the help of another person to force the release of the object he had grasped. Instances of groping occurred very often, particularly with his right hand.

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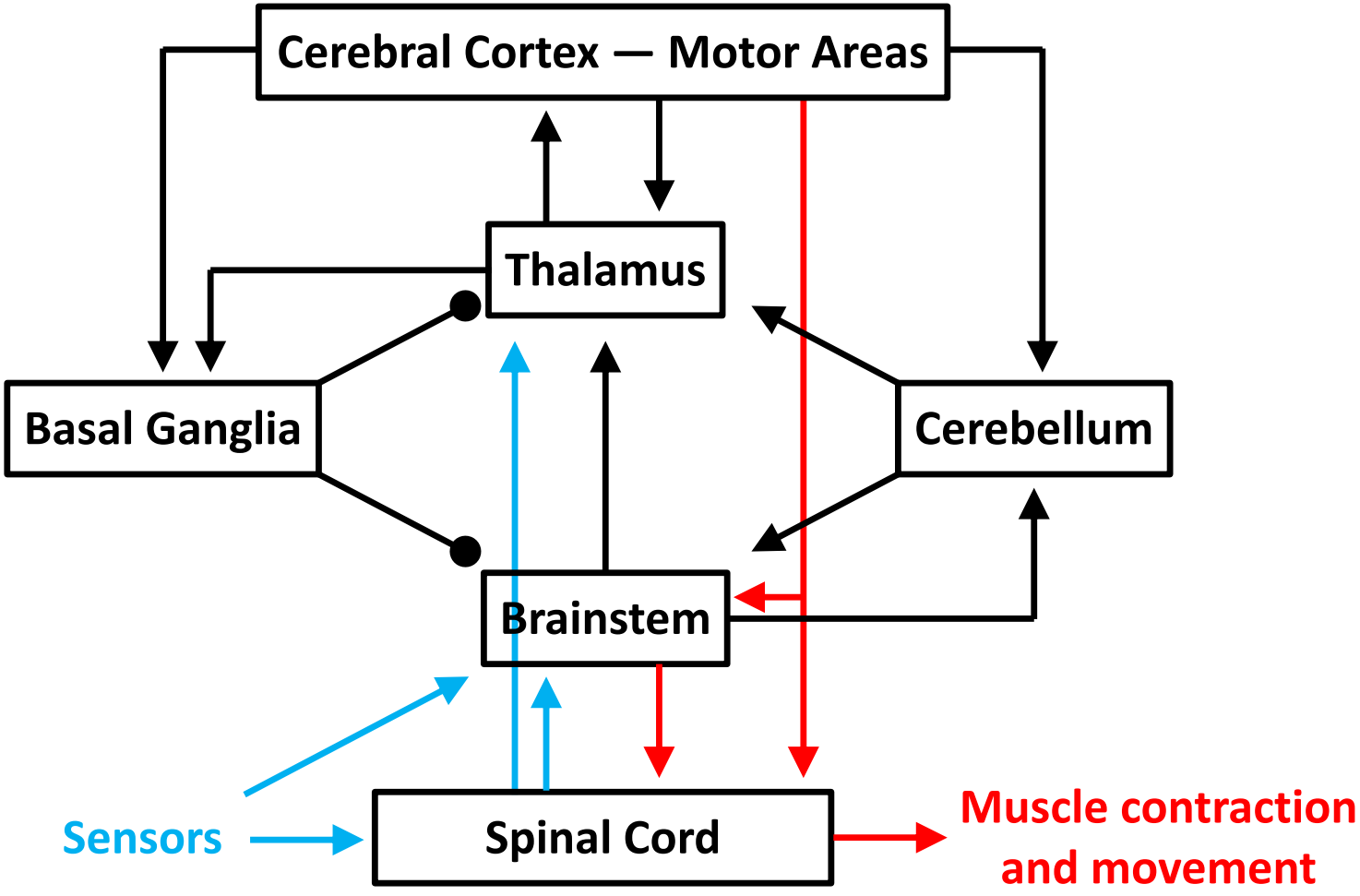
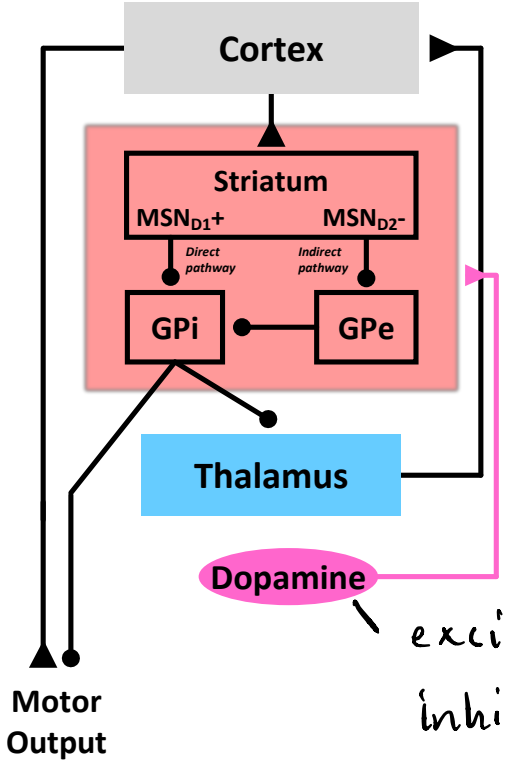
Next lecture is on the basal ganglia



NEXT LECTURE: Basal ganglia and Parkinson's Disease



Glutamate (+) – excitatory

Gaba (-) – inhibitory

MSN = Medium Spiny Neuron (main cell type in striatum)

GPi = Globus Pallidus, Internal Segment

GPe = Globus Pallidus, External Segment

MSN_{D1} neurons express are excited by dopamine via the D1 type dopamine receptor

MSN_{D2} neurons express are inhibited by dopamine via the D2 type dopamine receptor

excitatory on MSN_{D1}

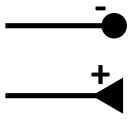
inhibitory on MSN_{D2}

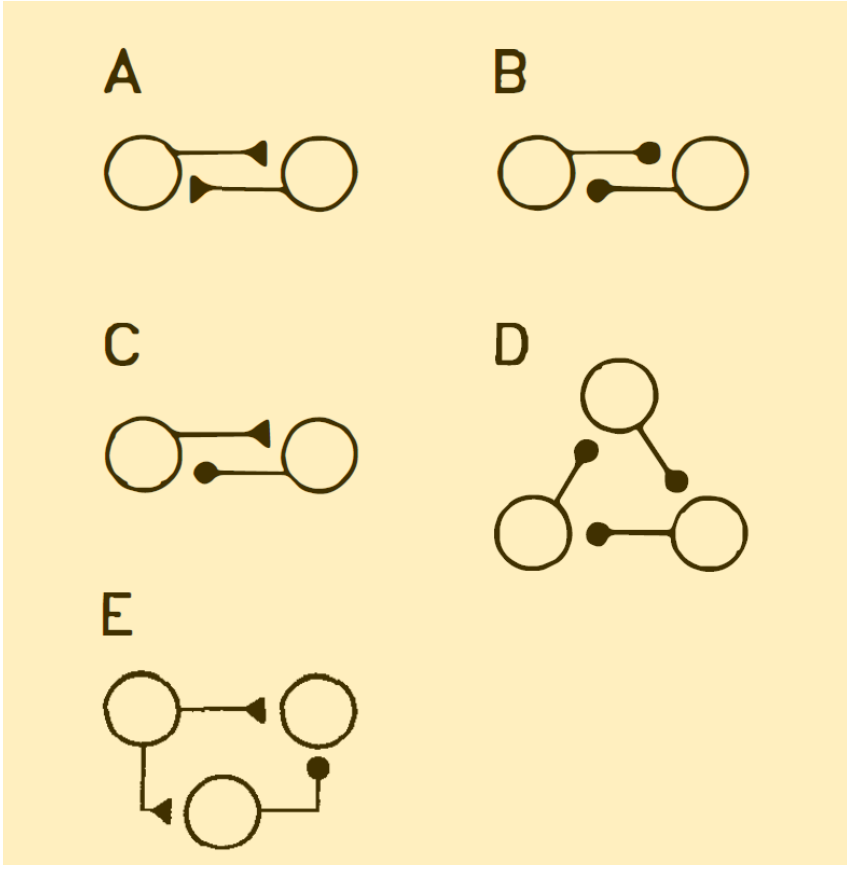
Memorize the BG microcircuit!

(if you want to get the most out of next lecture)

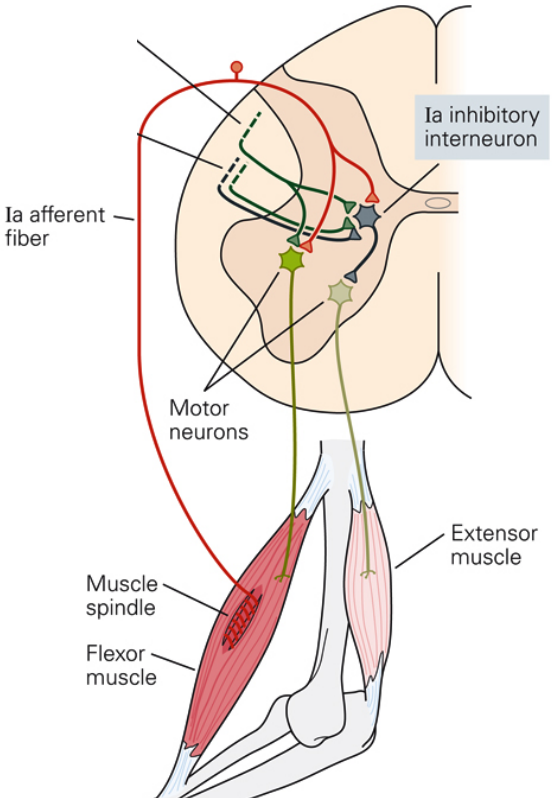
Know the direct and indirect pathways

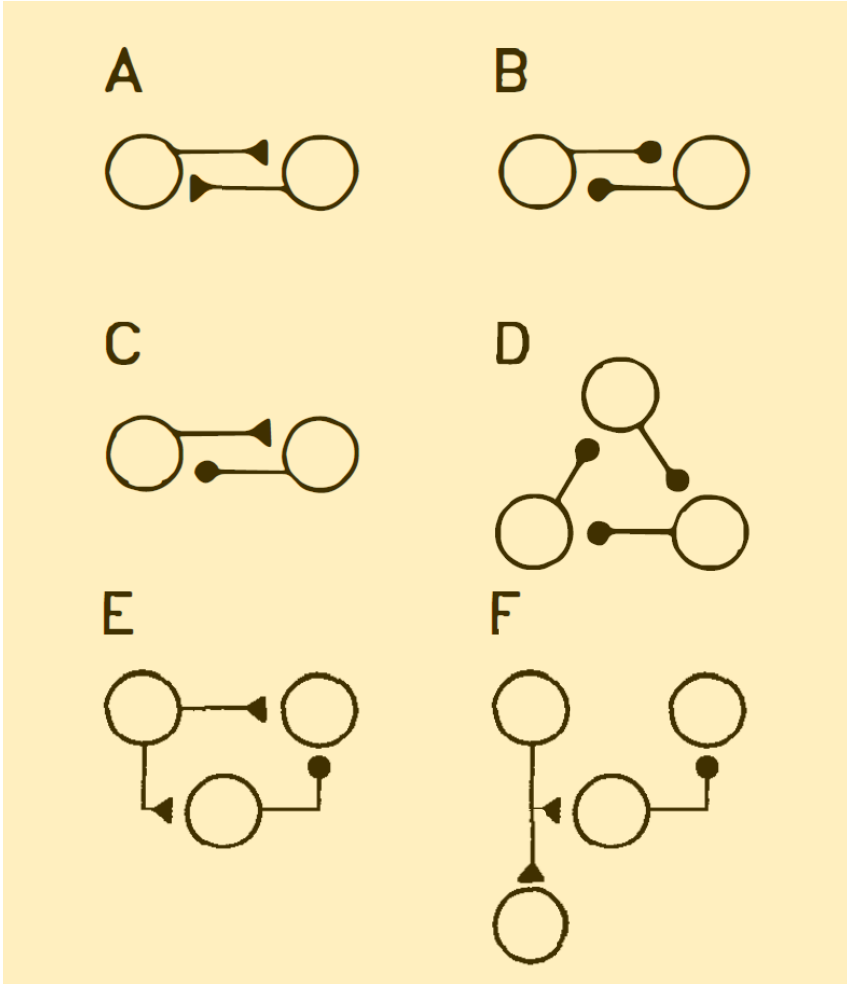
Discussion Question: All neurons in these microcircuits are oscillating. Which microcircuit definitely has an intrinsically bursting neuron driving the rhythm?





Discussion question: Which of these is the spinal microcircuit implementing the stretch reflex?





Little microcircuit diagrams…

Clicker question: The neuron whose activity is shown in the histogram below is likely coding for

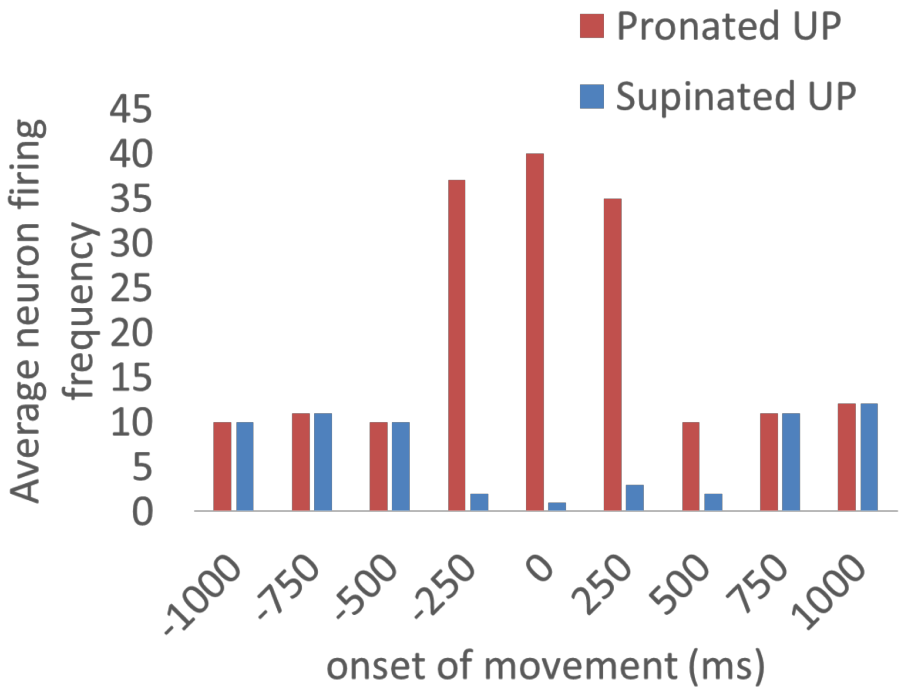
A. Kinetics

B. Kinematics

C. Affordances

D. Force

E. None of the above



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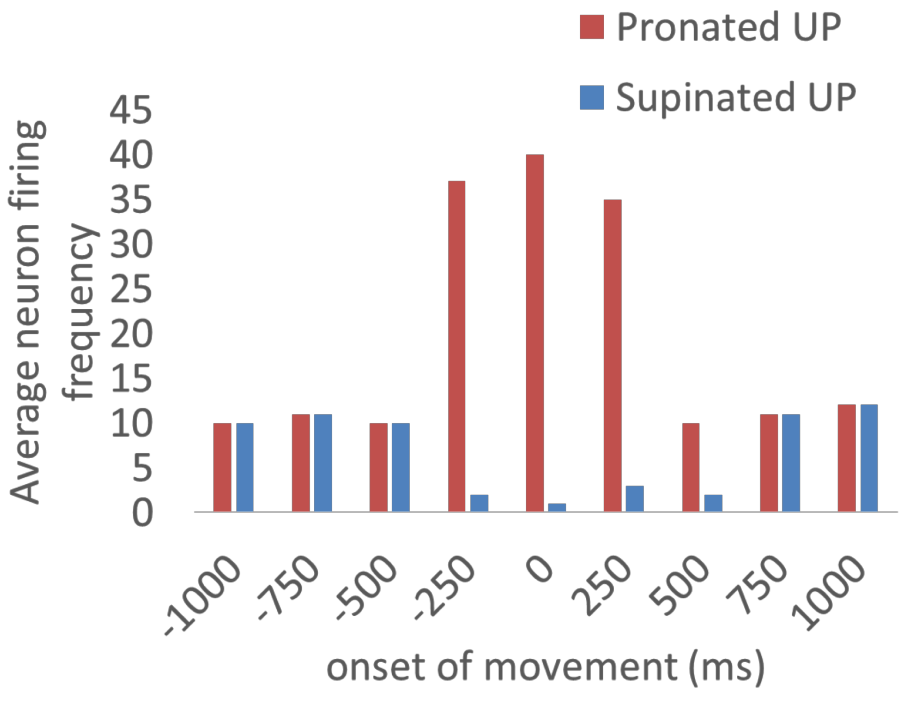

Graded Clicker question: A mirror neuron is active during…

A. Perception of a specific action

B. Taking that same specific action

C. A and B

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http://www.informationphilosopher.com/solutions/scientists/haggard/

A passage from Ian McEwan's novel, *Atonement*:

She raised one hand and she flexed its fingers and she wondered how this thing, this machine for gripping, this fleshy spider on the end of her arm, came to be hers, ENTIRELY at her command. Or did HER hand - have some little life of its own? She bent her finger and straightened it. The mystery was in the instant BEFORE the finger moved, the dividing line between not moving and moving, when her INTENTION took effect. It was like a WAVE breaking and If only she could only find herself at the CREST of the wave she thought she MIGHT find the secret of herself, that part of her that was REALLY in charge. She brought her forefinger close to her face and STARED at it, URGING it to move, but the finger remained still because she was preTENDing, she wasn't ENTIRELY serious, and because WILLING the finger to move, or being ABOUT to move it, was the not the same as ACTUALLY moving it. And when she did BEND the finger finally, the action seemed to start in the finger – and NOT in some part of her mind. When did the finger know to MOVE, when did SHE know to move the finger? There was NO catching herself out. It was EITHER - or. There was no stitching, no seam, and yet she KNEW that behind the smooth continuous fabric was the REAL self – her soul? – which took the decision to cease pretending, and gave the FINAL COMMAND.