Neuro 80 Lecture 20: Cognition

Nov 13, 2019

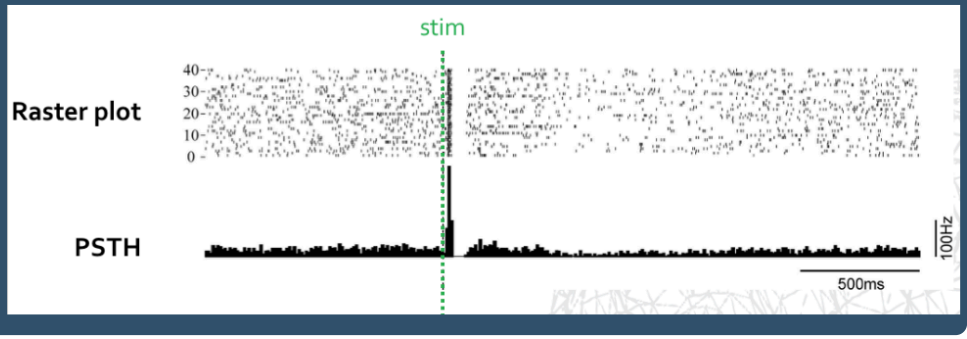
Which stream of visual information do you expect to be impaired in prosopagnosia?

dorsal : where

ventral : what

Is this neuron activated or inhibited by the stimulus

You can respond once



Activated and then Deactivated

MCB/Neuro 80 - Neurobiology of Behavior

Today's Topic:

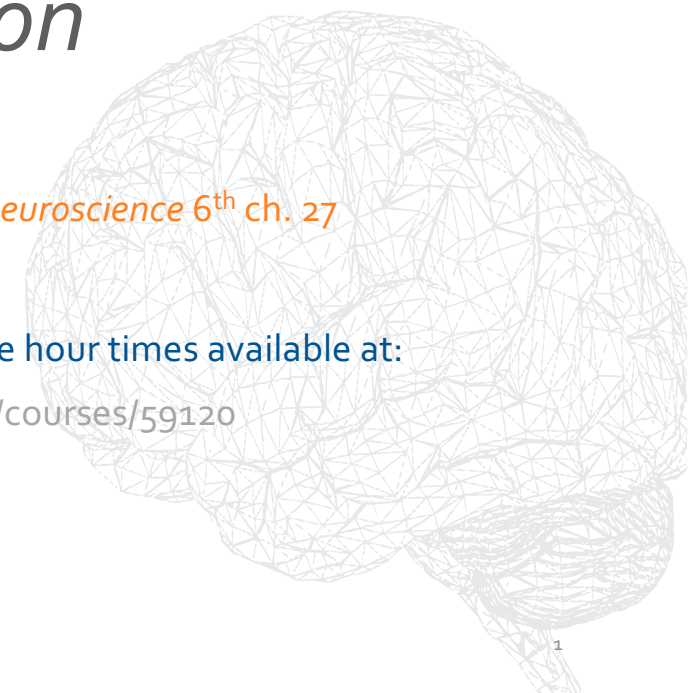
Cognition

Lecture 20

Optional reading: Purves et al., *Neuroscience* 6th ch. 27

Lecture notes, review questions, office hour times available at:

https://canvas.harvard.edu/courses/59120




CLIMBING MT. POTENTIAL
(IN PRACTICE)
Response
Sensory/motor diseases
Upper Motor
Spinal Circuits
Neuronal processing
Cognition
Structural changes and aging
Long term synaptic plasticity
Memory systems
Stimulus (sensing information)
Information Coding
Other Senses
Visual system:
• Sensory transduction
• Visual circuits
• Cortical visual processing

Outline

- Defining Cognition
- Brain Regions Involved in Cognition
- Association Cortex in Detail
- Neuronal Correlates of Cognition

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Defining Cognition

- Traditional forms of psychology are **introspective**

  End of 19th century: Depth psychology (Bleuler, Freud, Jung)

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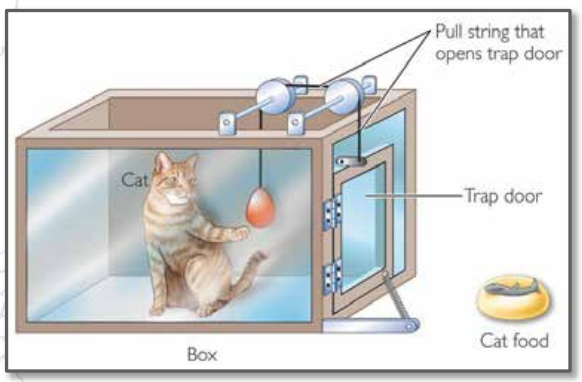
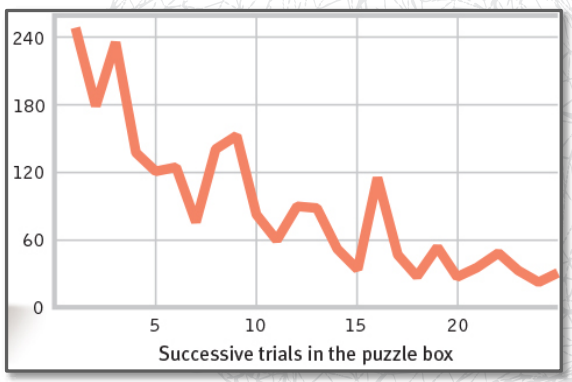
- 1898: Edward Thorndike, puzzle box





Lilienfeld, Understanding Psychology 3rd ed., fig. 6.5
Myers / DeWall, Psychology in Everyday Life 4th ed., fig. 6.6

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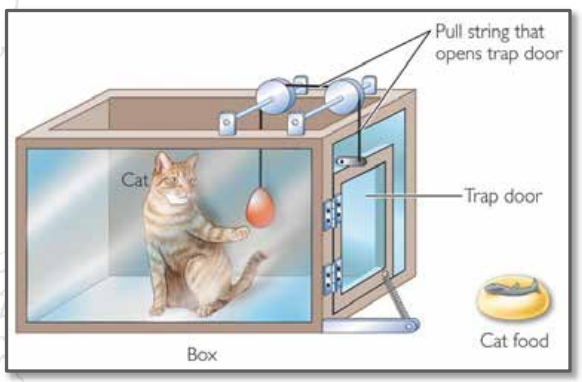

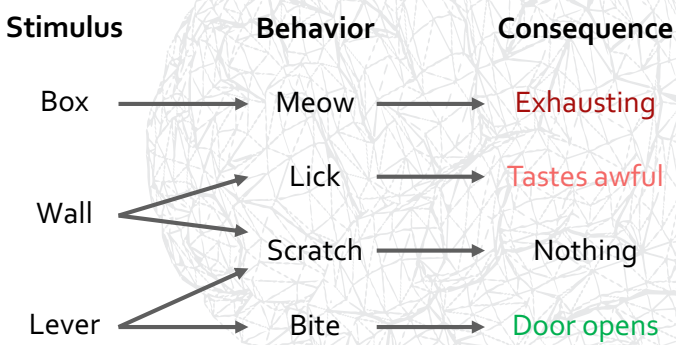

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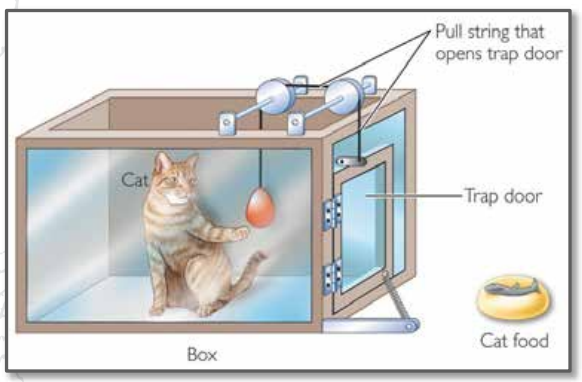

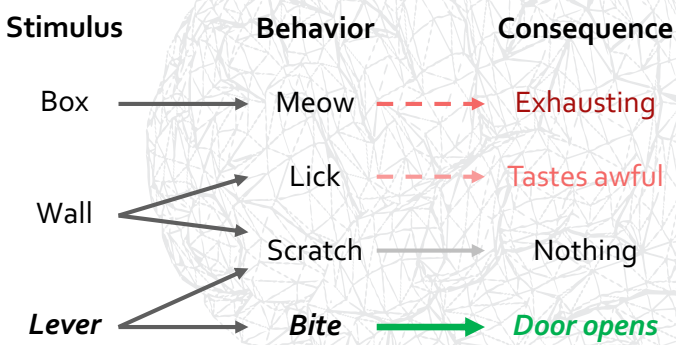

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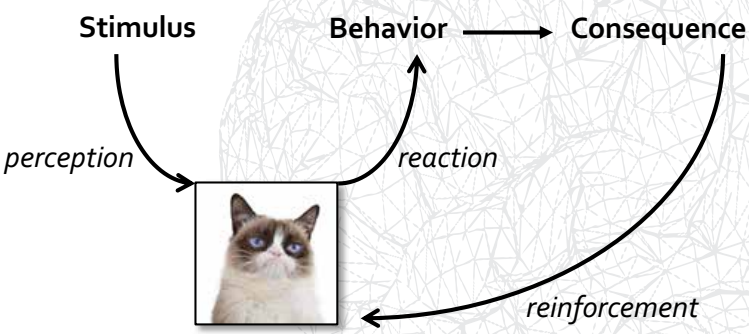

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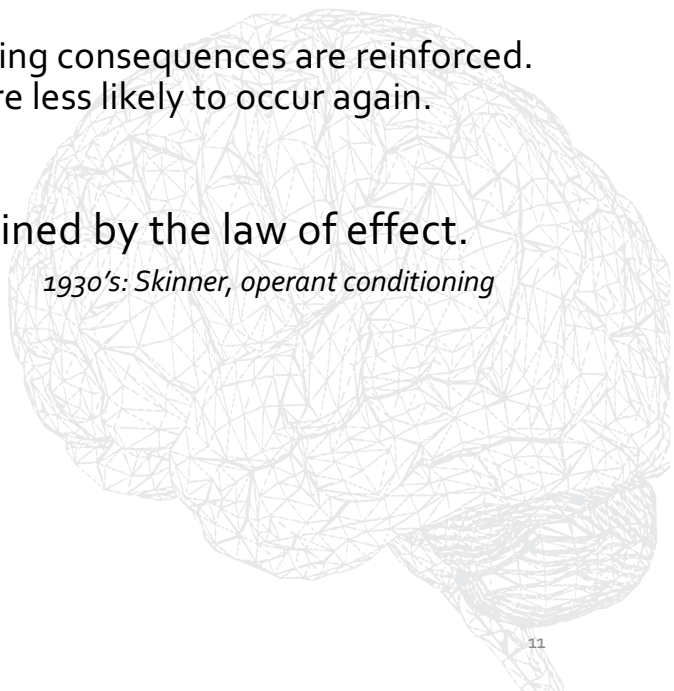
  End of 19th century: Pavlov, classical conditioning *1930's: Skinner, operant conditioning*



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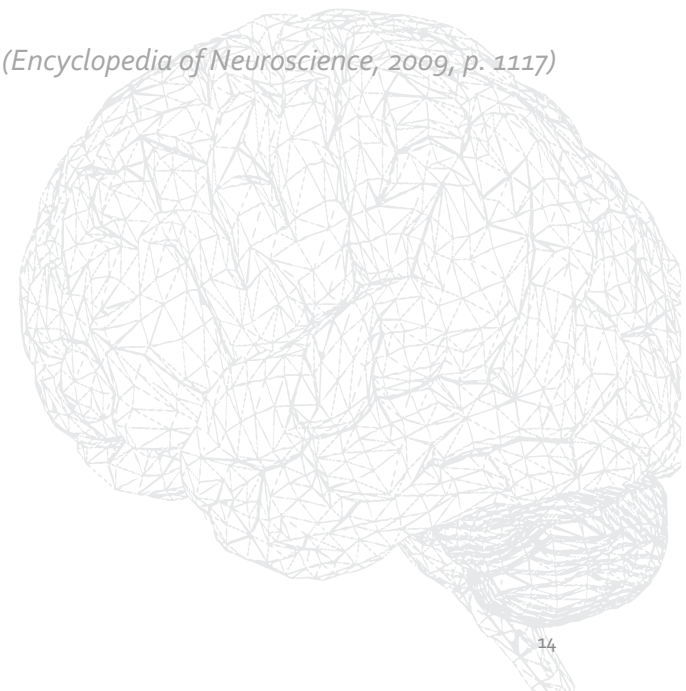
- **Cognitivism**: many behaviors are too complex to be explained by the law of effect. They are governed by mental states, which should be investigated.

  1950's: Miller, Chomsky, McCarthy, computational sciences (artificial intelligence)

Defining Cognition

- **Cognition**: Any form of information processing, mental operation, or intellectual activity such as thinking, reasoning, remembering, imagining, or learning.

(Encyclopedia of Neuroscience, 2009, p. 1117)



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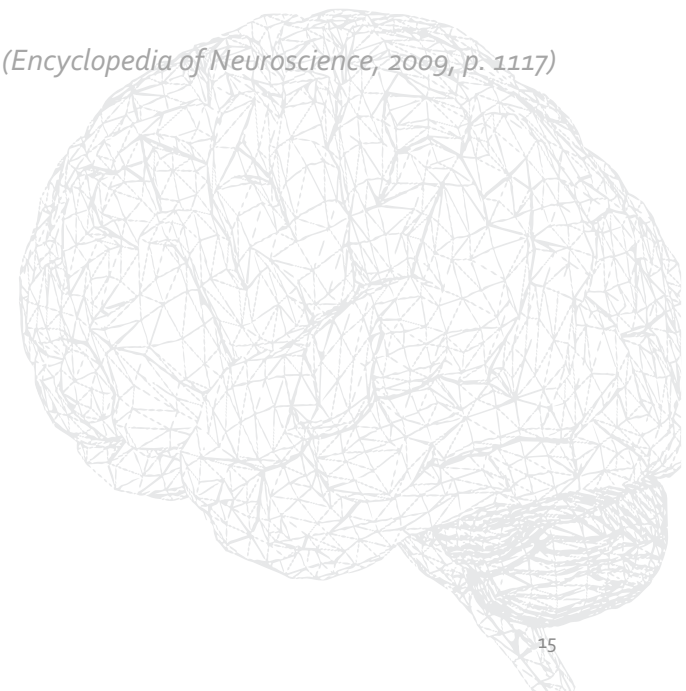
- **Examples of cognitive skills**:
  (1) Attention
  (2) Social recognition
  (3) Planning



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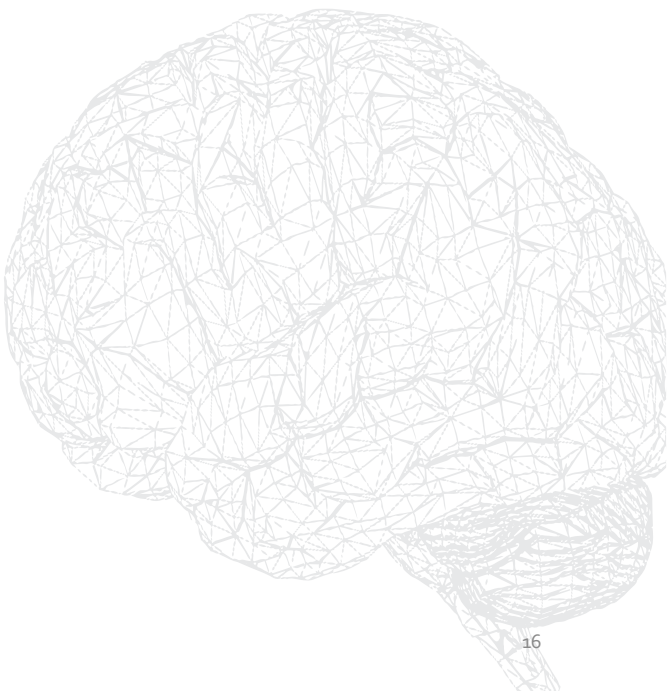
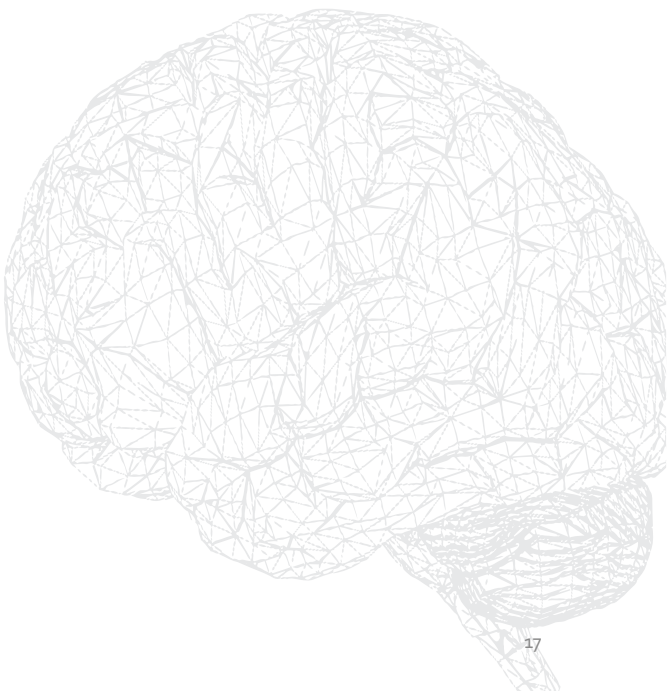


Brain Regions Involved in Cognition

- **Contralateral neglect syndrome** (CNS): reduced awareness of stimuli on one side of space with no sensory loss.



Brain Regions Involved in Cognition

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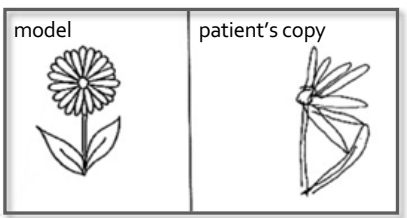
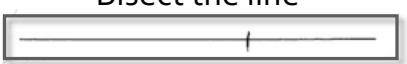
"Draw a flower"



"Bisect the line"



"Read the menu"

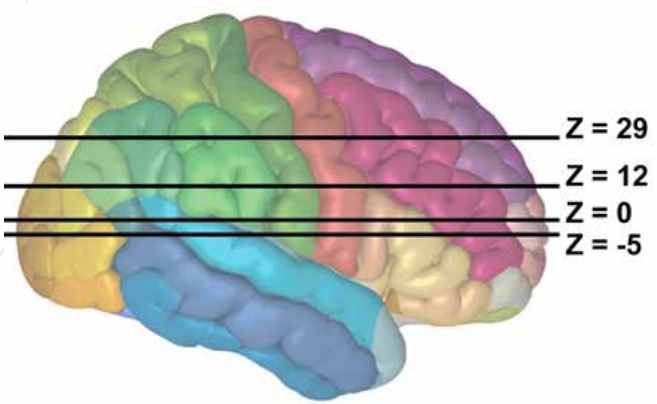
Tomato soup	Grapefruit	Tea	Roast chicken
Pork chop	Ham & eggs	Hamburger	Lamb chop
Shepperd's pie	Fried haddock	Salad	Turkey
Jam tart	Cheese	Milk	Veal
Ice cream	Biscuits	Apple tart	Boiled eggs
Coffee	Apple pie	Sandwich	Melon

Parton A. et al., J Neurol Neurosurg Psychiatry, vol. 75(1), 2004

Stone S. et al ., J Neurol Neurosurg Psychiatry, vol. 54(4), 1991

Brain Regions Involved in Cognition

- **Lesion study** of CNS:



Conrad J. et al ., Front. Neurolog., 2018 Mar 2;9:112

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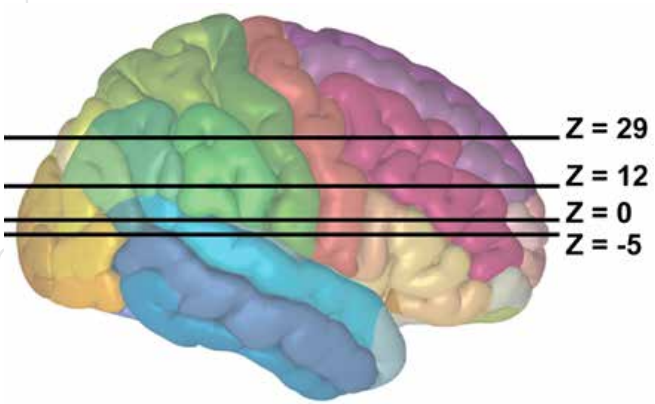

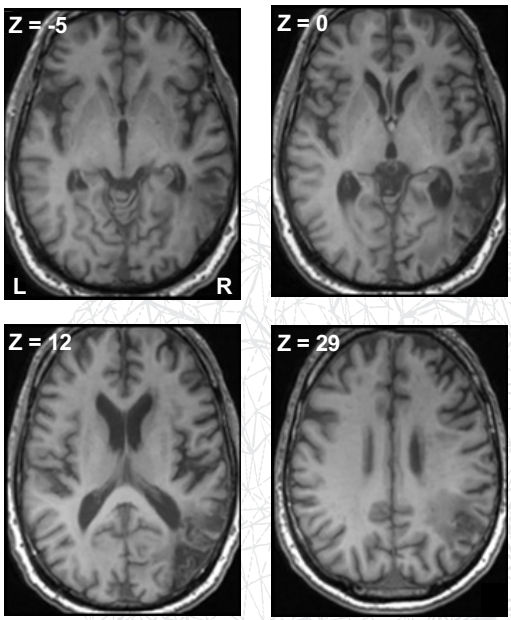

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Brain Regions Involved in Cognition

front of brain

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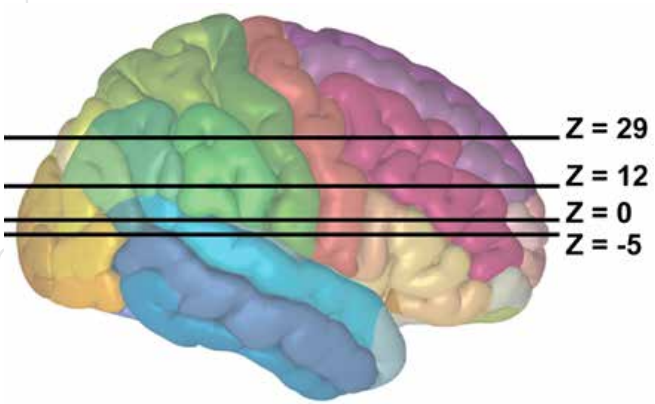

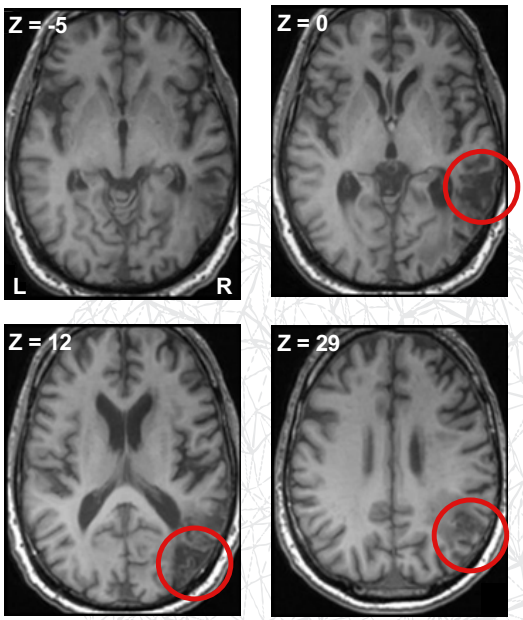

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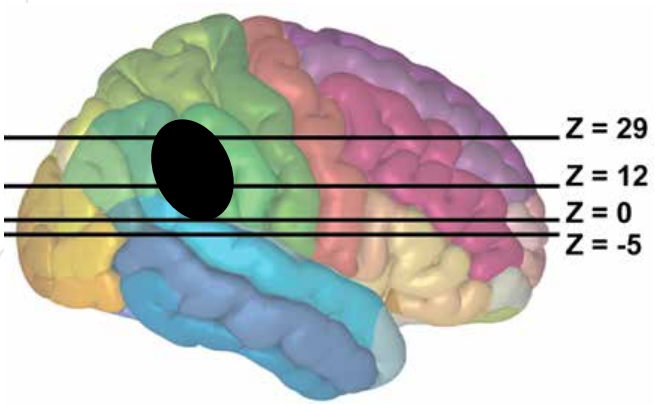

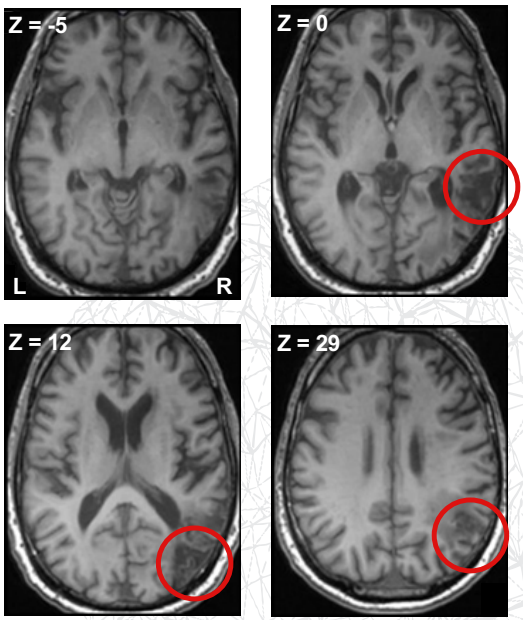

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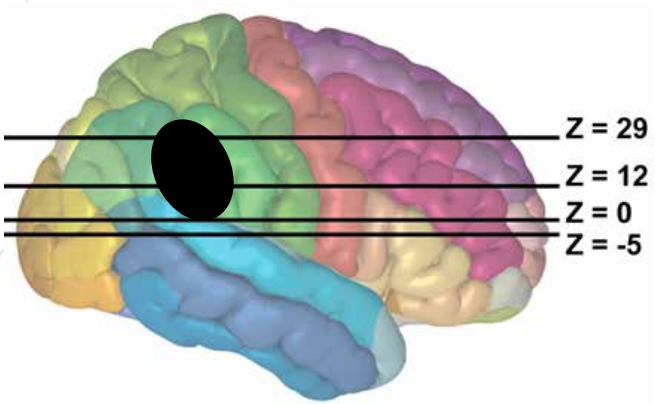
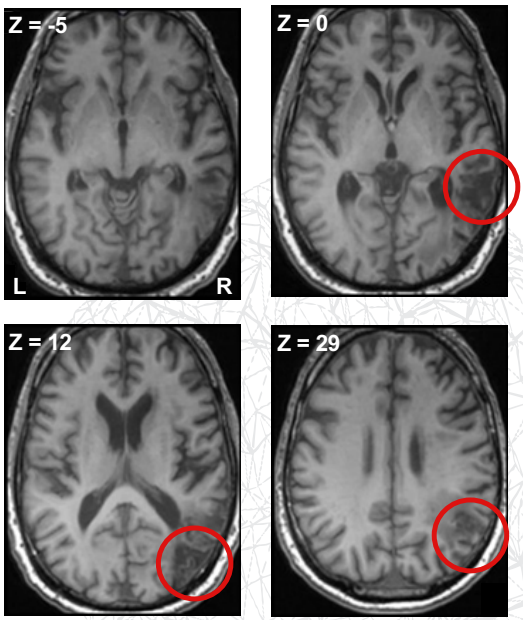


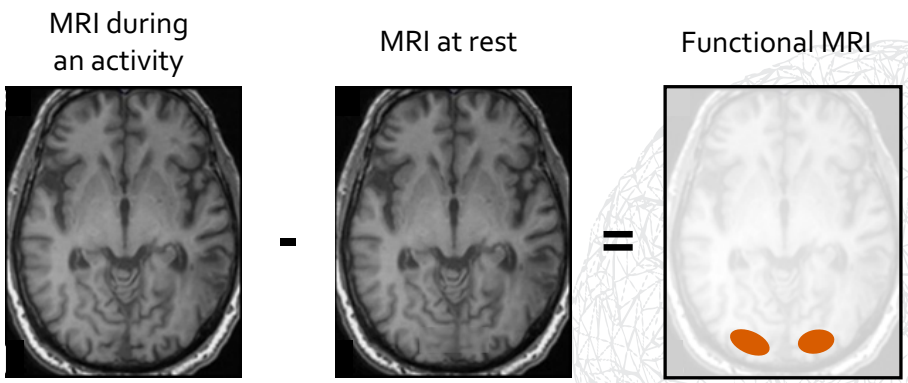


- Parietal cortex → Attention

Conrad J. et al ., Front. Neurolog., 2018 Mar 2;9:112

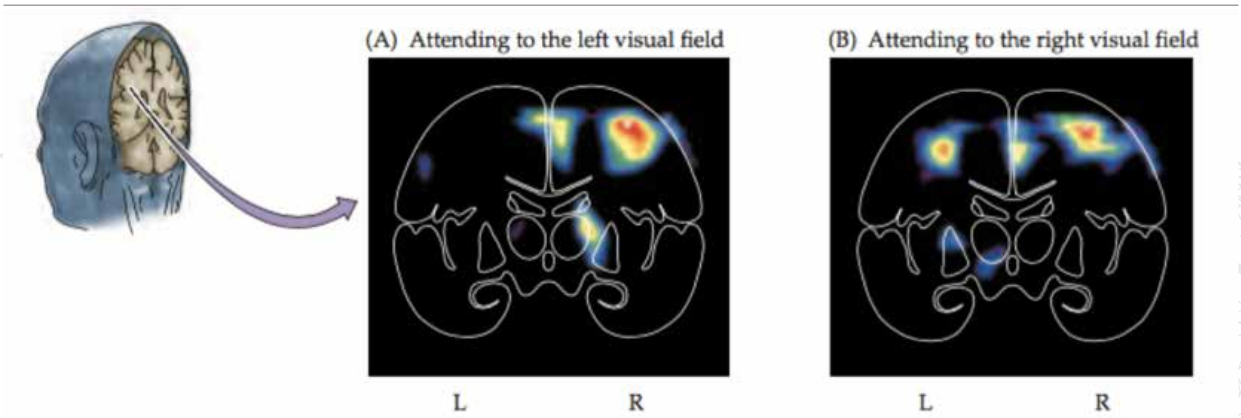
Brain Regions Involved in Cognition

- How fMRI images are made:



Brain Regions Involved in Cognition

- Confirmation of attention cortex in **healthy patients**:



coronal sections

Purves, Neuroscience 3rd ed., fig. 25.7

Brain Regions Involved in Cognition

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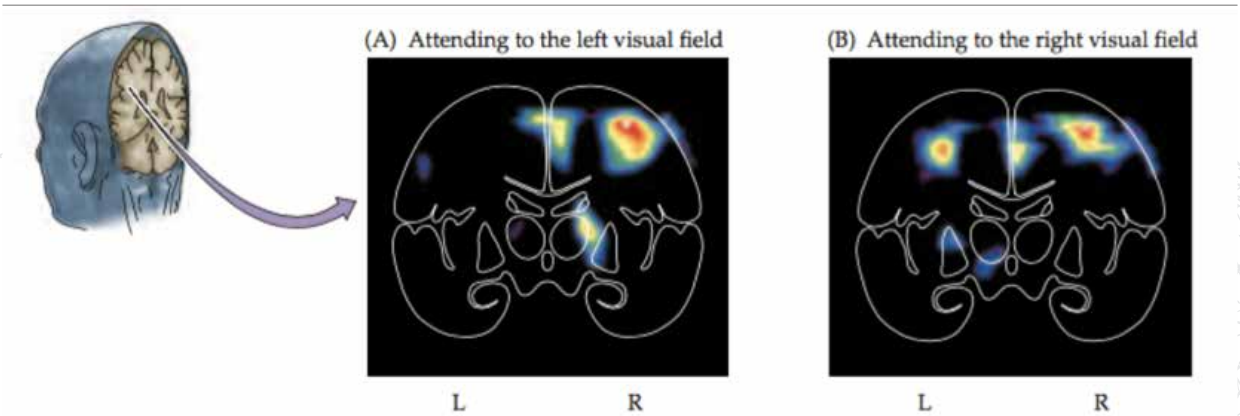

- Confirmation: parietal cortex → Attention

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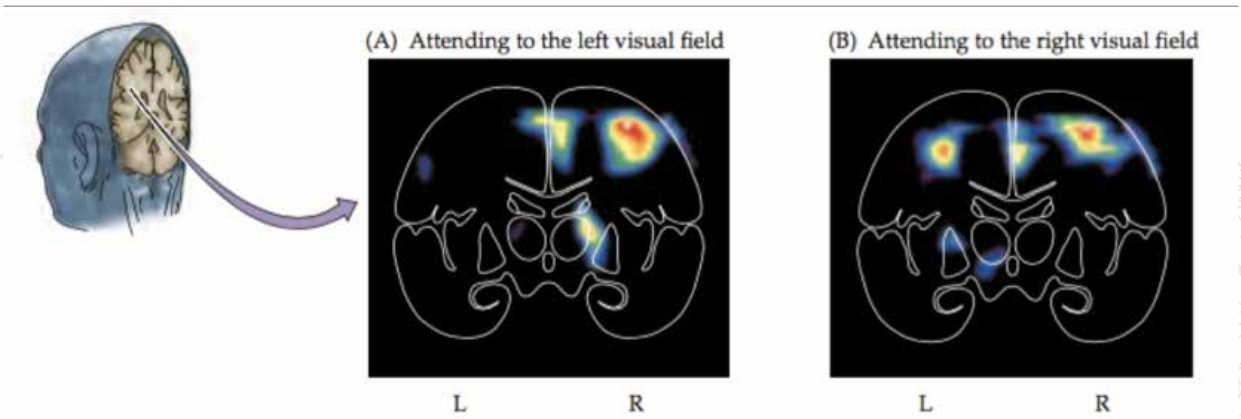

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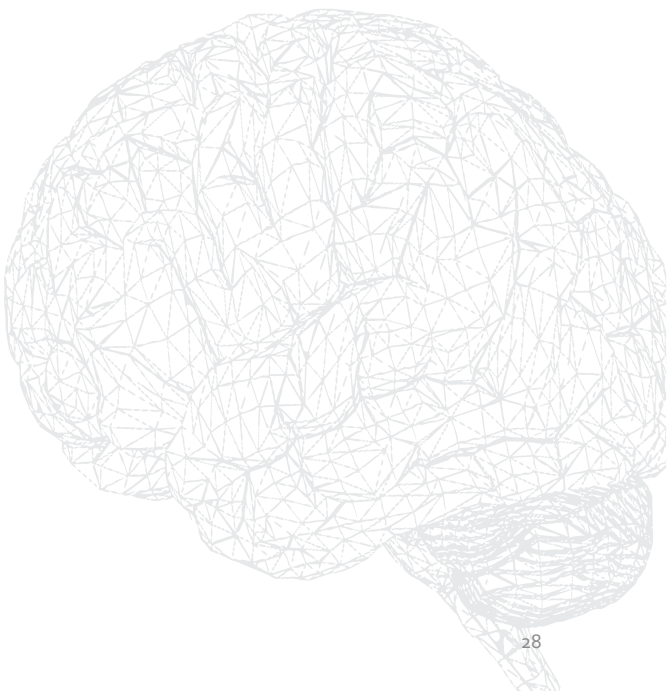
- **Side notes**:
  → Why is the contralateral hemisphere active in (A)?
  → CNS is usually left-sided… Why?

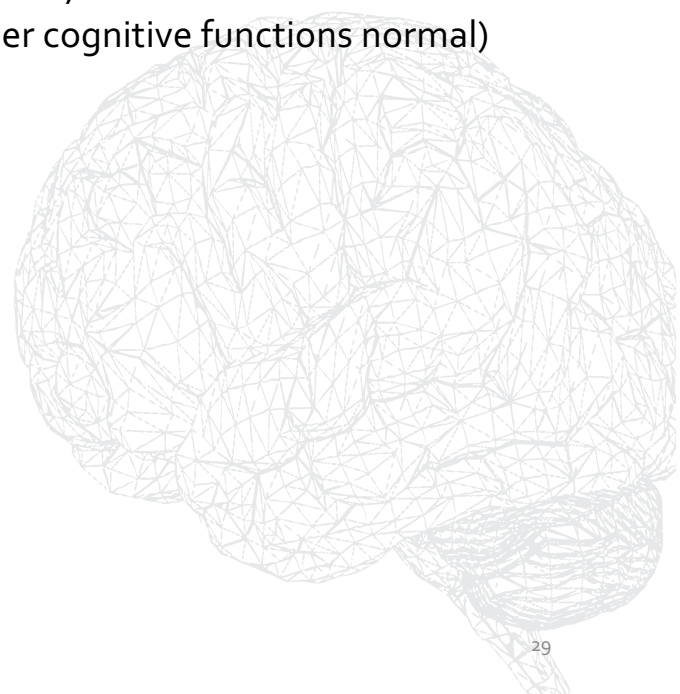
Brain Regions Involved in Cognition

- **Prosopagnosia**: inability to recognize faces.



Brain Regions Involved in Cognition

- **Prosopagnosia**: inability to recognize faces.
- Patient LH:
  - At 18, car accident → right temporal lobectomy.
  - After the surgery → prosopagnosia (all other cognitive functions normal)



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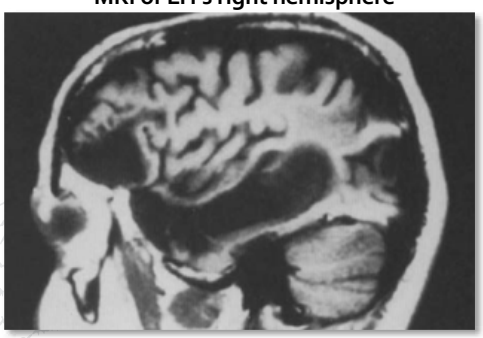

  - MRI → missing temporal lobe

Etcoff N. et al ., Journal of Cognitive Neuroscience, vol. 3(1), 1991

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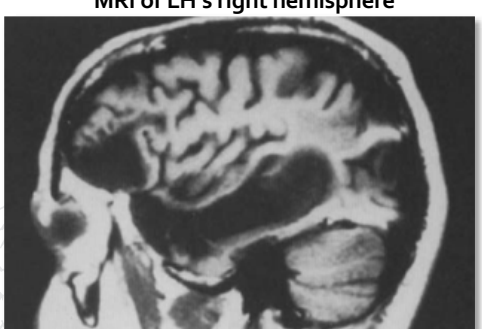

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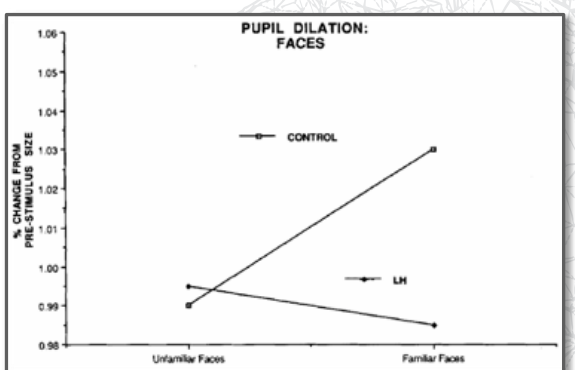

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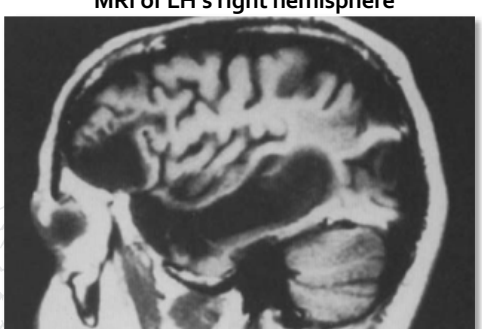

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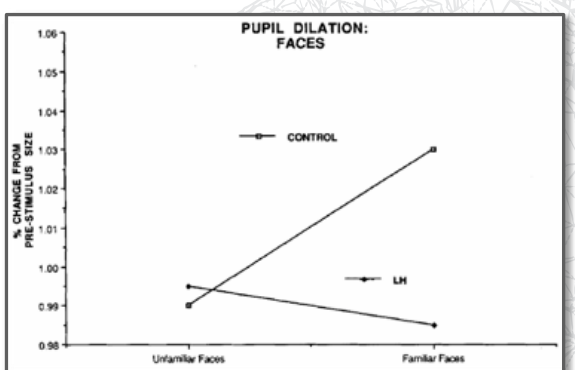

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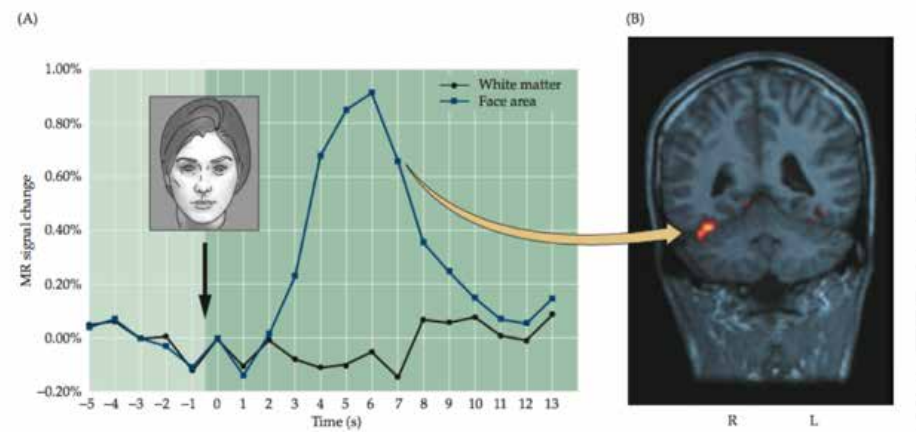
- Temporal cortex → Face recognition

Brain Regions Involved in Cognition

- Confirmation of face recognition cortex in **healthy patients**:



Purves, Neuroscience 3rd ed., fig. 25.8

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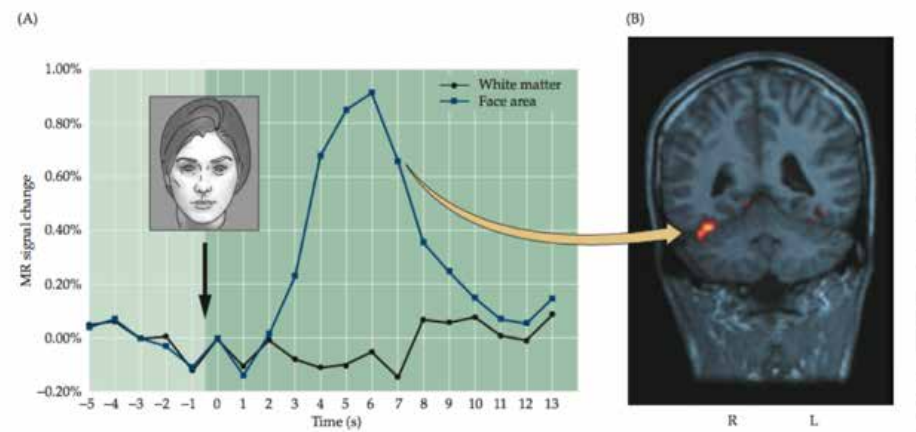

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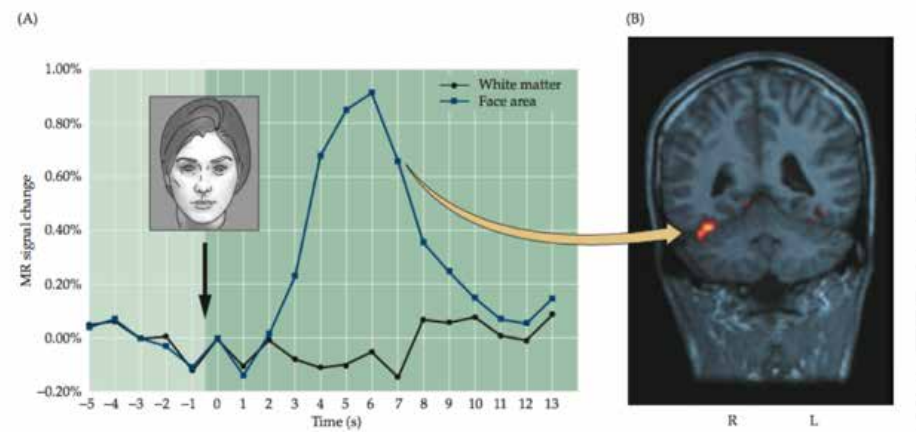

- Confirmation: temporal cortex → Face recognition

- **Side note**:

  → What if LH underwent a left temporal lobectomy?

Brain Regions Involved in Cognition

- **Phineas Gage**:
  - Railroad worker, accident while blasting rock → metal rod through skull
  - He survived the accident but **his personality was changed**

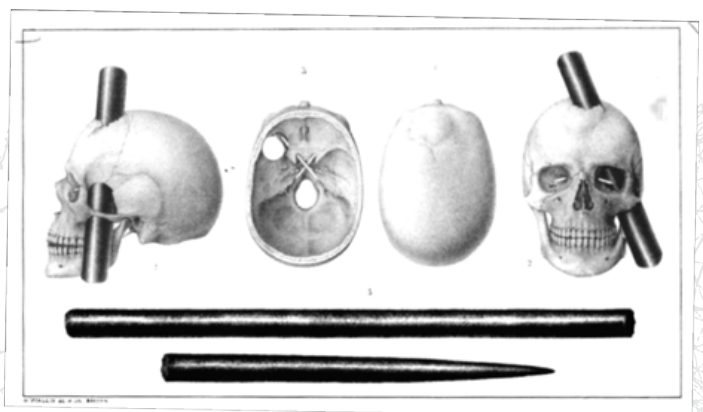

Diagram: Bigelow H., American Journal of the Medical Sciences, 1850

Actual skull: Countway Library of Medicine, Harvard Medical School

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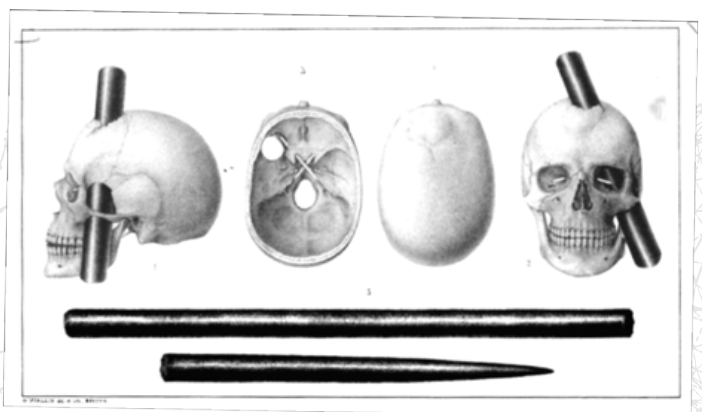
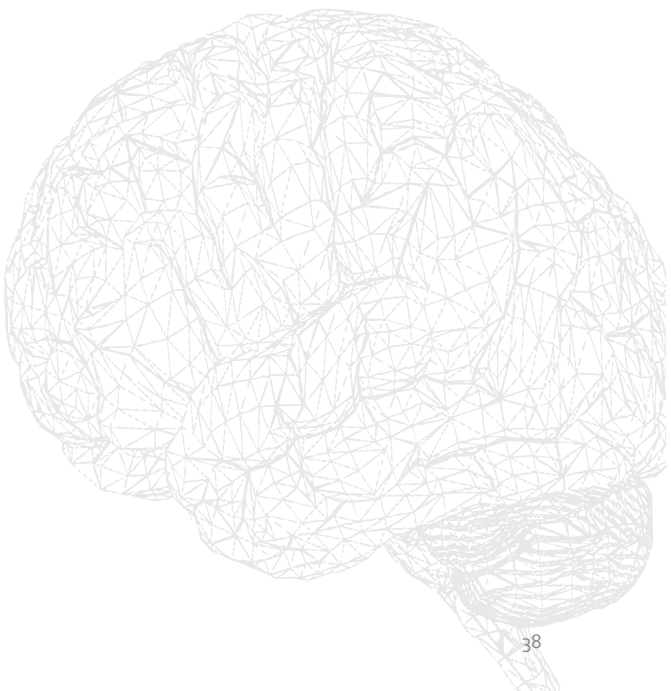


- Frontal cortex → Personality, planning

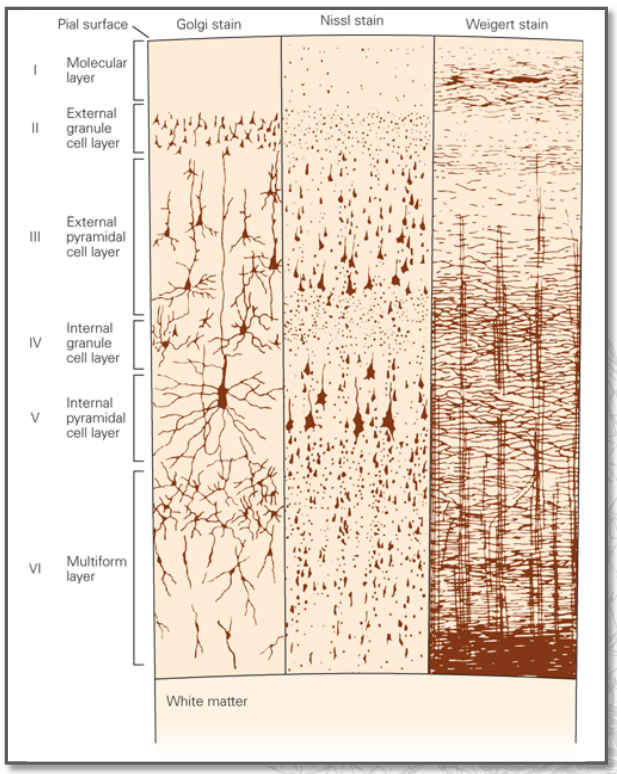
Outline

- Defining Cognition
- Brain Regions Involved in Cognition
- Association Cortex in Detail
- Neuronal Correlates of Cognition



Association Cortex in Detail

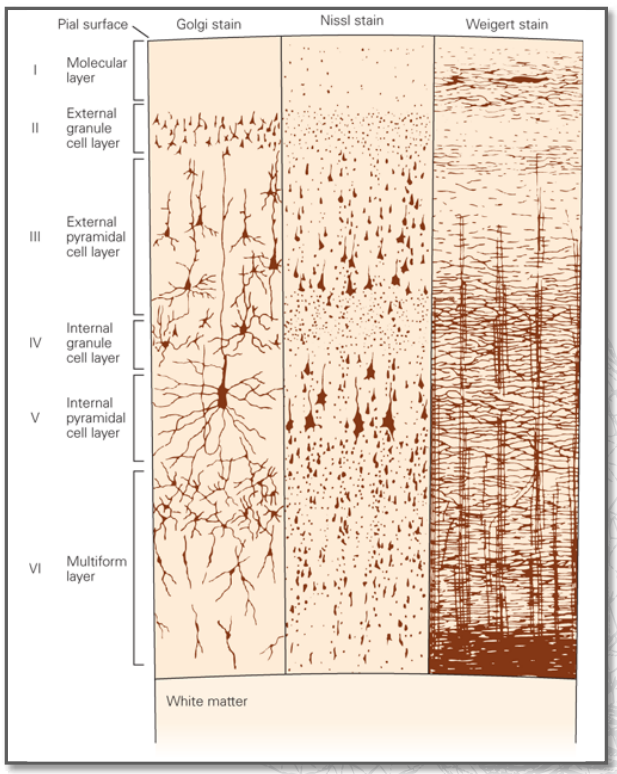
- The cortex is **laminated**.



Kandel, Principles of Neural Science 5th ed., fig. 15.6

Association Cortex in Detail

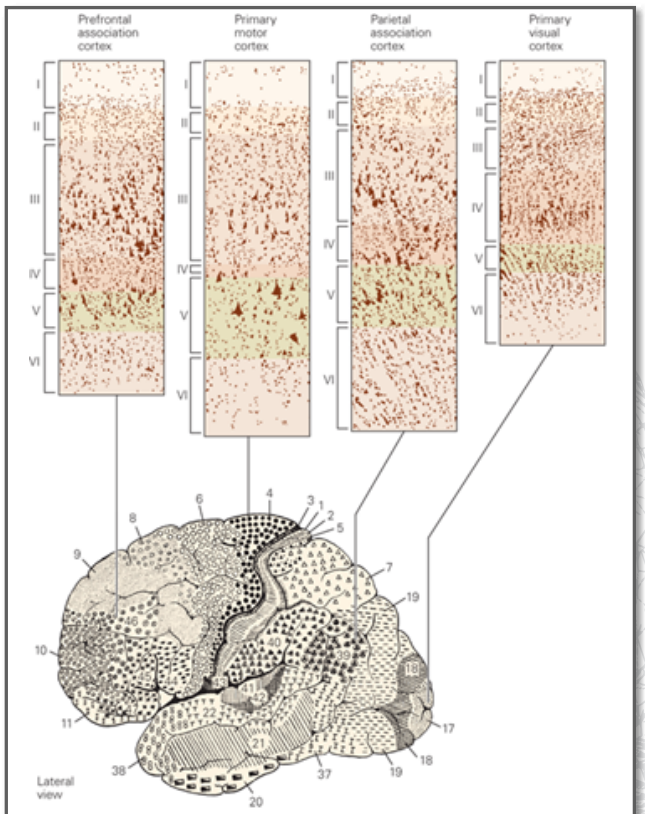
- The cortex is **laminated**.
- The neocortex is made of **6 layers**.
  → Pyramidal cells / Interneurons



Kandel, Principles of Neural Science 5th ed., fig. 15.6

Association Cortex in Detail

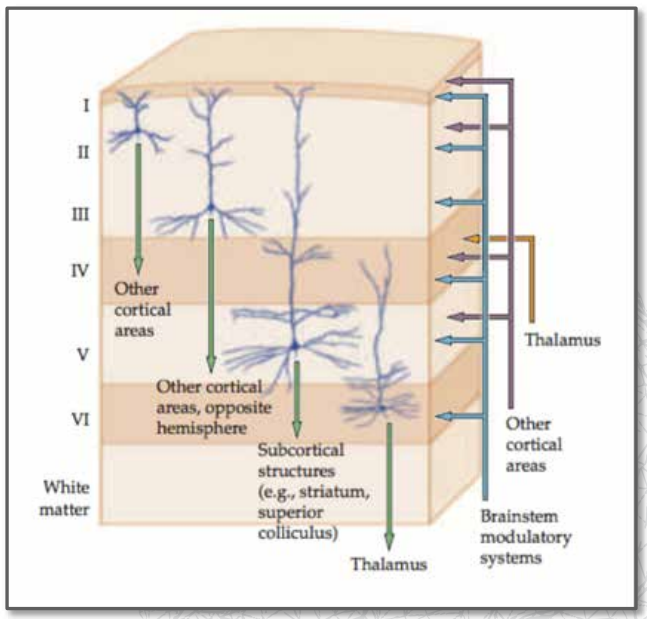
- The cortex is **laminated**.
- The neocortex is made of **6 layers**.
  → Pyramidal cells / Interneurons
- Diversity of **cytoarchitecture**
  → Brodmann areas (1909)



Kandel, Principles of Neural Science 5th ed., fig. 15.8

Association Cortex in Detail

- The cortex is **laminated**.
- The neocortex is made of **6 layers**.
  → Pyramidal cells / Interneurons
- Diversity of **cytoarchitecture**
  → Brodmann areas (1909)
- Organized **connectivity**
  → Layer IV: thalamic (sensory) inputs
  → Layers III and V: cortical + subcortical outputs



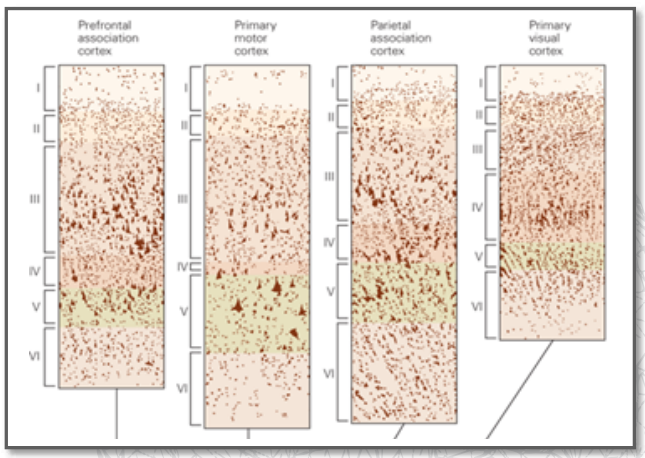
Purves, Neuroscience 6th ed., fig. 27.2

Association Cortex in Detail

- How is **association cortex** different?

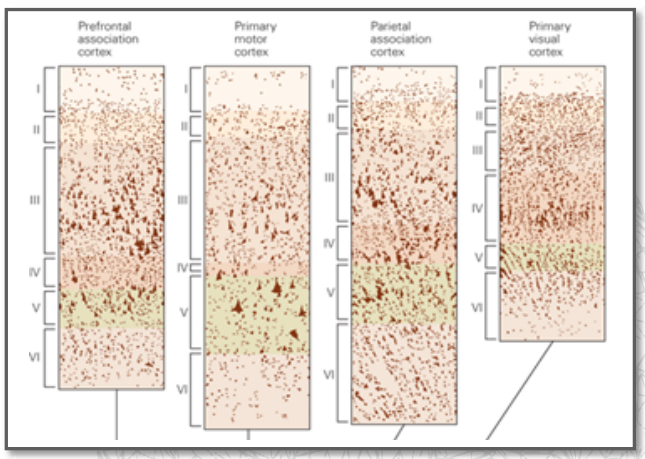
  → Inputs from specific thalamic nuclei

  thick layer IV, similar to sensory cortices



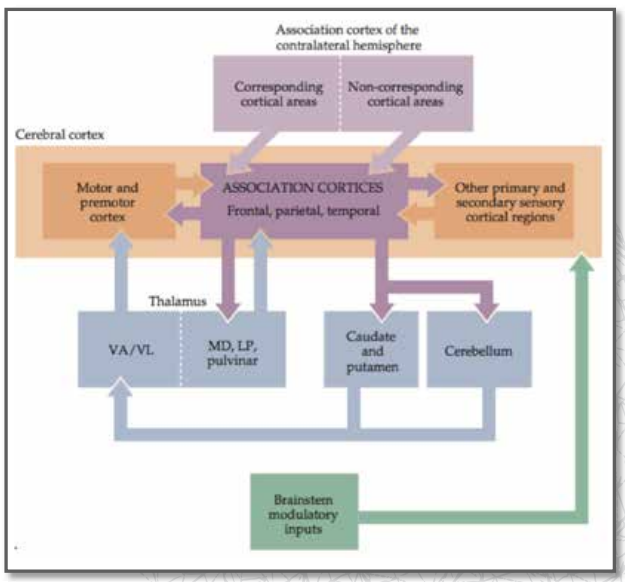
Association Cortex in Detail

- How is **association cortex** different?
  - → Inputs from specific thalamic nuclei
    - thick layer IV, similar to sensory cortices
  - → Cortico-cortical inputs / outputs
    - thick layers III and V, similar to motor cortices



Association Cortex in Detail

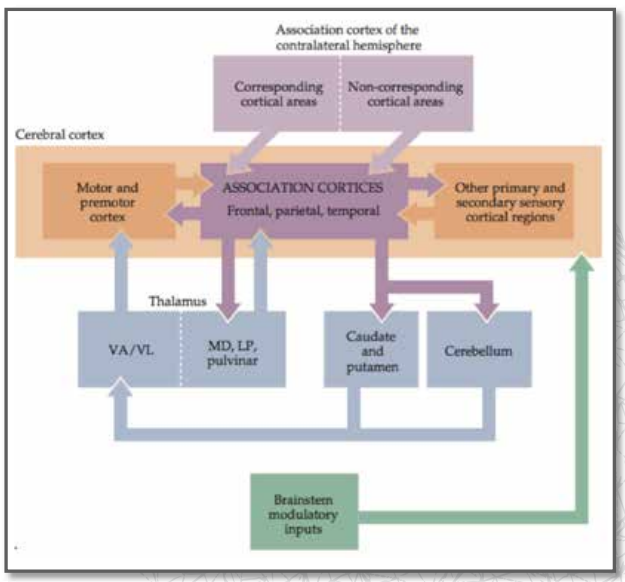
- How is **association cortex** different?
  - → Inputs from specific thalamic nuclei
    thick layer IV, similar to sensory cortices
  - → Cortico-cortical inputs / outputs
    thick layers III and V, similar to motor cortices
  - → Strong modulatory inputs



Purves, Neuroscience 6th ed., fig. 27.3

Association Cortex in Detail

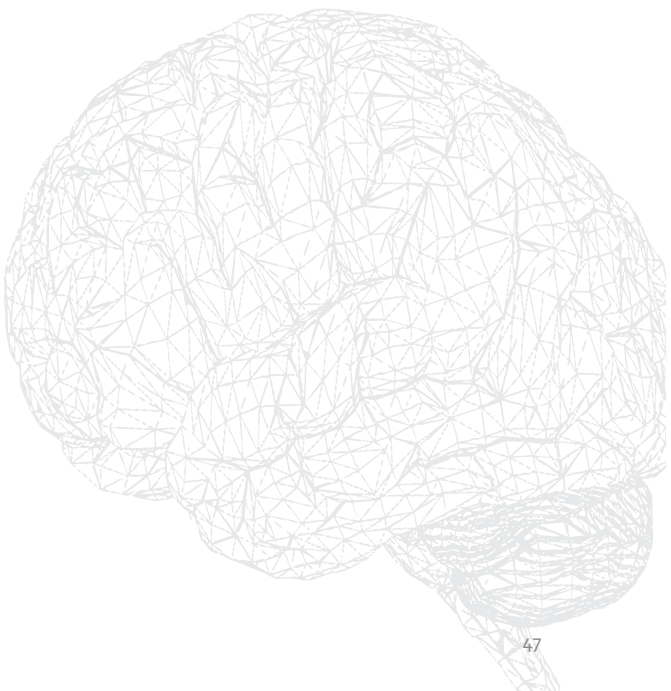
- How is **association cortex** different?
  - → Inputs from specific thalamic nuclei
    thick layer IV, similar to sensory cortices
  - → Cortico-cortical inputs / outputs
    thick layers III and V, similar to motor cortices
  - → Strong modulatory inputs



Note: not everything is connected to everything!

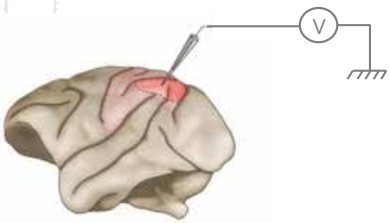
Outline

- Defining Cognition
- Brain Regions Involved in Cognition
- Association Cortex in Detail
- Neuronal Correlates of Cognition



Neuronal Correlates of Cognition

- How to make and read a peri-stimulus time histogram (PSTH)



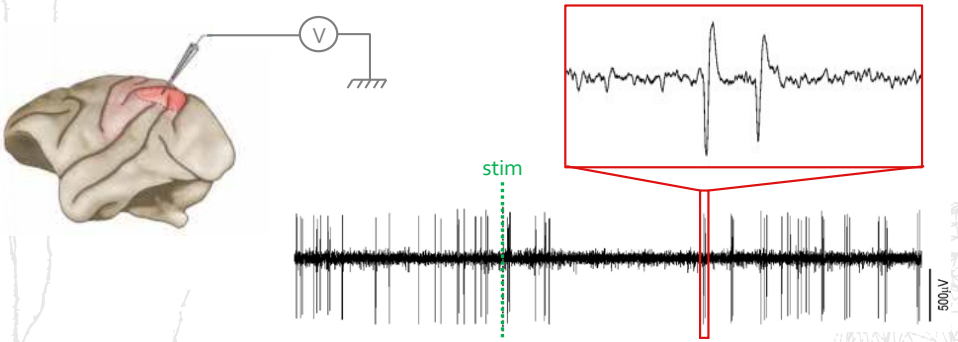
extracellular AP

(1) Record neuron activity (action potentials)…

Crowder N et al, J Neurophysiol vol. 91(1), 2004

Neuronal Correlates of Cognition

- How to make and read a peri-stimulus time histogram (PSTH)



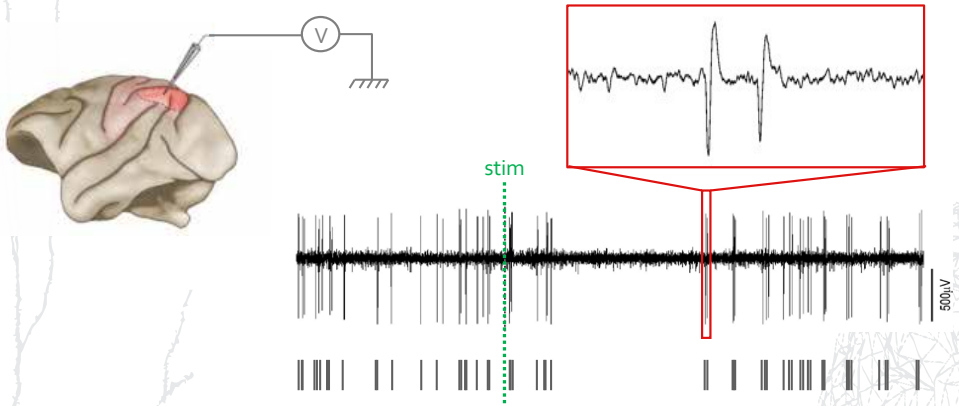
(1) Record neuron activity (action potentials)…

… while delivering a **stimulus**

Crowder N et al, J Neurophysiol vol. 91(1), 2004

Neuronal Correlates of Cognition

- How to make and read a peri-stimulus time histogram (PSTH)



(1) Record neuron activity (action potentials)…

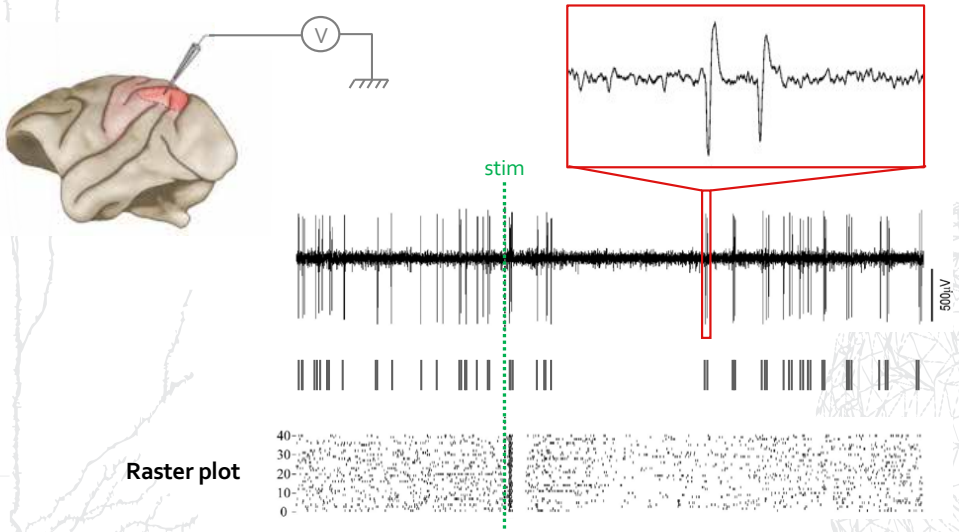
… while delivering a **stimulus**

(2) 1 tick per action potential

Crowder N et al, J Neurophysiol vol. 91(1), 2004

Neuronal Correlates of Cognition

- How to make and read a peri-stimulus time histogram (PSTH)



(1) Record neuron activity (action potentials)…
… while delivering a **stimulus**

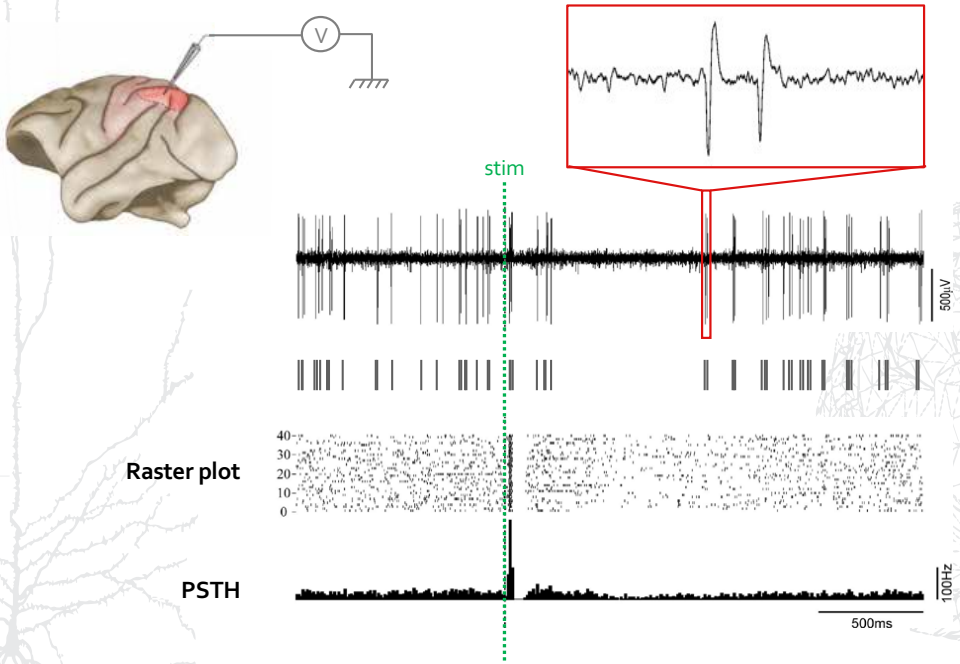
(2) 1 tick per action potential

(3) Repeat the stimulus…
… align activity with stimulus

Crowder N et al, J Neurophysiol vol. 91(1), 2004

Neuronal Correlates of Cognition

- How to make and read a peri-stimulus time histogram (PSTH)



(1) Record neuron activity (action potentials)…
… while delivering a **stimulus**

(2) 1 tick per action potential

(3) Repeat the stimulus…
… align activity with stimulus

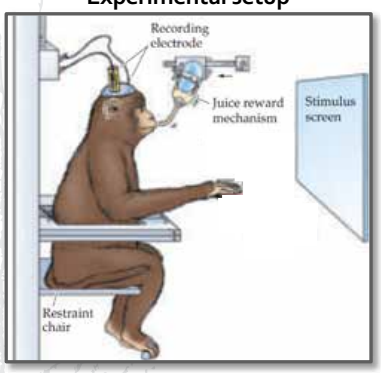
(4) Calculate the average activity over time

Crowder N et al, J Neurophysiol vol. 91(1), 2004

Neuronal Correlates of Cognition

- Face recognition task

Experimental setup

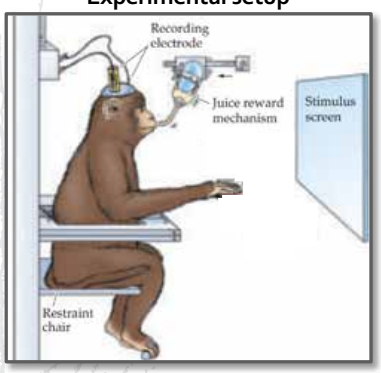


Tanaka K, Cereb Cortex vol. 13(1), 2003

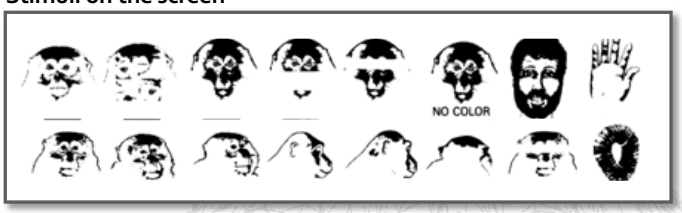
Neuronal Correlates of Cognition

- Face recognition task

Experimental setup



Stimuli on the screen

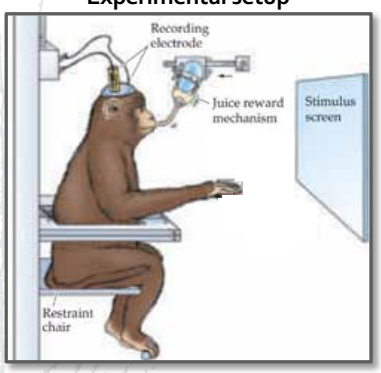


Tanaka K, Cereb Cortex vol. 13(1), 2003

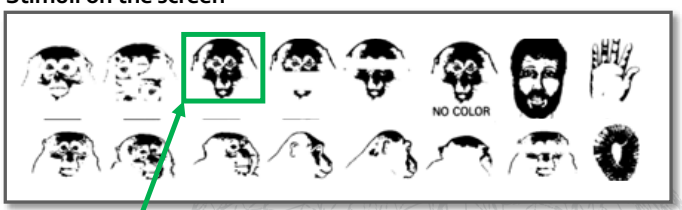
Neuronal Correlates of Cognition

- Face recognition task

Experimental setup



Stimuli on the screen



Very familiar
(live in the same facility)

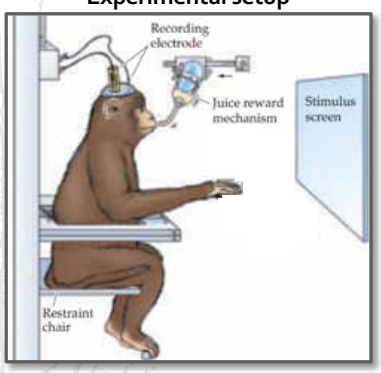
Tanaka K, Cereb Cortex vol. 13(1), 2003

Neuronal Correlates of Cognition

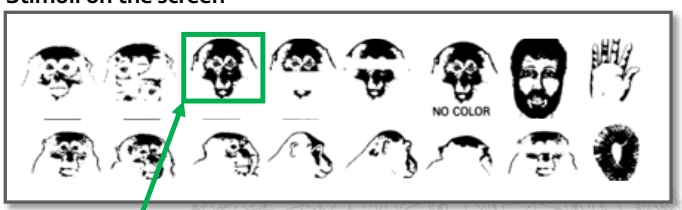
- Face recognition task

  + electrodes in temporal lobe

Experimental setup



Stimuli on the screen



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Neuronal Correlates of Cognition

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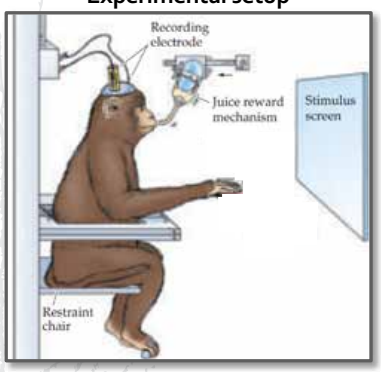
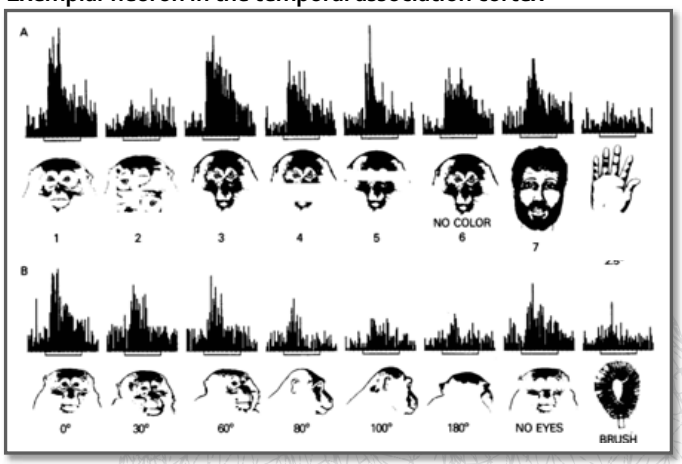


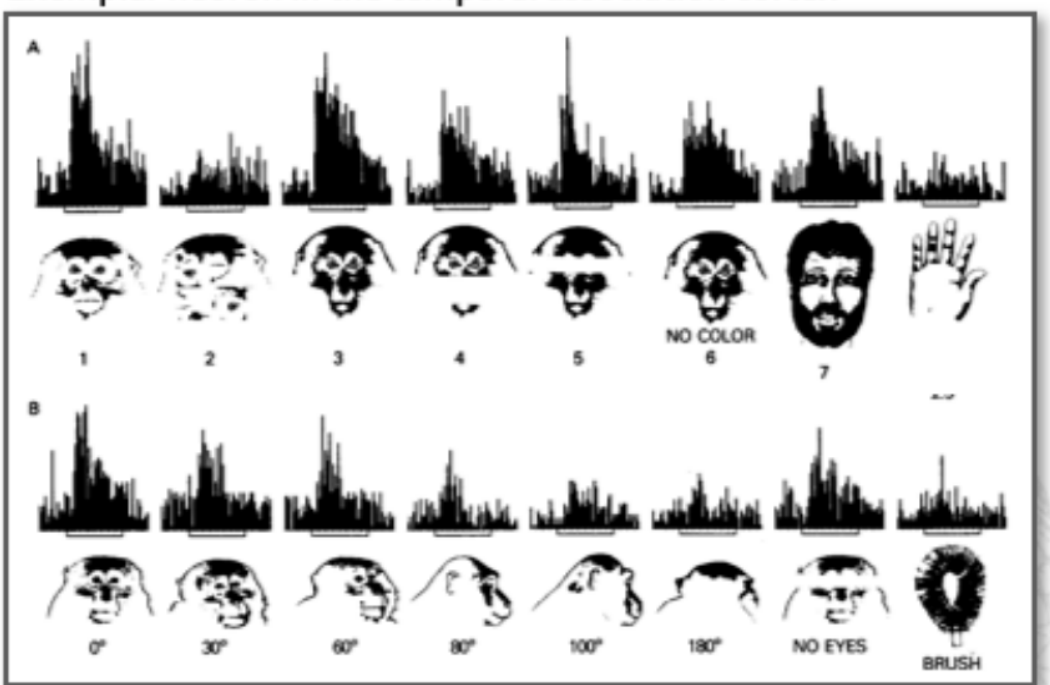
Exemplar neuron in the temporal association cortex



Tanaka K, Cereb Cortex vol. 13(1), 2003

Click on the stimulus that elicits the strongest response for this neuron.

Exemplar neuron in the temporal association cortex

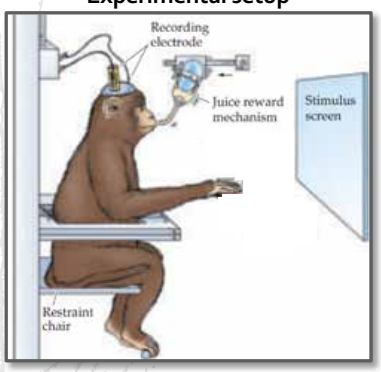


Neuronal Correlates of Cognition

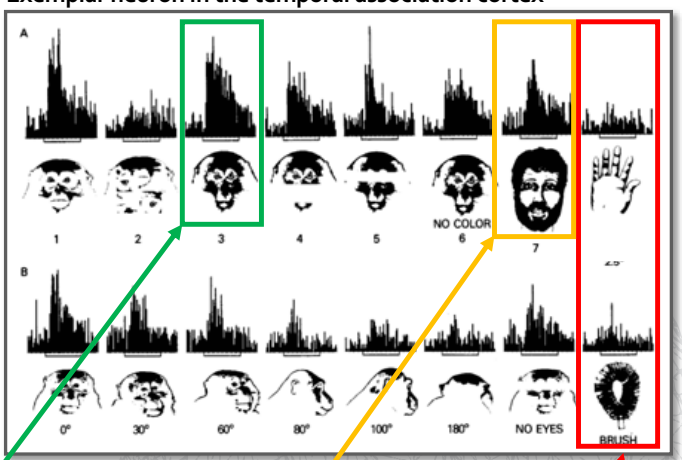
- Face recognition task

  + electrodes in temporal lobe

Experimental setup



Exemplar neuron in the temporal association cortex



Most familiar face:
Highest response

Non-familiar face:
Lower response

Non-face images:
Little to no response

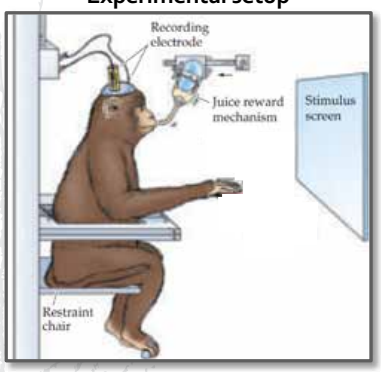
Tanaka K, Cereb Cortex vol. 13(1), 2003

Neuronal Correlates of Cognition

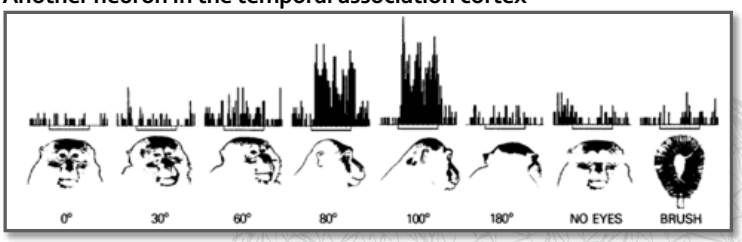
- Face recognition task

  + electrodes in temporal lobe

Experimental setup



Another neuron in the temporal association cortex



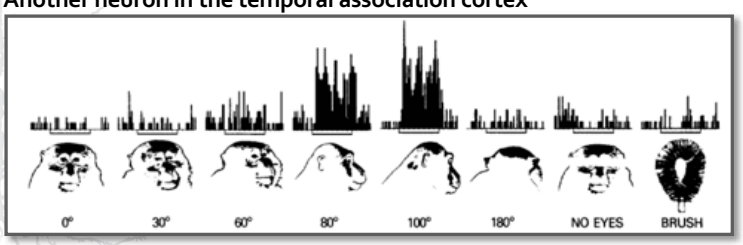
Neuronal Correlates of Cognition

- Face recognition task

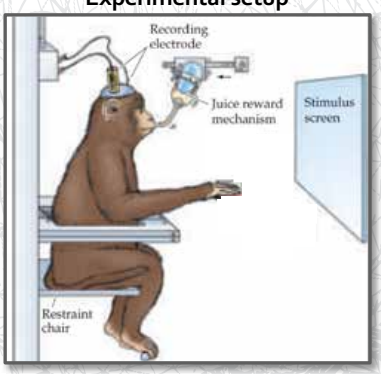
  \+ electrodes in temporal lobe

- Face neurons
  - → In temporal cortex
  - → Best activated by familiar faces
  - → Best activated by faces at a specific angle

Another neuron in the temporal association cortex



Experimental setup



Neuronal Correlates of Cognition

- Face recognition task

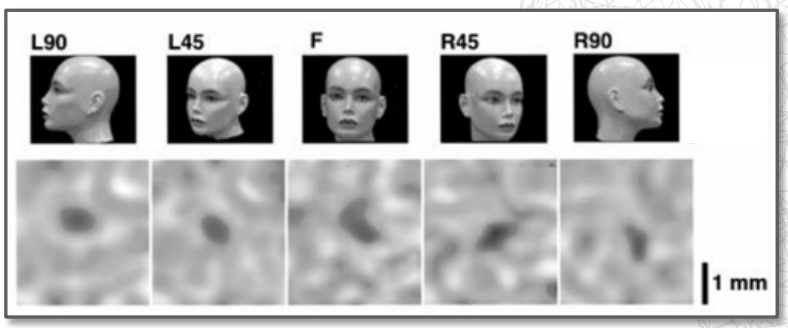
  + electrodes in temporal lobe

- Face neurons

  → In temporal cortex

  → Best activated by familiar faces

  → Best activated by faces at a specific angle



Wang G et al., Science vol. 272(5268), 1996

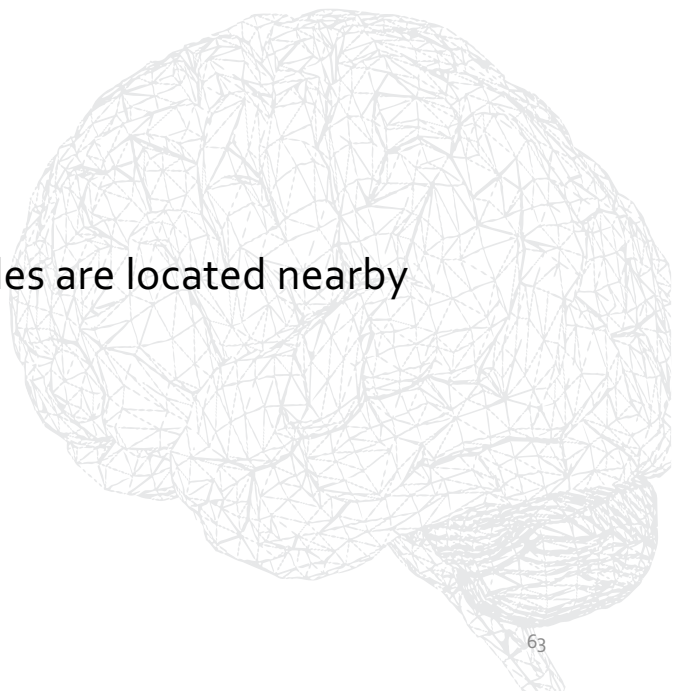
Neuronal Correlates of Cognition

- Face recognition task

  + electrodes in temporal lobe

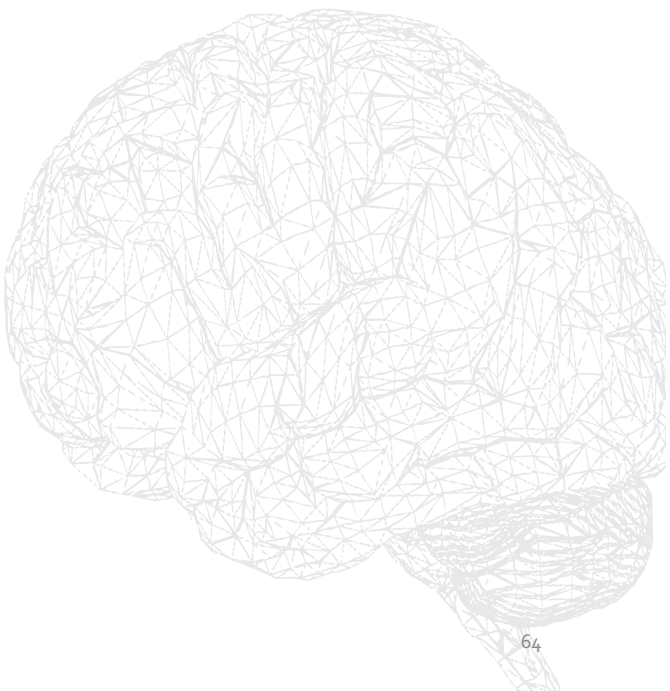
- Face neurons
  - → In temporal cortex
  - → Best activated by familiar faces
  - → Best activated by faces at a specific angle

- Face neurons responding to nearby angles are located nearby
  - → Face orientation columns



Neuronal Correlates of Cognition

- Delayed-response task



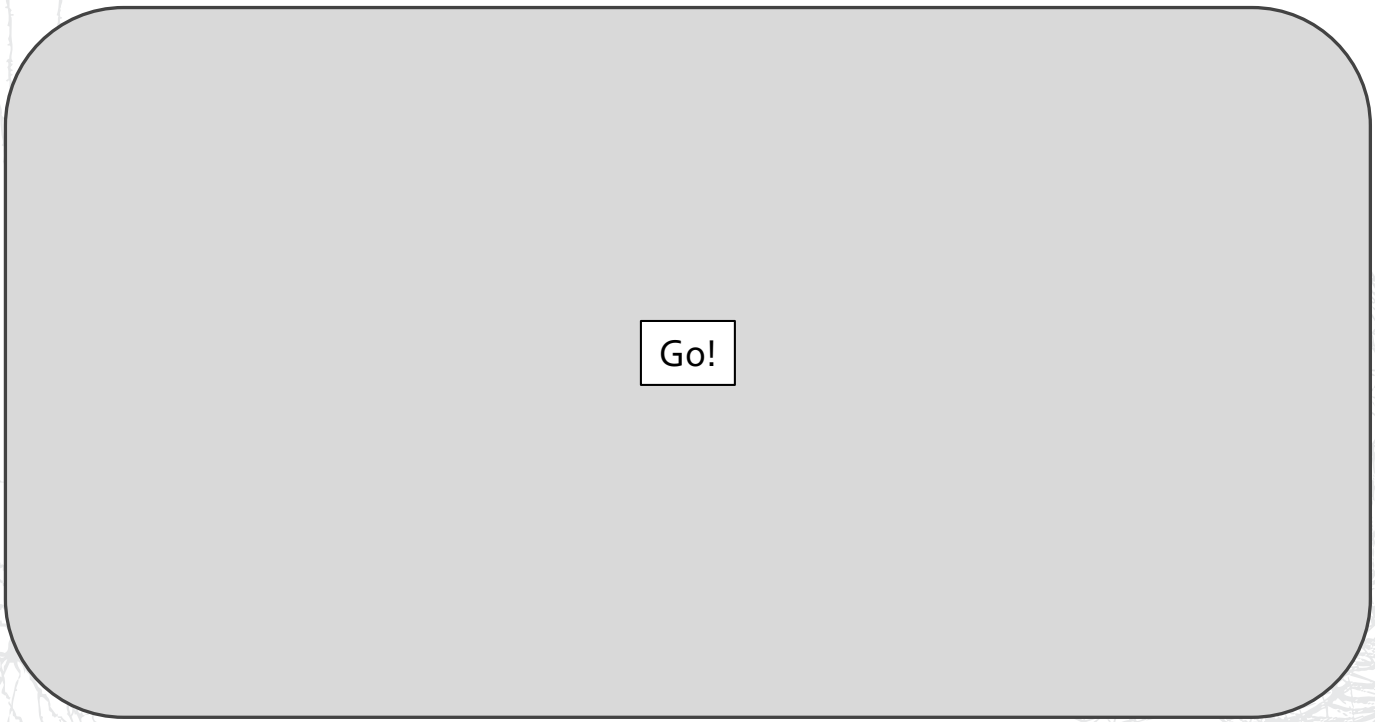
Neuronal Correlates of Cognition

- Delayed-response task

(1) Fix the red dot at the center of the screen.
(2) A black square will flash somewhere on the screen. Keep looking at the red dot.
(3) When the red dot disappears, move your eyes where the black square was.

Neuronal Correlates of Cognition

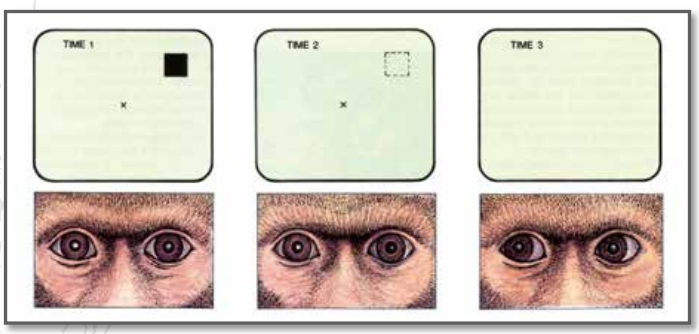
- Delayed-response task



Neuronal Correlates of Cognition

- Delayed-response task

Task structure

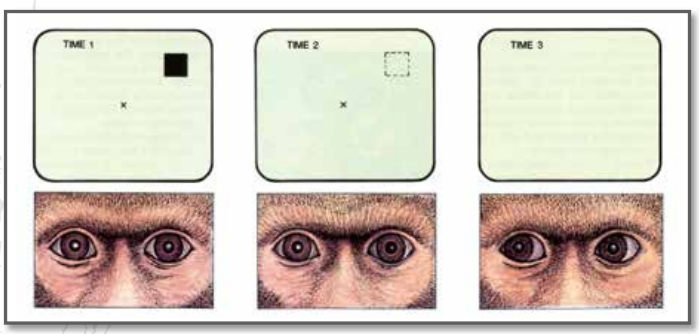


Goldman-Rakic P, Scientific American, Sept 1992

Neuronal Correlates of Cognition

- Delayed-response task
  + electrodes in frontal lobe

Task structure



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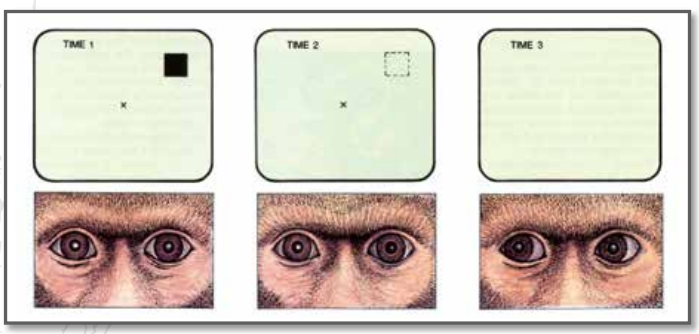
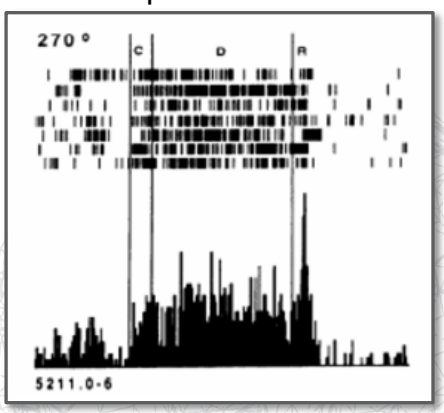
Neuronal Correlates of Cognition

- Delayed-response task
  + electrodes in frontal lobe

Task structure



Neuron in the prefrontal association cortex



C: cue
D: delay
R: reaction

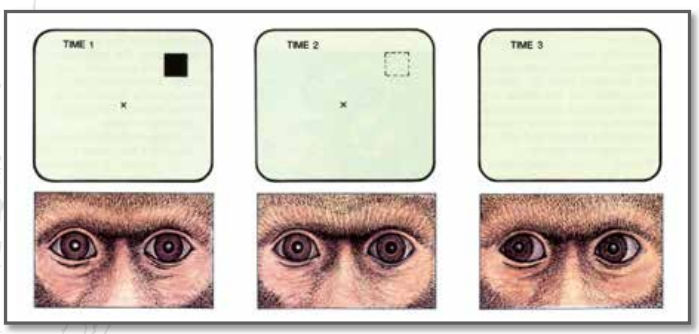
Funahashi S et al., J Neurophysiol vol. 61(2), 1989

Goldman-Rakic P, Scientific American, Sept 1992

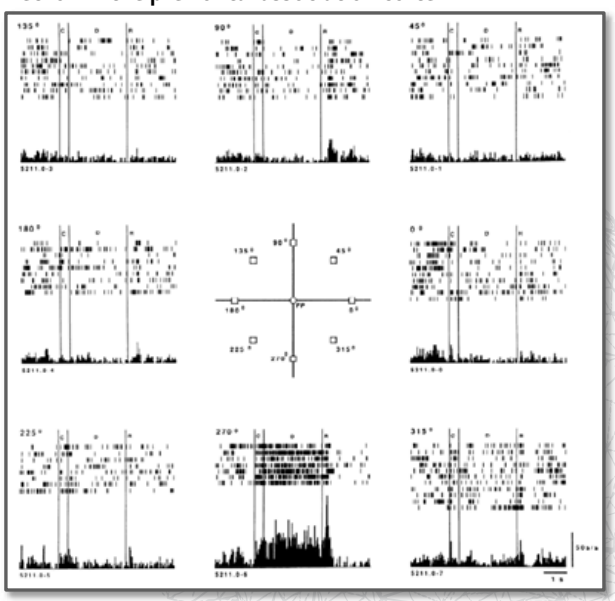
Neuronal Correlates of Cognition

- Delayed-response task
  + electrodes in frontal lobe

Task structure



Neuron in the prefrontal association cortex



Funahashi S et al., J Neurophysiol vol. 61(2), 1989

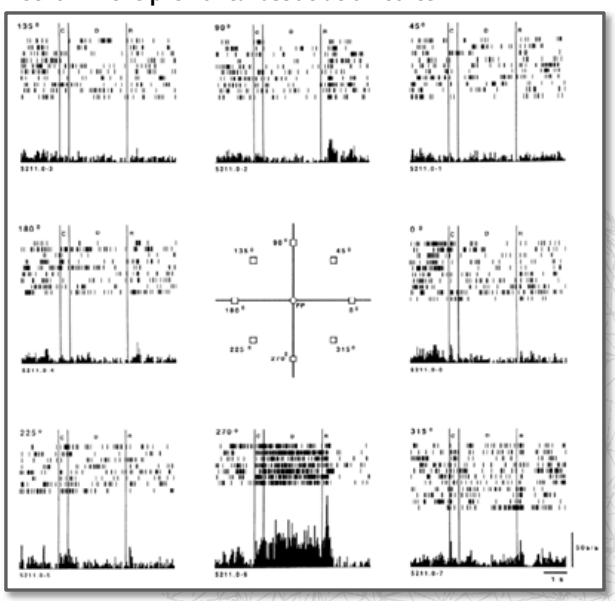
Goldman-Rakic P, Scientific American, Sept 1992

Neuronal Correlates of Cognition

- Delayed-response task

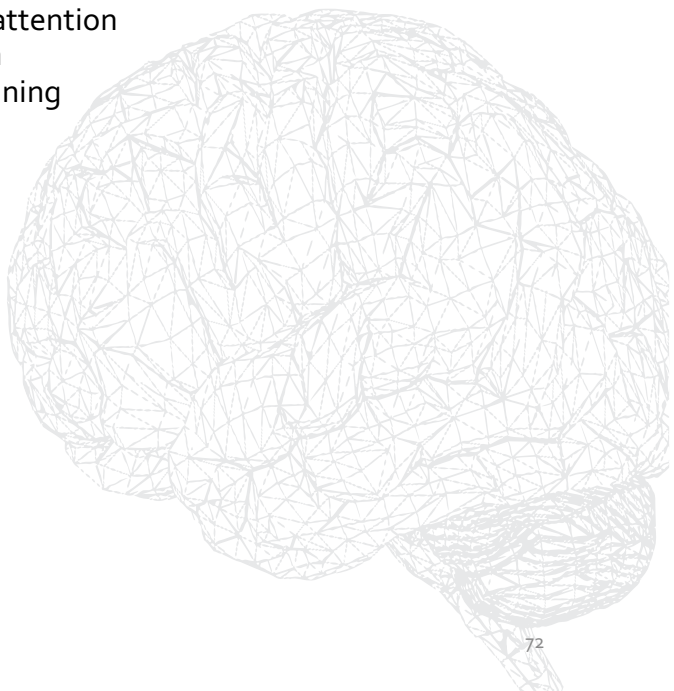
- Visual attention neurons
  - → In frontal cortex
  - → Best activated during delay period
  - → Angle specific

Neuron in the prefrontal association cortex



Summary

- Defining Cognition
  - From behaviorism to cognition
  - Definition of cognition, examples of cognitive skills
- Brain Regions Involved in Cognition
  - Contralateral neglect syndrome → parietal cortex, attention
  - Prosopagnosia → temporal cortex, face recognition
  - Phineas Gage → prefrontal cortex, personality, planning
- Association Cortex in Detail
  - Structure, connections from / to neocortex
  - Specificities of association cortices
- Neuronal Correlates of Cognition
  - Raster plot, PSTH
  - Face recognition task → temporal neurons
  - Delayed response task → prefrontal neurons



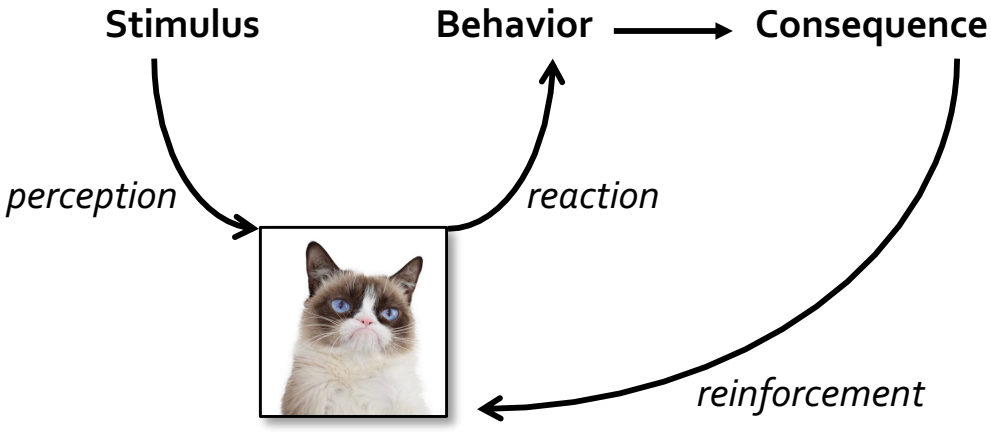
Learning objectives for Lecture 20

- Define the term "cognition".
- Cite the cortical regions involved in cognition. How do these cortical regions differ from sensory and motor cortices?
- Give an example how neural activity in these regions correlates with cognitive functions.
- Describe some experimental strategies to investigate the function(s) of a brain region.
- Know what a peri-stimulus time histogram (PSTH) is and how to interpret it.

Lecture 20 - Cognition

Pre-class notes for November 13, 2019
Reading: *Neuroscience ed. 6* by Purves et al., pages 627-641, 667-677,

Law of effect - behaviors leading to satisfying consequences are reinforced. Behaviors leading to unpleasant outcomes are less likely to occur again.

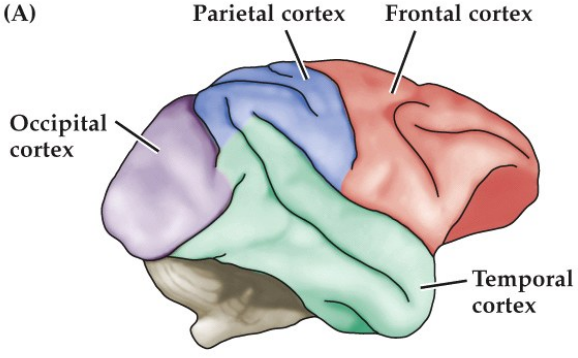


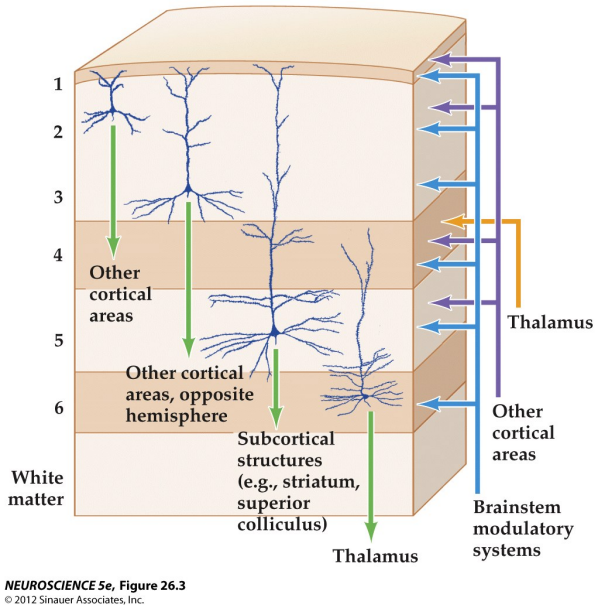
Behavioralism - the belief that all behaviors can be explained by the law of effect, or through conditioning by the environment without the need to consider internal mental states or consciousness. Based on many different animal studies (e.g. Pavlov's classical conditioning and Skinner and operant conditioning), where it may be difficult to investigate complex behaviors like emotion and attention.

Cognitivism - the belief that many behaviors are too complex to be explained by the law of effect. They are governed by mental states, which should be investigated.

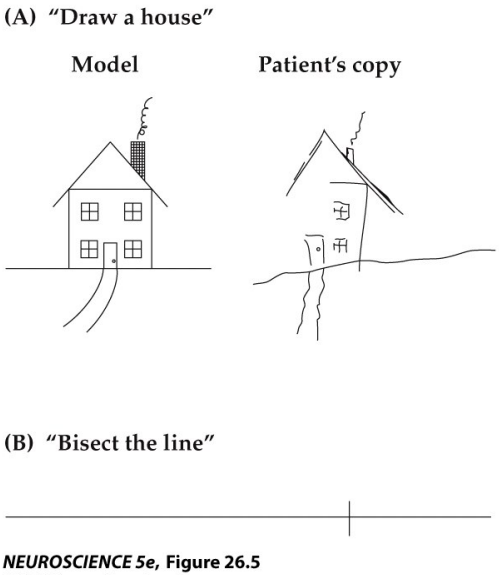
Cognition - any form of information processing, mental operations, or intellectual activity such as thinking, reasoning, remembering, imagining, or learning.

Association cortex - large part of the cortex that is neither primary sensory nor primary motor. Integrates information from multiple, areas - including different sensory, memory, emotional and motor planning areas. The part of the brain that "puts things together" and as such is enriched by inputs from other cortical areas (*corticocortical connections*), specific thalamic nuclei and also receives strong modular input.





Contralateral neglect syndrome (or hemispatial neglect syndrome)- reduced awareness of stimuli on one side of space without any sensory deficits. *See drawings by patient on the right.* Usually caused by injury to the right inferior parietal lobe and adjacent regions, impacting attention and not visual sensation.

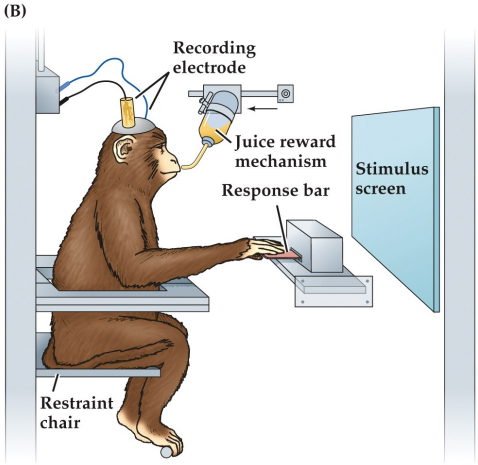


NEUROSCIENCE 5e, Figure 26.5

Prosopagnosia - the inability to recognize faces, despite awareness of some sort of visual stimulus present. Usually caused by injury to the right temporal lobe. Other related *agnosias* may involve the inability to recognize other objects.

Frontal association cortex - the frontal cortex integrates complex information from sensory and motor cortices as well as the parietal and temporal association regions. Damage to the frontal cortex, as was the case for Phineas Gage, can result in changes in personality, difficulty carrying out complex/appropriate behavior, and difficulty planning for the future while keeping intellectual capabilities largely intact.

When studying the response of a cell, it is typical to repeat the experiment over many trials to see how similar (or different) the neuronal responses are in response to a given stimulus. A *raster plot* is a simple method to visually examine the trial-by-trial variability of the responses. Each row will represent the neuron's response to a single trial (or occasionally the response of one neuron within a population), and the x axis will represent time.



NEUROSCIENCE 5e, Figure 26.8 (Part 2)
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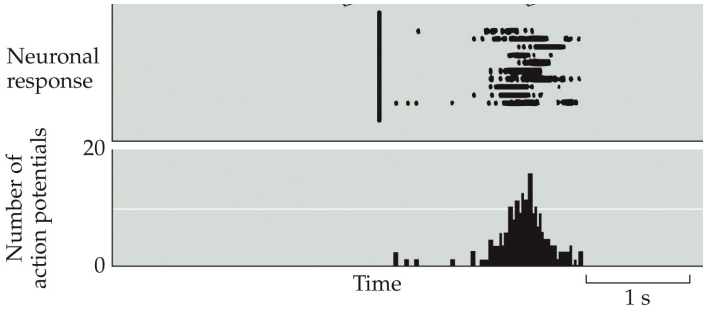

Peri-stimulus time histogram (PSTH) - a histogram of the times at which a recorded neuron fires in relationship to a stimulus, typically each trial is aligned to the onset of a stimulus. PSTs are used to visualize the rate and timing of neuronal activity (action potentials) in relation to a stimulus or external event.

Learning Objectives: (By the <u>end</u> of Lecture 20 you should be able answer questions about the following)

1. Define the term "cognition".
2. Cite the cortical regions involved in cognition. How do these cortical regions differ from sensory and motor cortices?
3. Give an example how neural activity in these regions correlates with cognitive functions.
4. Describe some experimental strategies to investigate the function(s) of a brain region.
5. Know what a peri-stimulus time histogram (PSTH) is and how to interpret it.