MOTOR CONTROL

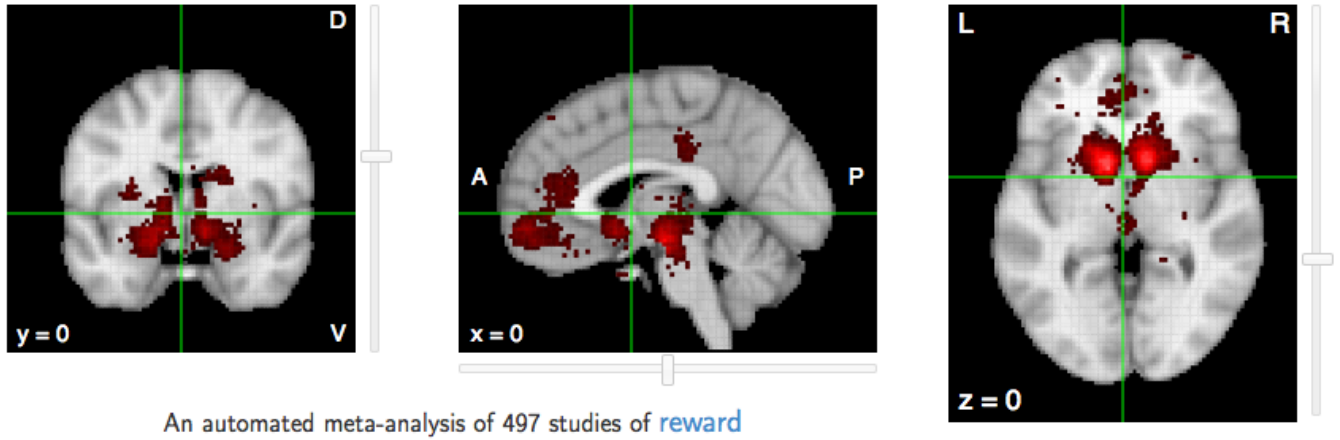
https://physicsworld.com/a/brain-computer-interface-that-allowed-a-paralysed-man-to-walk-is-the-physics-world-2023-breakthrough-of-the-year/

Neurosynth Part 2 (Due 3.18.25 @ 11:59 pm)

neurosynth.org

Neurosynth is a platform for large-scale, automated synthesis of functional magnetic resonance imaging (fMRI) data.

It takes thousands of published articles reporting the results of fMRI studies, chews on them for a bit, and then spits out images that look like this:

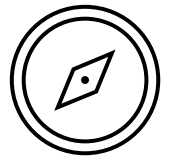


An automated meta-analysis of 497 studies of reward

Focus: Understanding structure-function relationships in terms of brain activation and functional localization

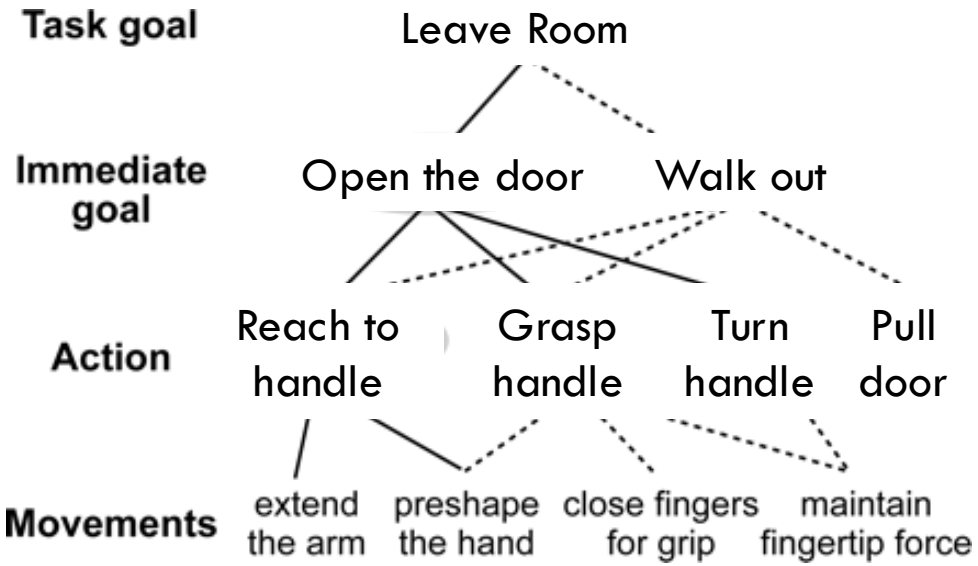
Review critical concepts from earlier in the course

The Plan



Go to next class

- How movements are generated
  - Motor plan
  - Posterior parietal cortex to muscles
- Selection and evaluation of movement
  - Basal ganglia
  - Cerebellum
  - Anterior cingulate, right inferior frontal cortex
- Movement disorders
  - Parkinson's Disease
  - Huntington's Disease



Hamilton & Grafton (2006)

Suppose you are at a restaurant and very thirsty. You're ready to grab the water but the server is filling your glass. Which region may represent where you intend to reach once it's full?

0

- Supplementary motor cortex
- Premotor cortex
- Intraparietal lobule
- Retrosplenial cortex

Suppose you are at a restaurant and very thirsty. You're ready to grab the water but the server is filling your glass. Which region may represent where you intend to reach once it's full?

0

Supplementary motor cortex

0%

Premotor cortex

0%

Intraparietal lobule

0%

Retrosplenial cortex

0%

Suppose you are at a restaurant and very thirsty. You're ready to grab the water but the server is filling your glass. Which region may represent where you intend to reach once it's full?

0

Supplementary motor cortex

0%

Premotor cortex

0%

Intraparietal lobule

0%

Retrosplenial cortex

0%

The Basic Process

Major Structures and Functions

Goal: Avoid being hit & hit the other player

Given trajectory, move left and low

First duck, then throw

Move legs, torso, neck

Movement Sequences

Supplementary Motor Complex

Anterior Cingulate Cortex

Medial Prefrontal Cortex

Basal Ganglia

Cerebellum

"How"/"Where"

States

Selection

Posterior Parietal Cortex

M1

Dorsal & Ventral Premotor

Right Inferior Frontal Cortex

Coordination

Goals, motivations

Did it work?

Should I keep doing it?

Select actual, concrete movements

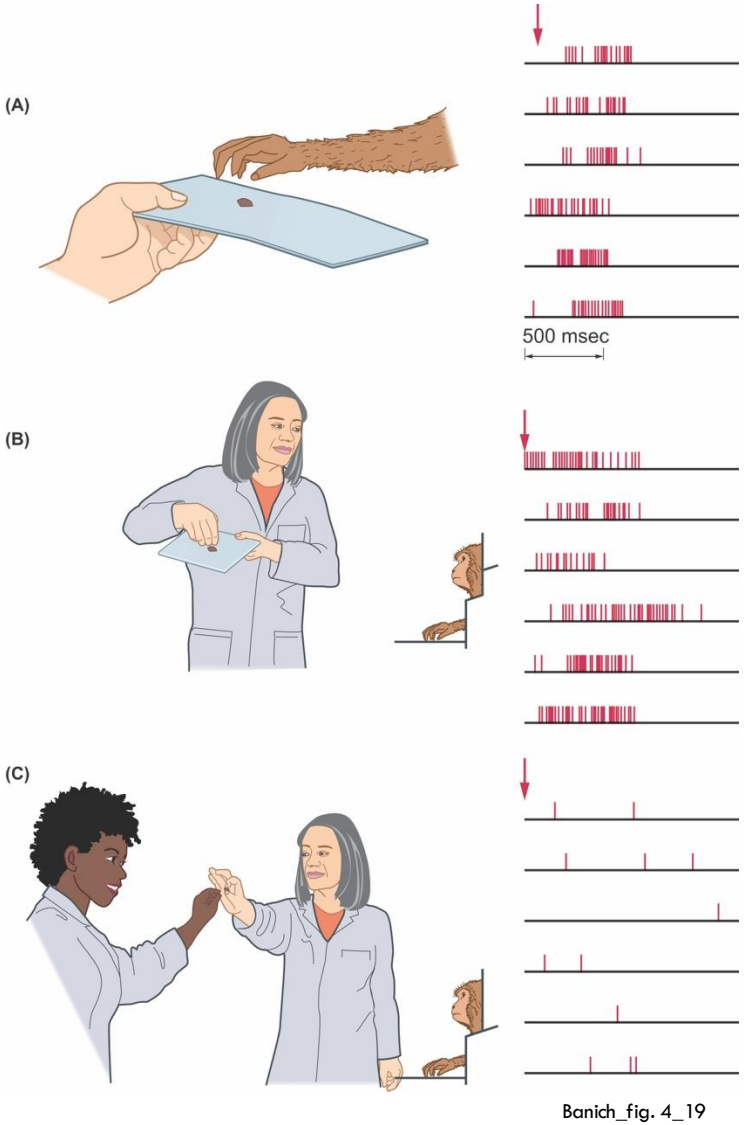
Dorsal: pointing, looking

Ventral: grip

https://www.youtube.com/watch?v=sT7hztKDRdc

Integrating motor commands with sensory info

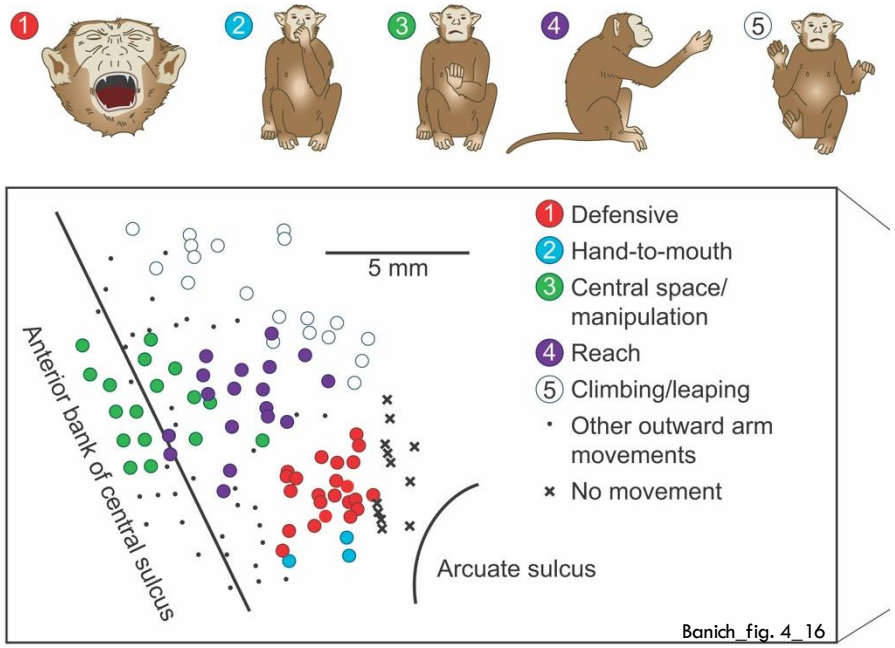
- Premotor selects and modifies movements
- PMd: select based on sensory information
  - Voluntary actions to locations
  - Frontal eye field
- PMv: adjust as manipulating
  - Shaping hand for grasping
  - Mirror neurons



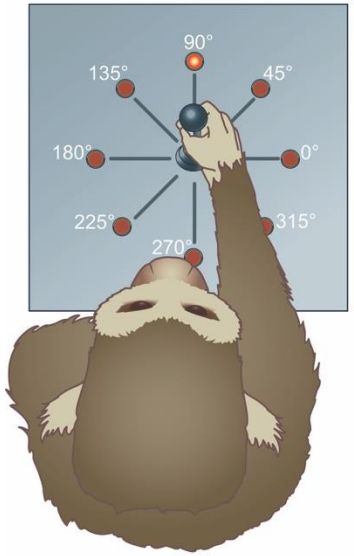
Banich_fig. 4_19

Executing the movement

- Motor cortex
  - Somatotopically organized
  - Which muscles, how much force?
  - Population coding



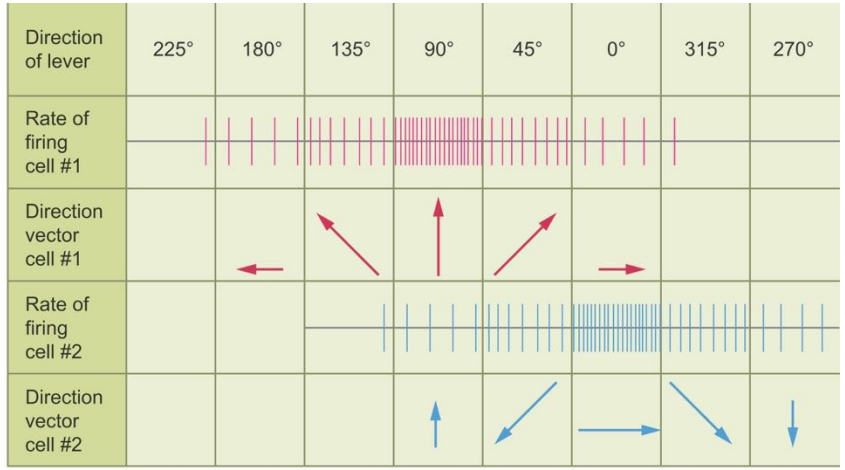
Banich_fig. 4_16



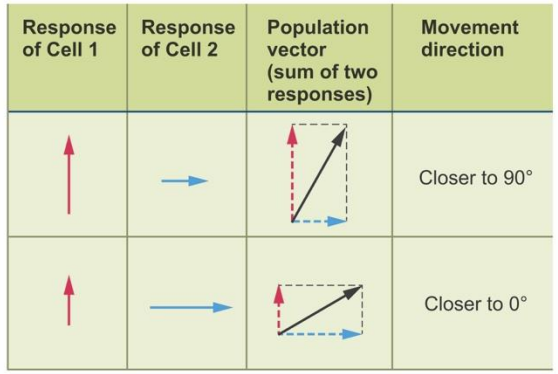
(A) The monkey and apparatus

Banich_fig. 4_15

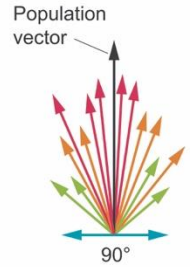
Tuning Curve



(B) Responses of a single cell



(C) Individual direction vectors and population vectors from two neurons



(D) Vector representing summed activity fom a population of neurons

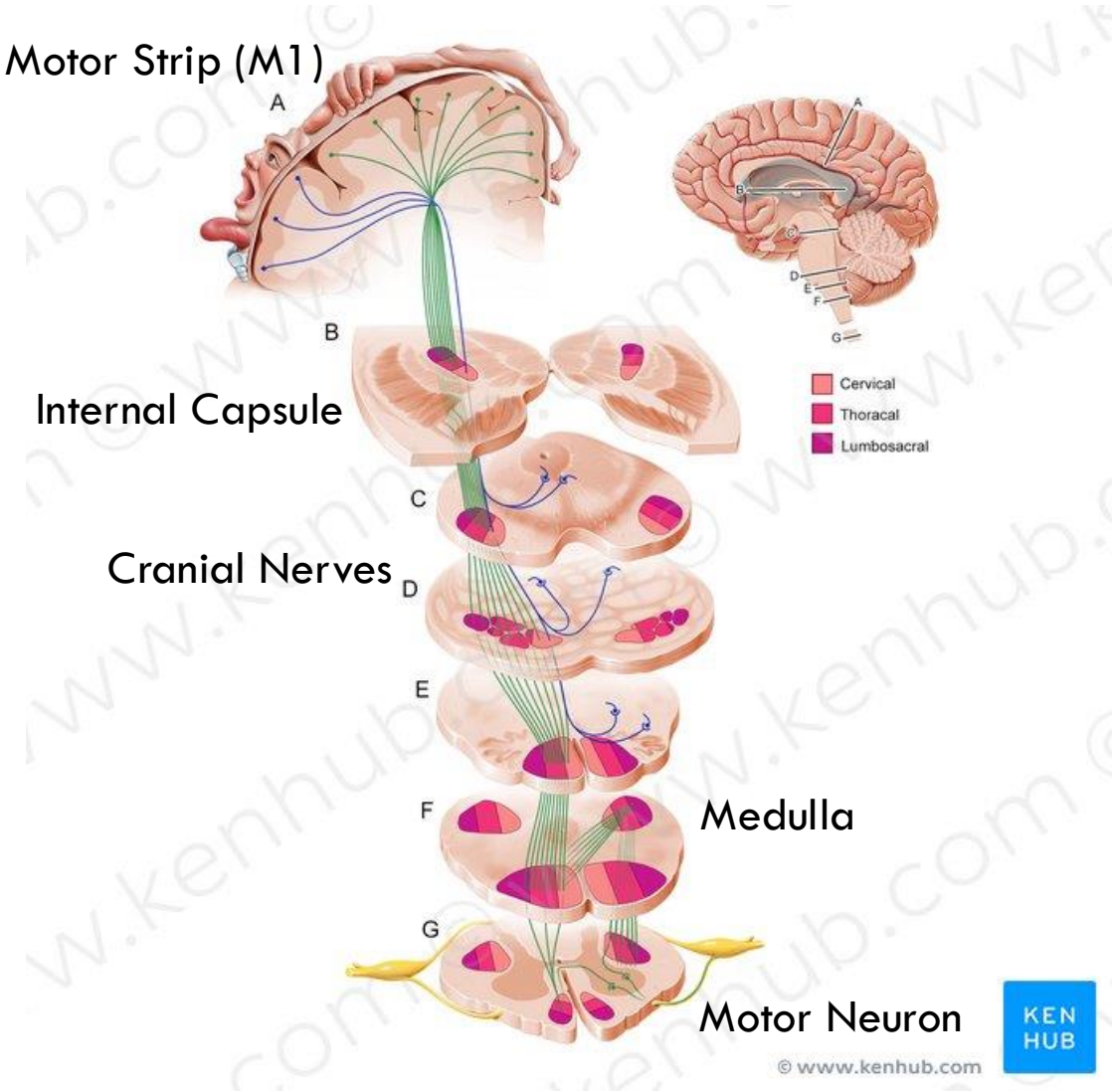
*Check out optional Schwarzlose reading for more!

Executing the movement

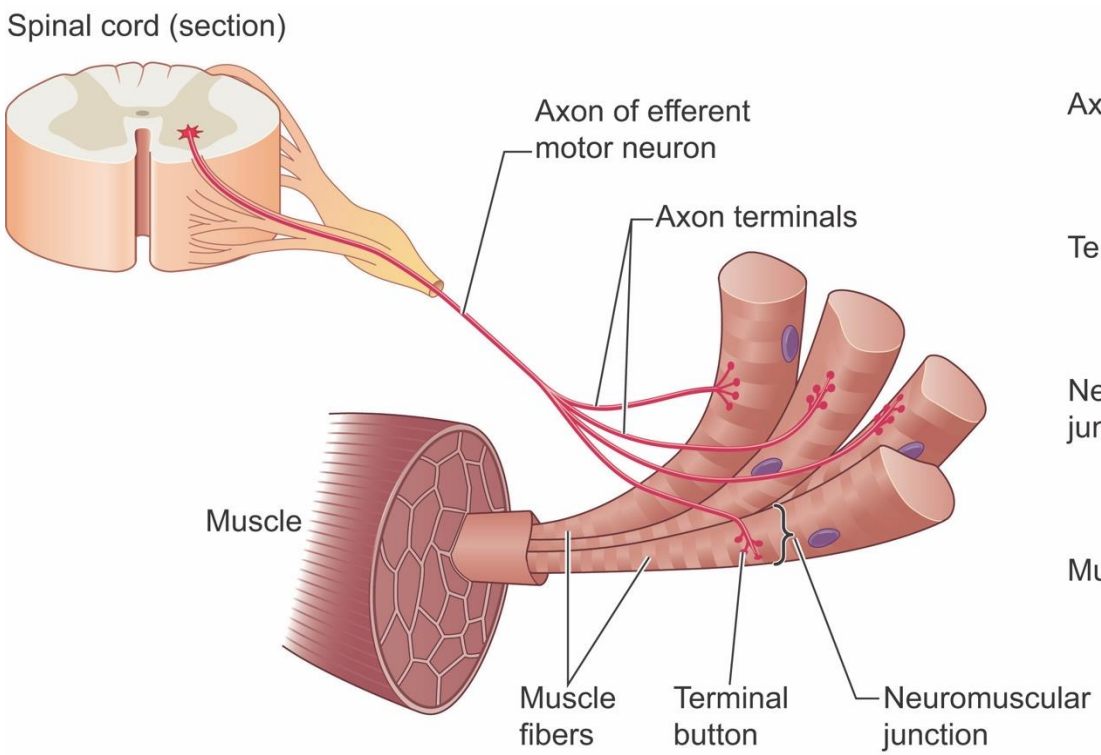
- Cell bodies in primary motor cortex (upper motor neurons)

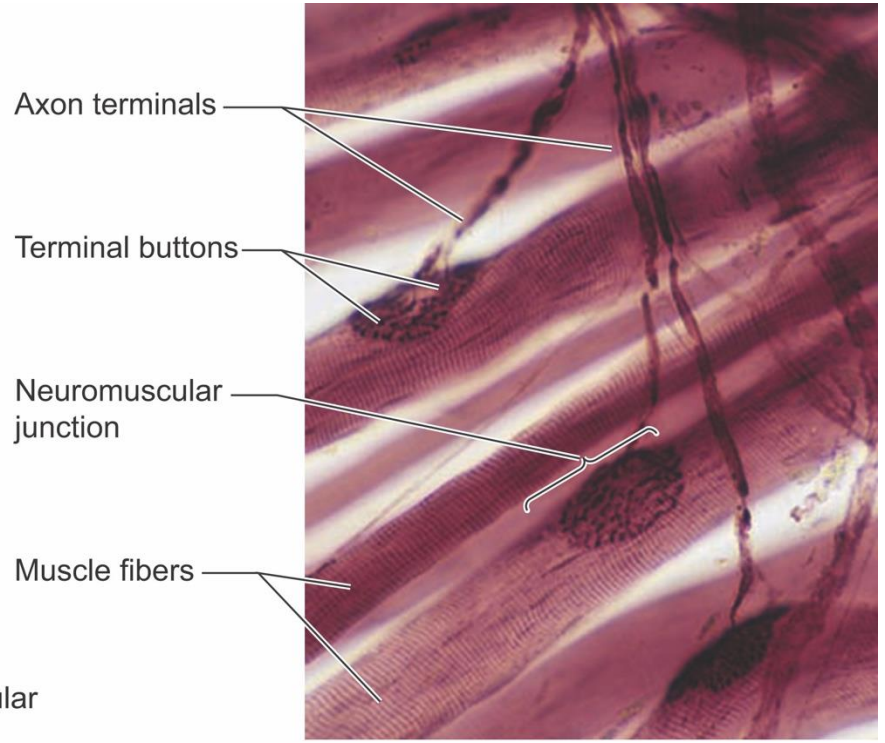
- Axon path
  - Mouth, tongue throat: cranial nerves
  - Medulla
    - Lateral: crossover, limb
    - Medial: partial crossover, torso
  - Synapse at lower motor neuron

- Activation causes movement



Moving the limbs and torso





- Lower motor neuron
  - Fewer synapses where finer motor control needed
  - Acetylcholine released at neuromuscular junction causes muscle fiber contraction
  - More activation, more force
  - Causes sensory changes

Banich_fig. 4_2

When walking, the motor cortex must signal each muscle movement.

True

False

When walking, the motor cortex must signal each muscle movement.

True

0%

False

0%

When walking, the motor cortex must signal each muscle movement.

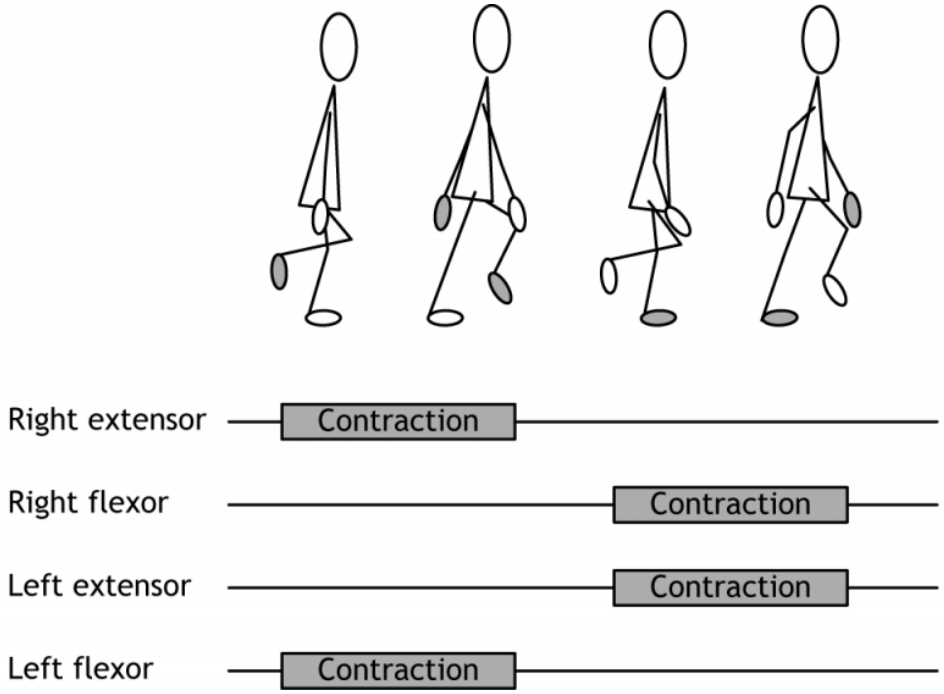
True

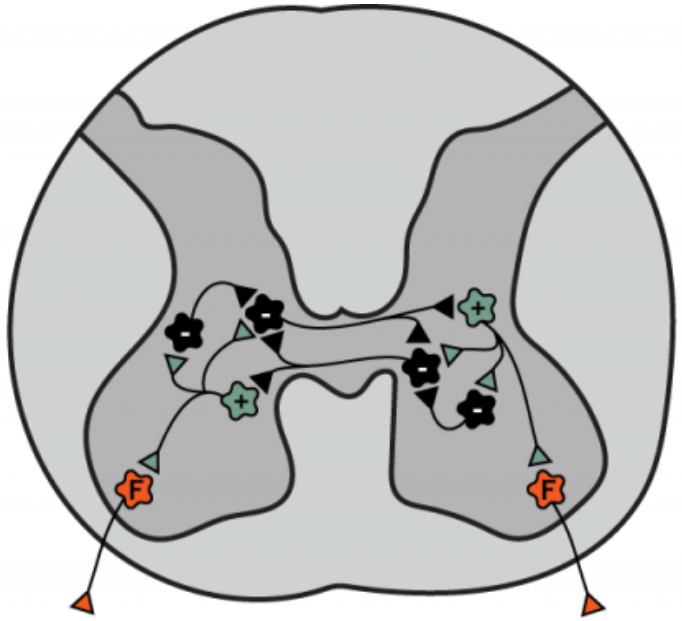
0%

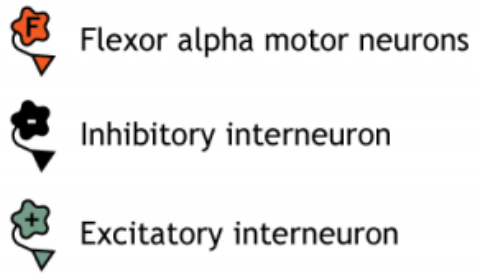
False

0%

Spinal cord can coordinate some movement



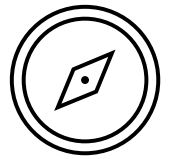




- Reflexes and central pattern generators
  - No cortical input needed for the pattern
  - Dynamics, offloading of computation

https://openbooks.lib.msu.edu/introneuroscience1/chapter/central-pattern-generators/

The Plan



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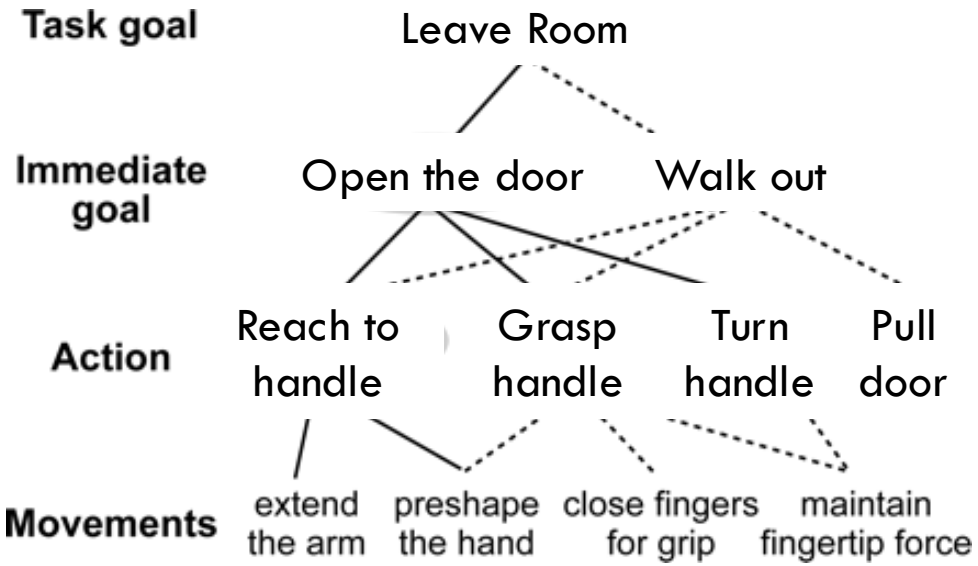


Hamilton & Grafton (2006)

Modulating Movement With Selection and Feedback

Major Structures and Functions

Goal: Avoid being hit & hit the other player

Given trajectory, move left and low

First duck, then throw

Move legs, torso, neck

"How"/"Where" States

Movement Sequences

Supplementary Motor Complex

Anterior Cingulate Cortex

Medial Prefrontal Cortex

Basal Ganglia

Cerebellum

Selection

Posterior Parietal Cortex

M1

Dorsal & Ventral Premotor

Right Inferior Frontal Cortex

Coordination

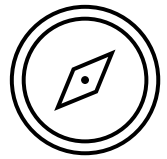
Goals, motivations
Did it work?
Should I keep doing it?

Select actual, concrete movements

Dorsal: pointing, looking
Ventral: grip

https://www.youtube.com/watch?v=sT7hztKDRdc

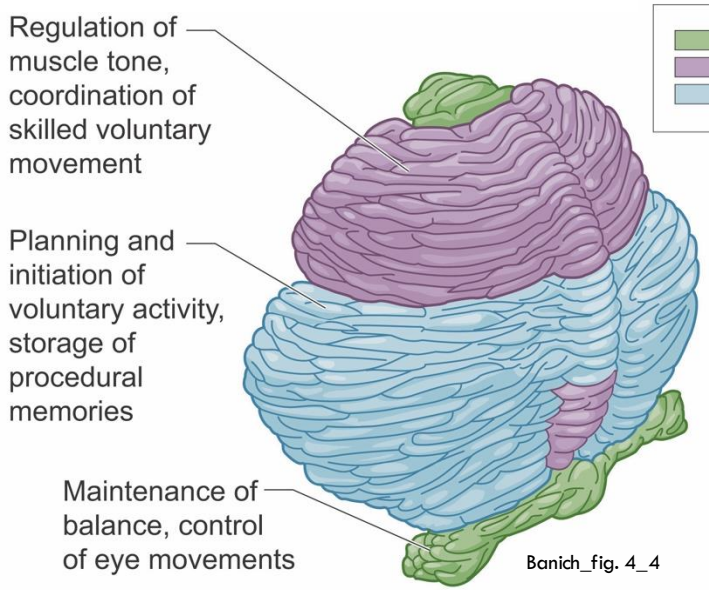
Modulating Movement



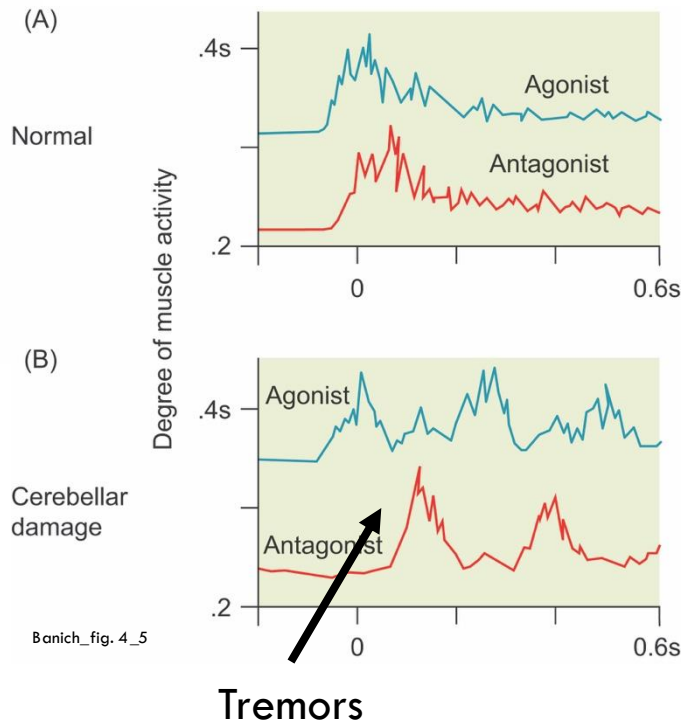
- Cerebellum
  - Several parts, several functions
  - Forward models
  - Learning
- Basal Ganglia
  - Selecting movements, actions
  - Two diseases
- Subcortical motor structures also contribute to cognition

Cerebellum Dynamically Coordinates Movement

- Multiple loop like circuits
  - Vestibular
  - Spinal
  - Cerebral
- Coordinates, times movement of muscles
  - Ipsilateral
  - Smooths movement
  - Ballistic, fast movements
  - Balance and posture

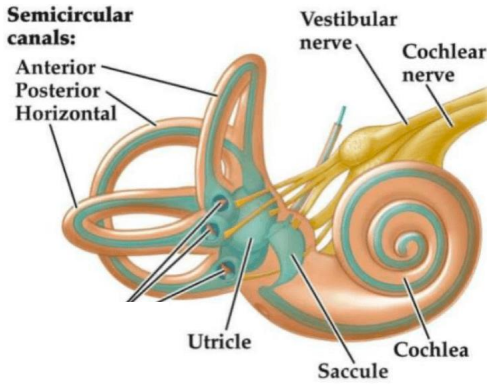


Banich_fig. 4_4



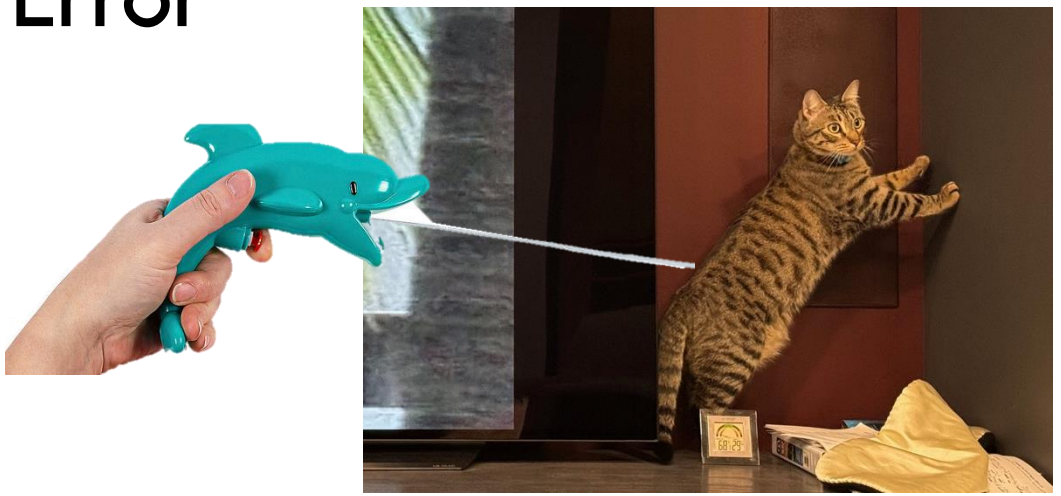
Banich_fig. 4_5

Vestibular System

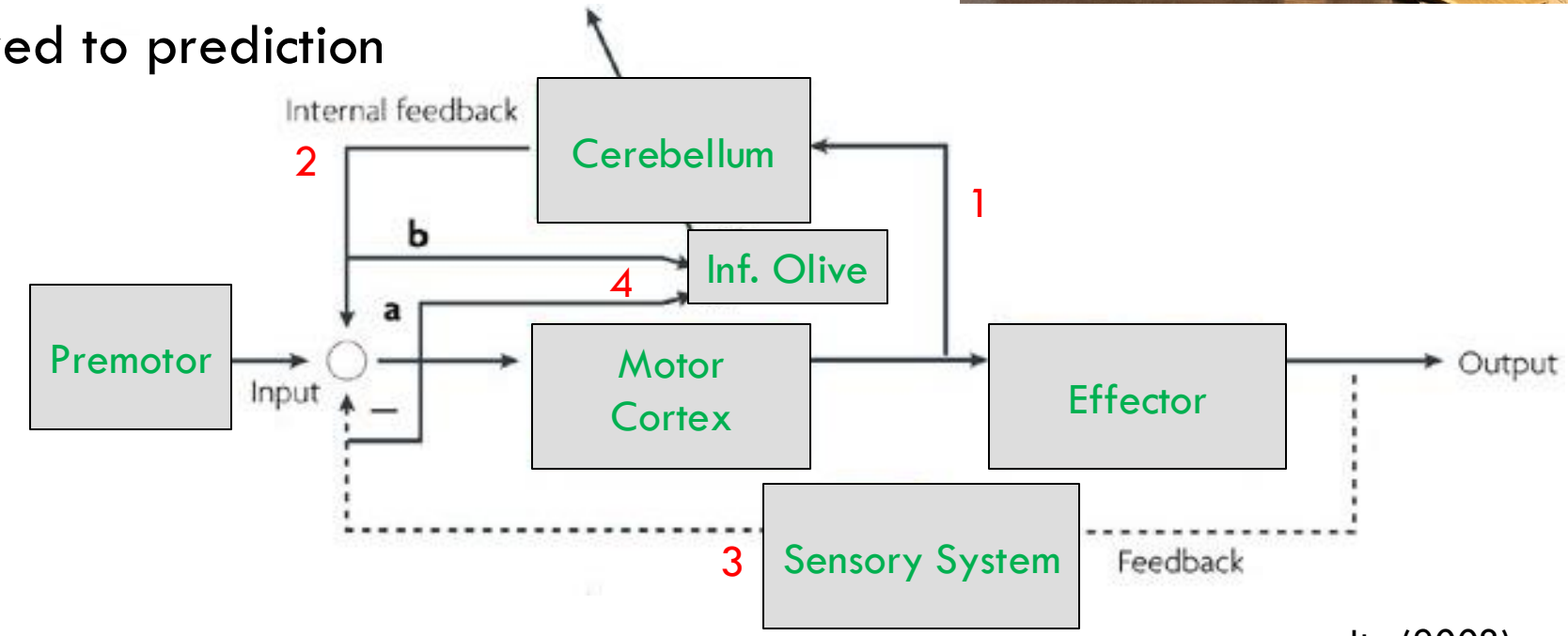


Cerebellum Estimates Movement Error

- Forward model
  1. Movement command is copied to cerebellum
  2. Cerebellum computes expected sensory info
  3. Movement creates sensation
  4. Sensory info compared to prediction

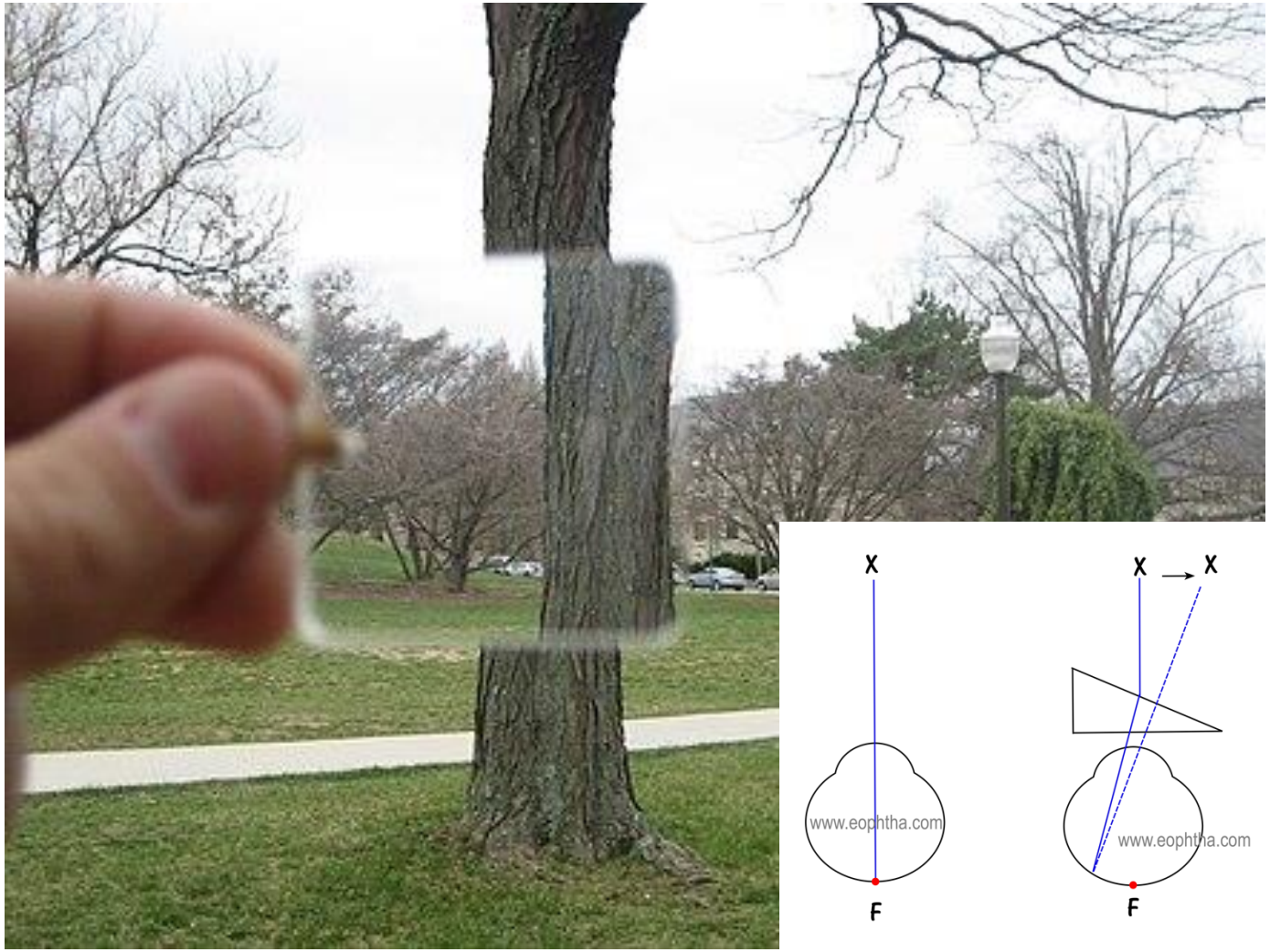


- Error used for…
  - Learning
  - Adjustments



Ito (2008)

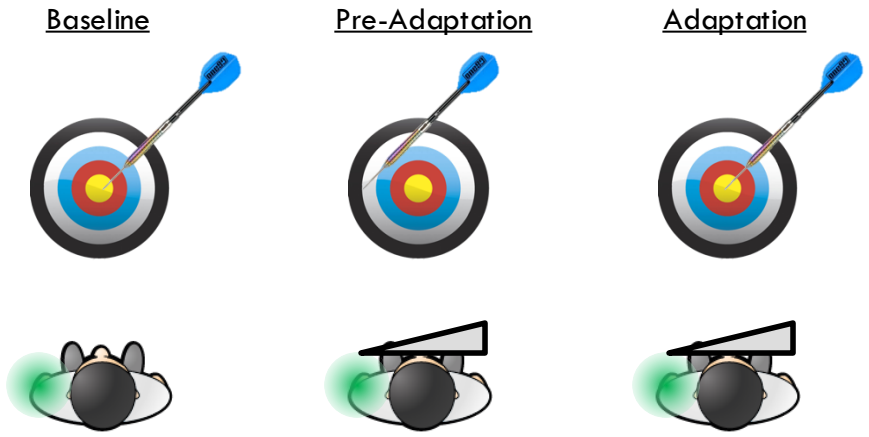
Prism Adaptation



Prism Adaptation

- Goggles invert (or otherwise distort) the visual field
- After a week, visual field is perceived as normal
- Removing goggles flips the visual field, but adaptation is faster

Prism Adaptation Depends on Action



See Martin, et al., 1996

What do you think will happen when the person switches to throwing the dart with their right arm?

They will still show adaptation and hit the target

It will be like they never adapted, so they will throw the dart to the left

They will show stronger adaptation, and they will throw the dart to the right

What do you think will happen when the person switches to throwing the dart with their right arm?

They will still show adaptation and hit the target

0%

It will be like they never adapted, so they will throw the dart to the left

0%

They will show stronger adaptation, and they will throw the dart to the right

0%

What do you think will happen when the person switches to throwing the dart with their right arm?

They will still show adaptation and hit the target

0%

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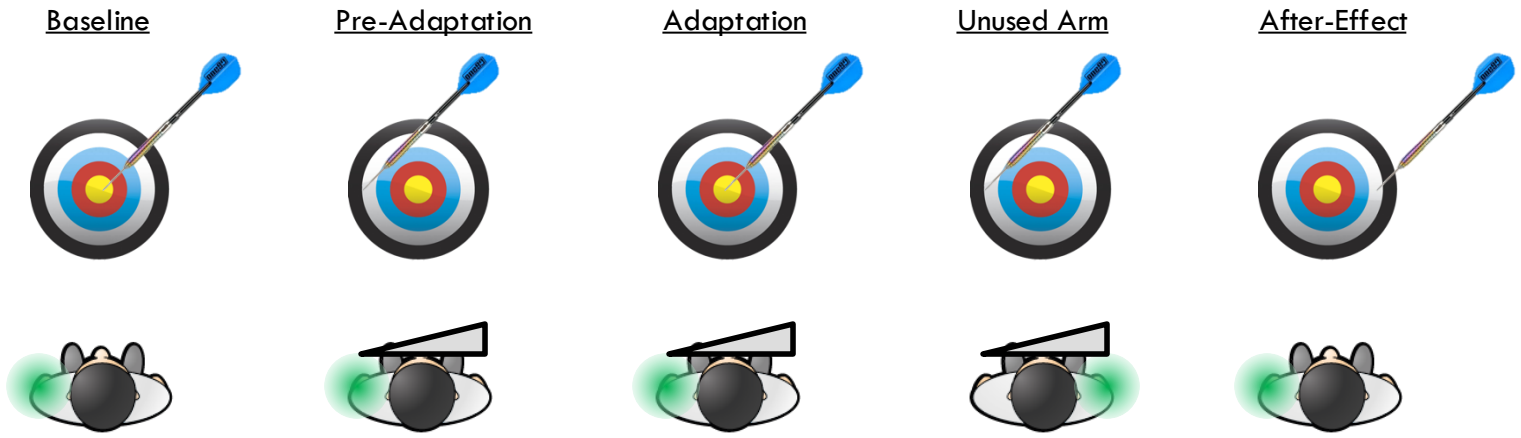
0%

They will show stronger adaptation, and they will throw the dart to the right

0%

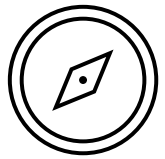
Prism Adaptation Depends on Action



- Adapt motor routines to match visual input
- Adaptation is specific to the part of the body being used
- Depends on sensorimotor activity
- Action (in this case throwing) is not just a matter of cortical control

See Martin, et al., 1996

Modulating Movement



- Cerebellum
  - Several parts, several functions
  - Forward models
  - Learning

What would that movement have felt like, had it worked?

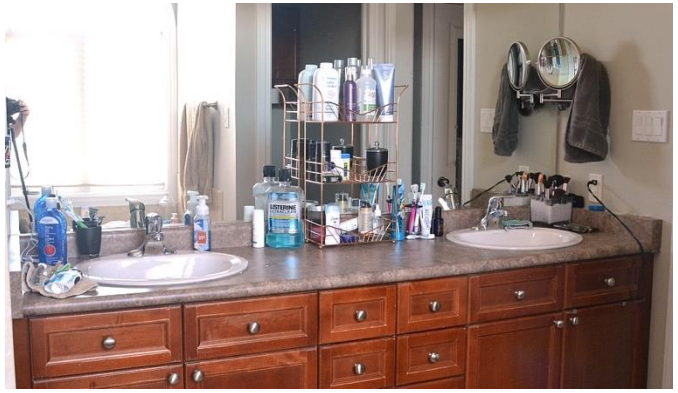
- Basal Ganglia
  - Selecting movements, actions
  - Two diseases

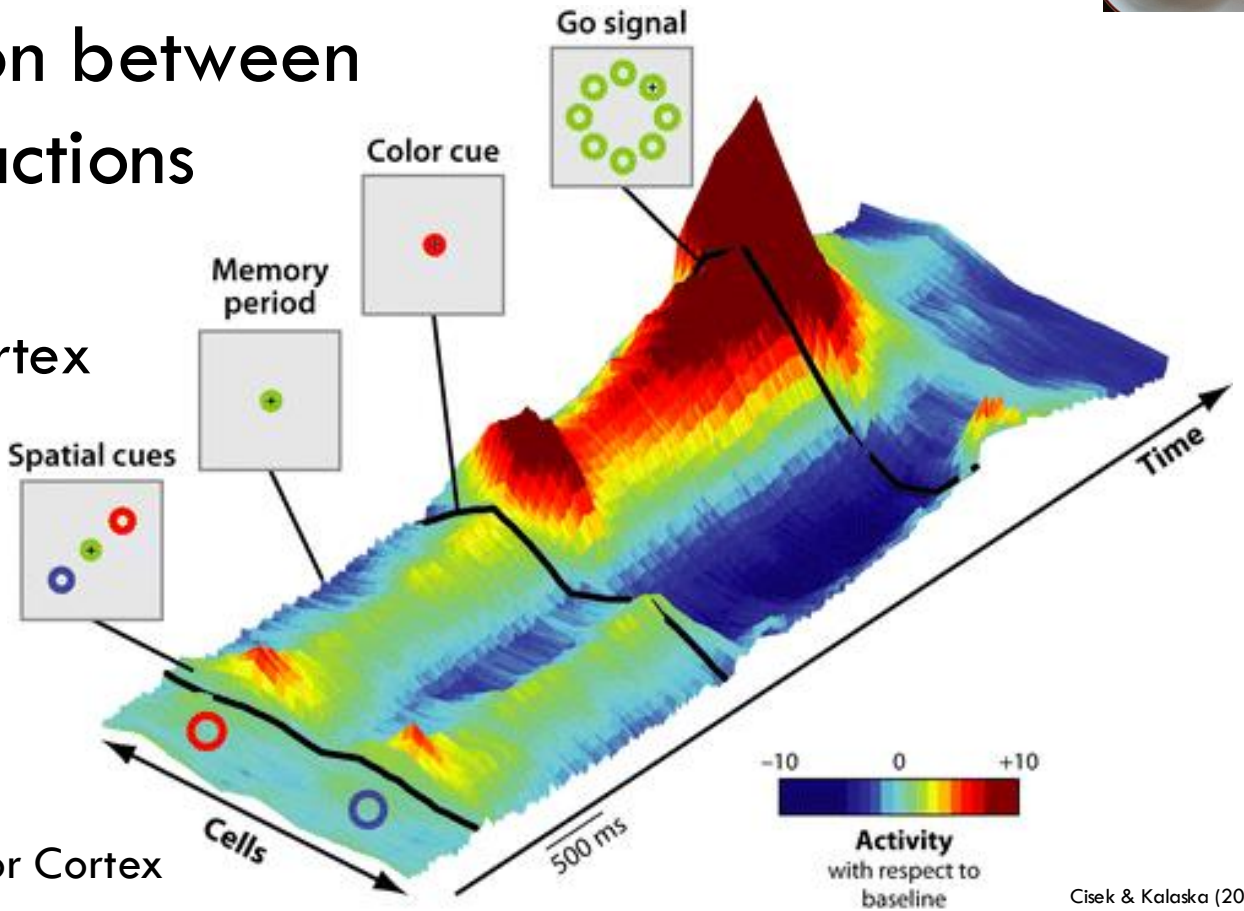
- Subcortical motor structures also contribute to cognition

Basal Ganglia Gate Movement

- Too many possibilities!

- Competition between potential actions
  - Affordances
  - Premotor cortex



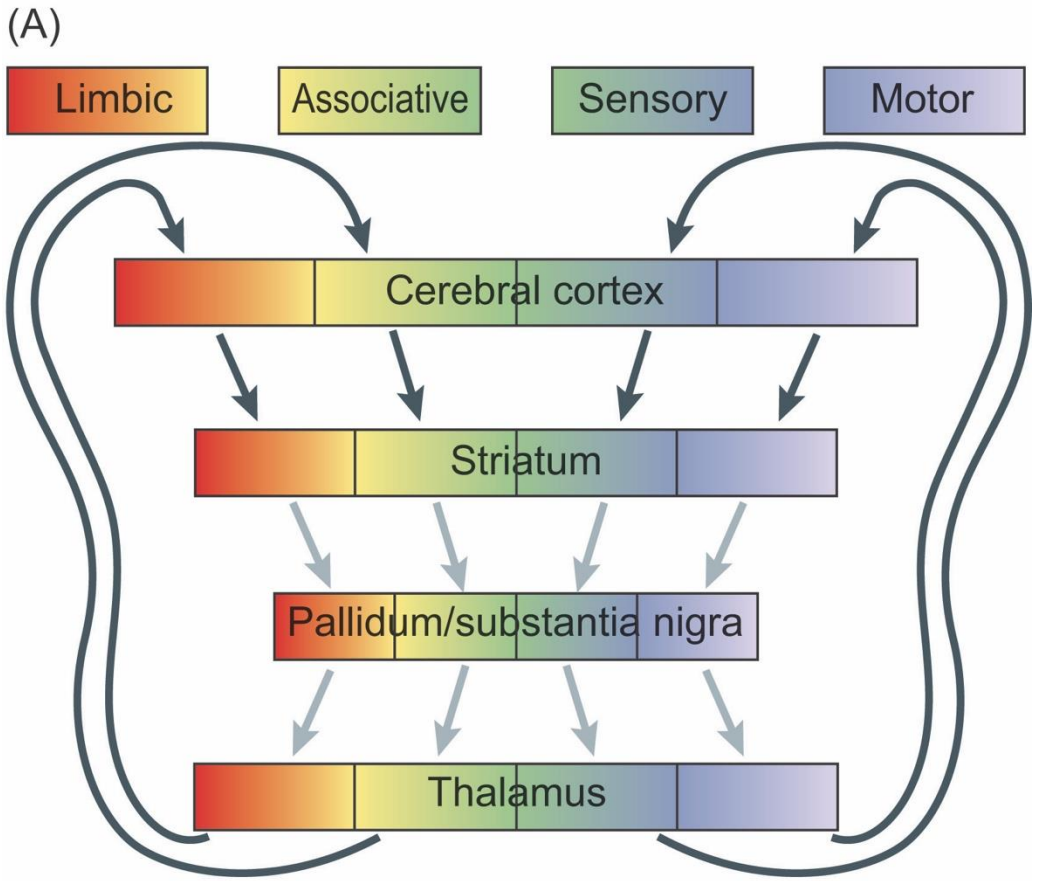


Premotor Cortex

Cisek & Kalaska (2010)

Basal Ganglia Gate Movement

- Select, amplify, initiate desired actions
  - Goals
  - Value
  - Urgency
- Inhibited unwanted actions
- Chunking & habit
- Also does this for cognitive "actions"

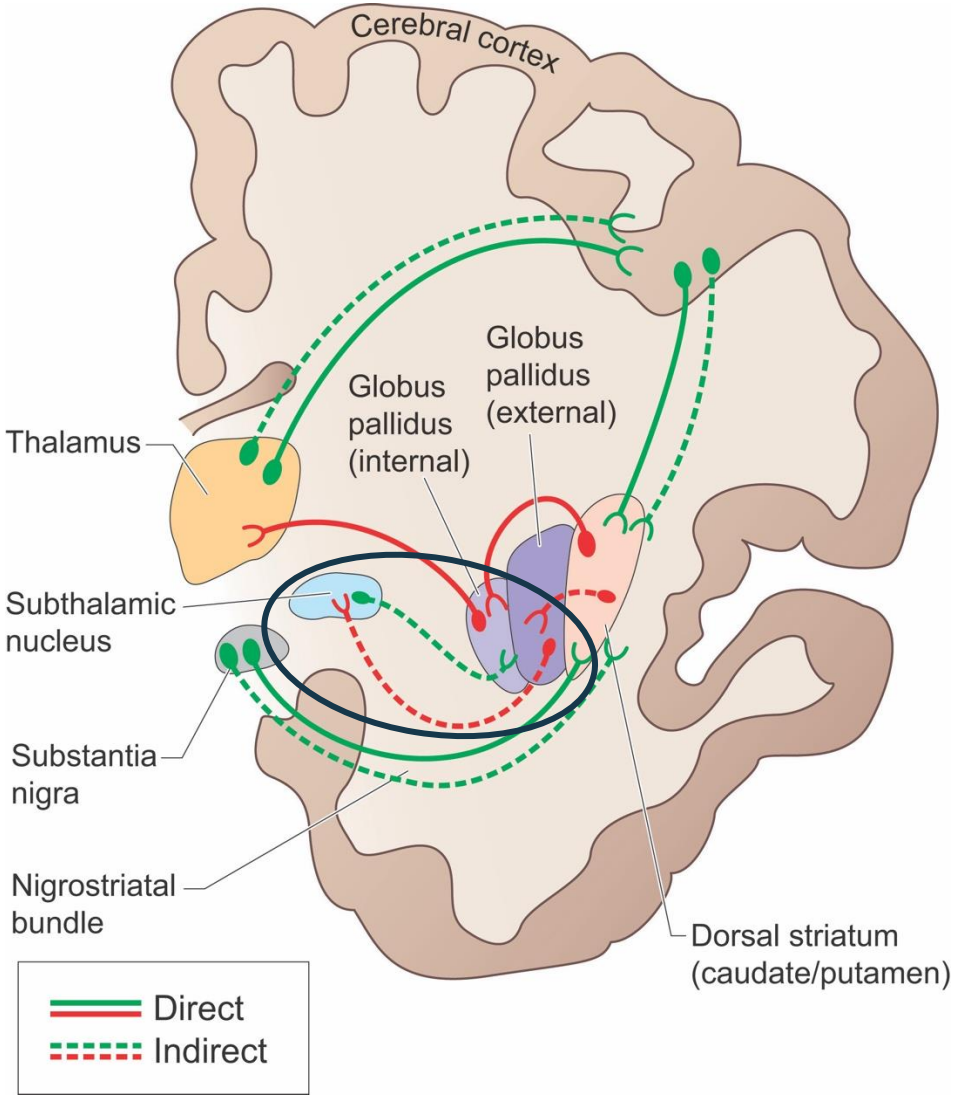


Banich_fig. 4_8

Basal Ganglia Gate Movement

- Corticostriatal loops
  - Complicated: Inhibiting inhibitor allows activation
  - Direct pathway: Excitatory for wanted movements
  - Indirect pathway: Inhibits unwanted movements
  - Usually in balance

- Nigrostriatal (dopamine):
  - Facilitate direct (D1 receptors)
  - Inhibit indirect (D2 receptors)
  - Effect is to increase activity



Banich_fig. 4_9