Learning and Memory

Monsoon 2024

1st August

Dr. Bhaktee Dongaonkar

NO NEGOTIATION OF GRADES AT THE END OF THE SEMESTER.

No Quiz1 or Quiz2 – only surprise class quizzes.

Type of Evaluation	Weightage (in %)
Surprise In-class quizzes	35%
Mid Sem-Exam	25%
End Sem Presentations in Class (group of 4 students design novel experiments to test behaviour) Contributions made by every student in the group will be assessed	30%
Participation in-class discussions (those who think and make interesting observations and ask relevant/critical questions in class)	5%
Participation in experiments	5%

Grade	%
A	>= 88
A-	81-87.5
B	74-80.5
B-	66 -73.5
C	59-65.5
C-	52-58.5
D	40 – 51.5
F	Below 40

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What does ‘learning’ mean?

How do sensations become linked in the mind?

Aristotle and Associationism

(384–322 BC)

Aristotle described the linkages between ideas in the mind as reflecting three fundamental principles, or universal laws, of association

- Contiguity
- Frequency
- Similarity

Aristotle's theory of **associationism**

Argued that memory depends on the formation of linkages ("associations") between pairs of events, sensations, or ideas, so that recalling or experiencing one member of the pair elicits a memory or anticipation of the other

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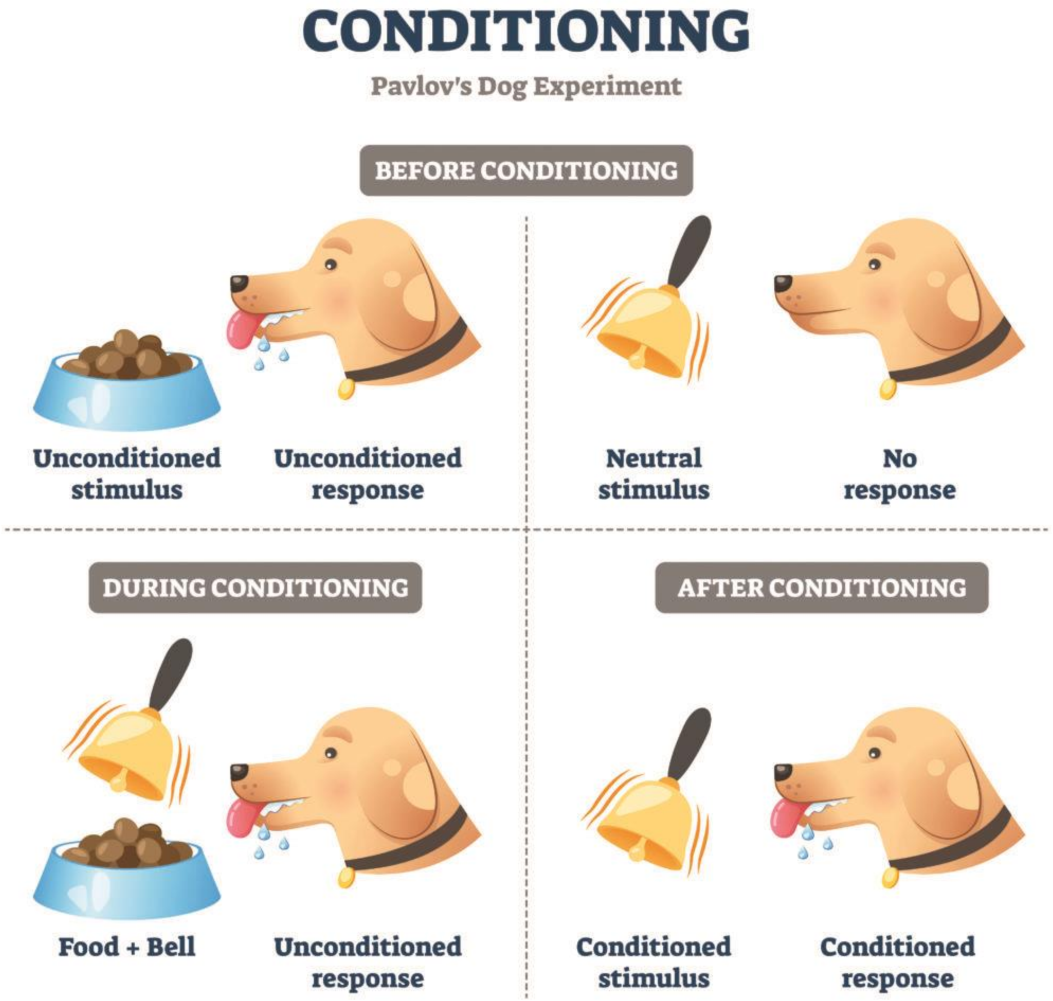
Ivan Pavlov's Conditioning Studies

(1849–1936)

- Ivan Pavlov is known for developing methods for studying animal learning that are still in widespread use today

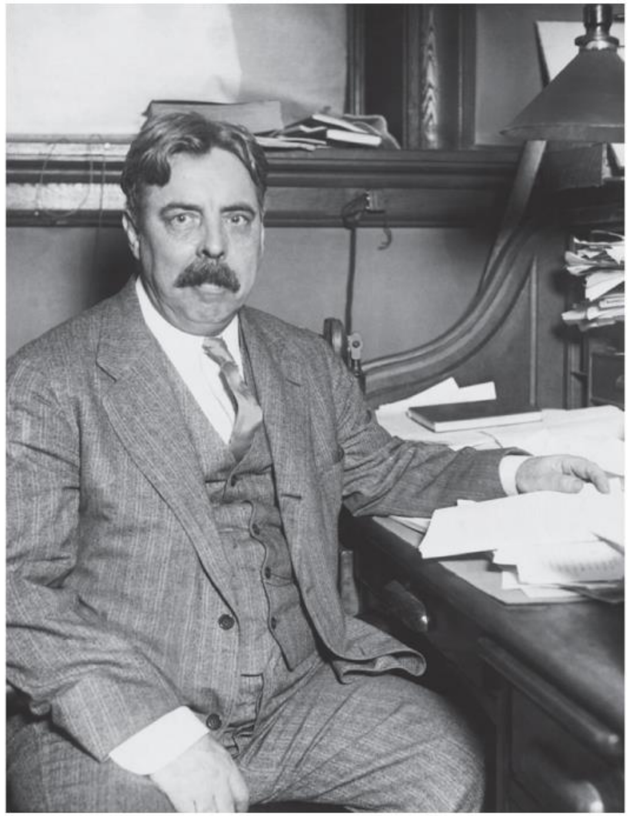


Edward Thorndike and the Law of Effect
(1874–1949)

Instrumental (Operant) conditioning: organisms learn to make responses in order to obtain or avoid important consequences

Reward/Punishment

Thorndike observed that the probability of a particular behavioral response increased or decreased depending on the consequences that followed; he called this the **law of effect**



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Some of Thorndike's most influential studies involved observing how cats learn to escape from puzzle boxes

B. F. Skinner’s Radical Behaviorism
(1904–1990)

- Burrhus Frederic Skinner
  - Believed psychologists should limit themselves to the study of observable behaviors that can be learned through experience, and not try to speculate about what is going on in the mind of an animal while it learns

Bettmann/Getty Images

Serendipity and Variable Reinforcement (reward based behaviour)

Skinner argued that humans, like all other animals, function by blindly producing learned responses to environmental stimuli

radical behaviorism - free-will is an illusion

Clark Hull and Mathematical Models of Learning (1884–1952)

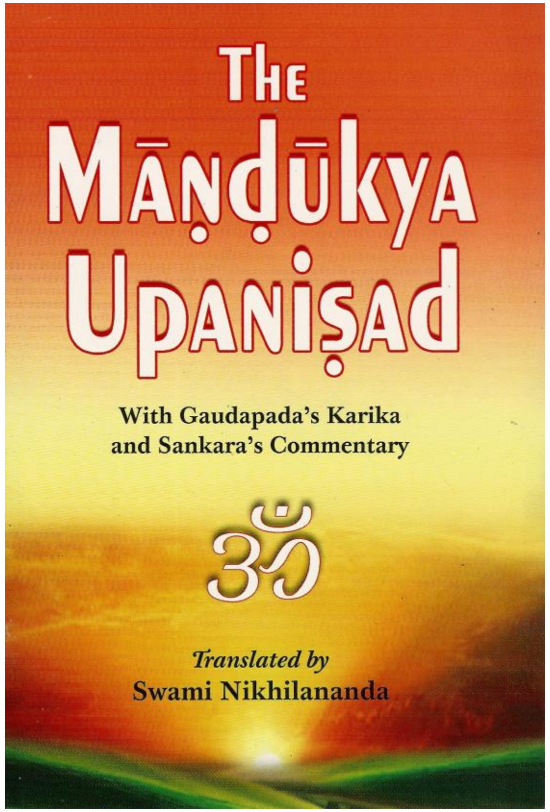
- Hull's goal was to develop a comprehensive mathematical model of animal learning that would predict exactly what an animal will learn in any given situation

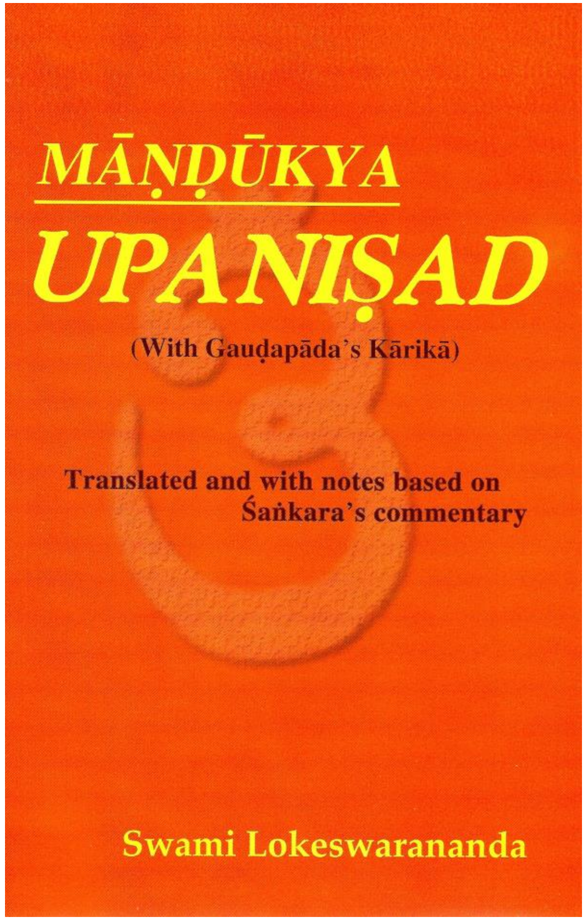
- Most learning theorists of that era, including Hull, assumed that learning should be viewed as the development of associations between a stimulus and a response driven by the need to fulfil an intrinsic drive (Drive Reduction theory).

Office of Public Affairs, Yale University, Photographs of Individuals (RU686). Manuscripts and Archives, Yale University Library.

Why do we have memories?

Śaṅkara (788-820)

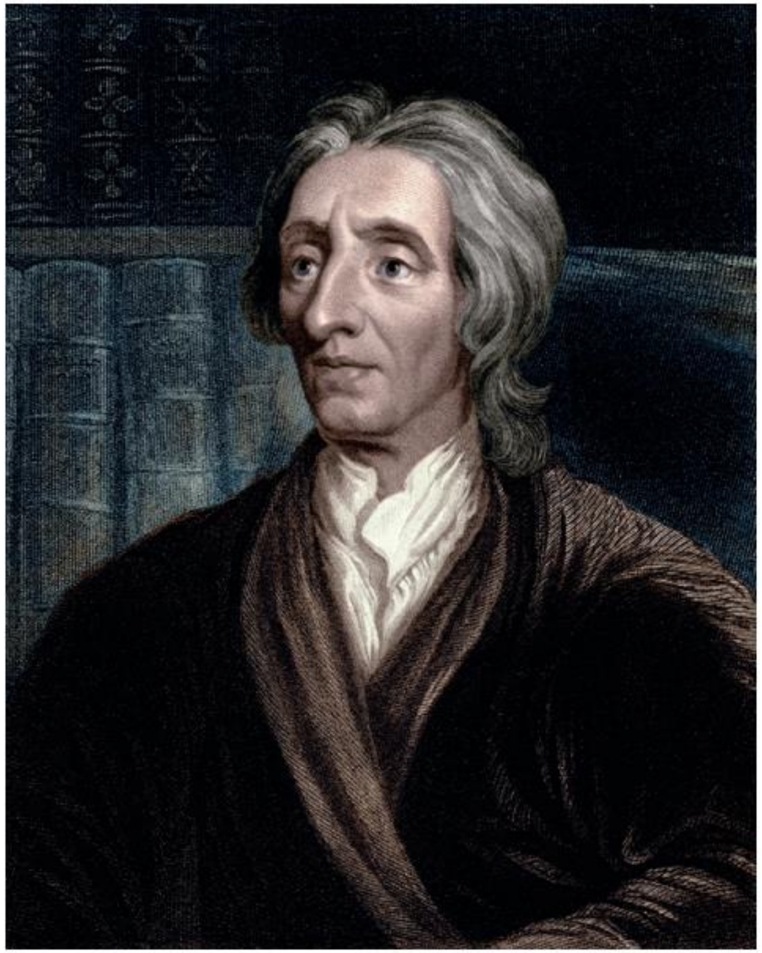




- Adi Shankara
- Sage/scholar
- Notable Indian thinker
- Interpretations vary across translators
- Memory is an extension of our consciousness
- Memory has a purpose – our past experiences help us to navigate or interpret the present

John Locke the Blank Slate

(1632–1704)



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Isaac Newton’s Light and Robert Boyle’s chemicals
•Associationism (Green, Bitter/Sour vs. Limes)

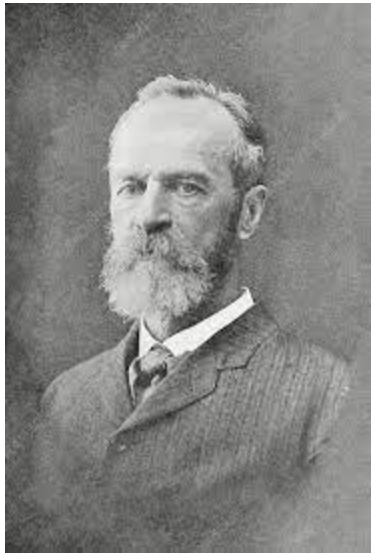
- John Locke argued that all knowledge is derived from experience
- Suggested that children arrive in the world as a blank slate (tabula rasa), ready to be influenced by experience and learning

Locke argued that access to a good education should be available to all children, regardless of their class or family wealth, because common people, through striving and learning, could transcend the limits and barriers of class

William James and Memory Networks

(1842–1910)

(MS Am 1092.) Houghton Library, Harvard University



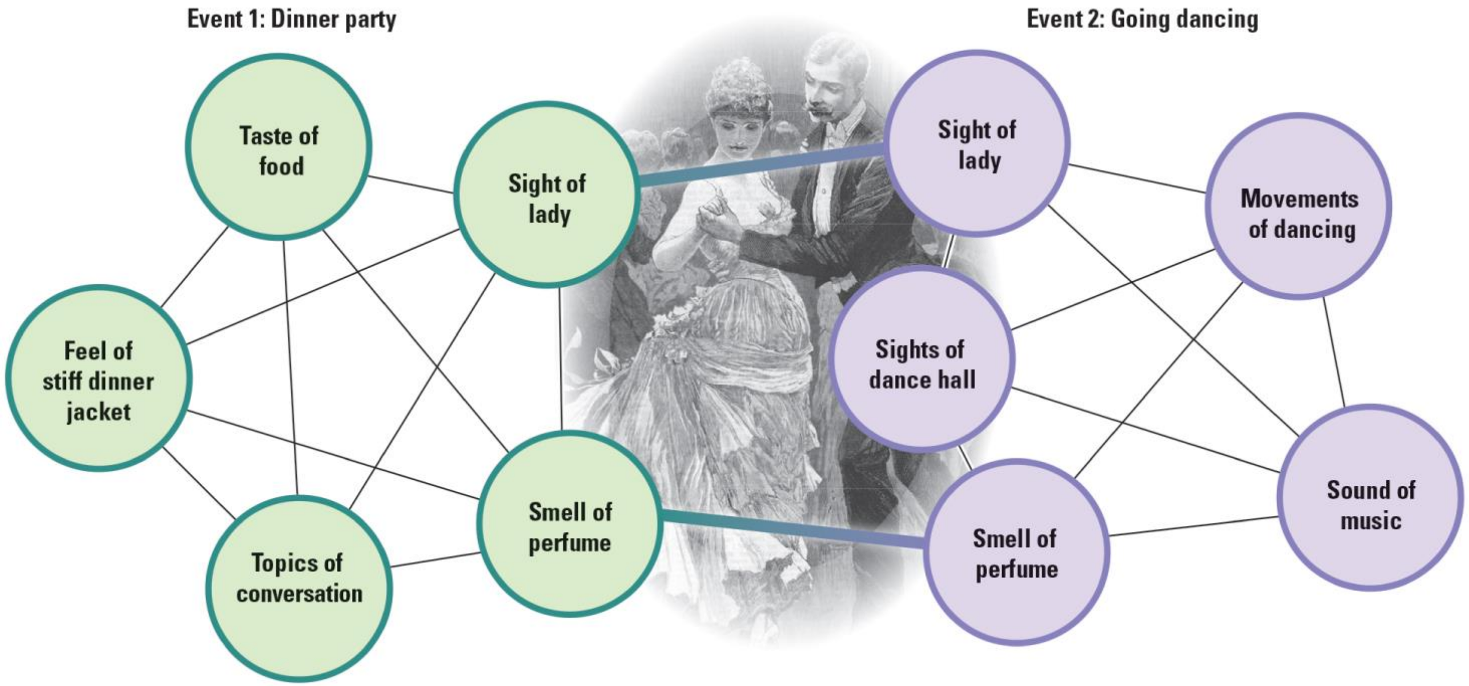


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Image from Mansell/Time Life Pictures/Getty Images

Memory depends on:

1. Strengthening of reflex pathways
2. Associational Links

especially interested in how we learn new habits and acquire new memories

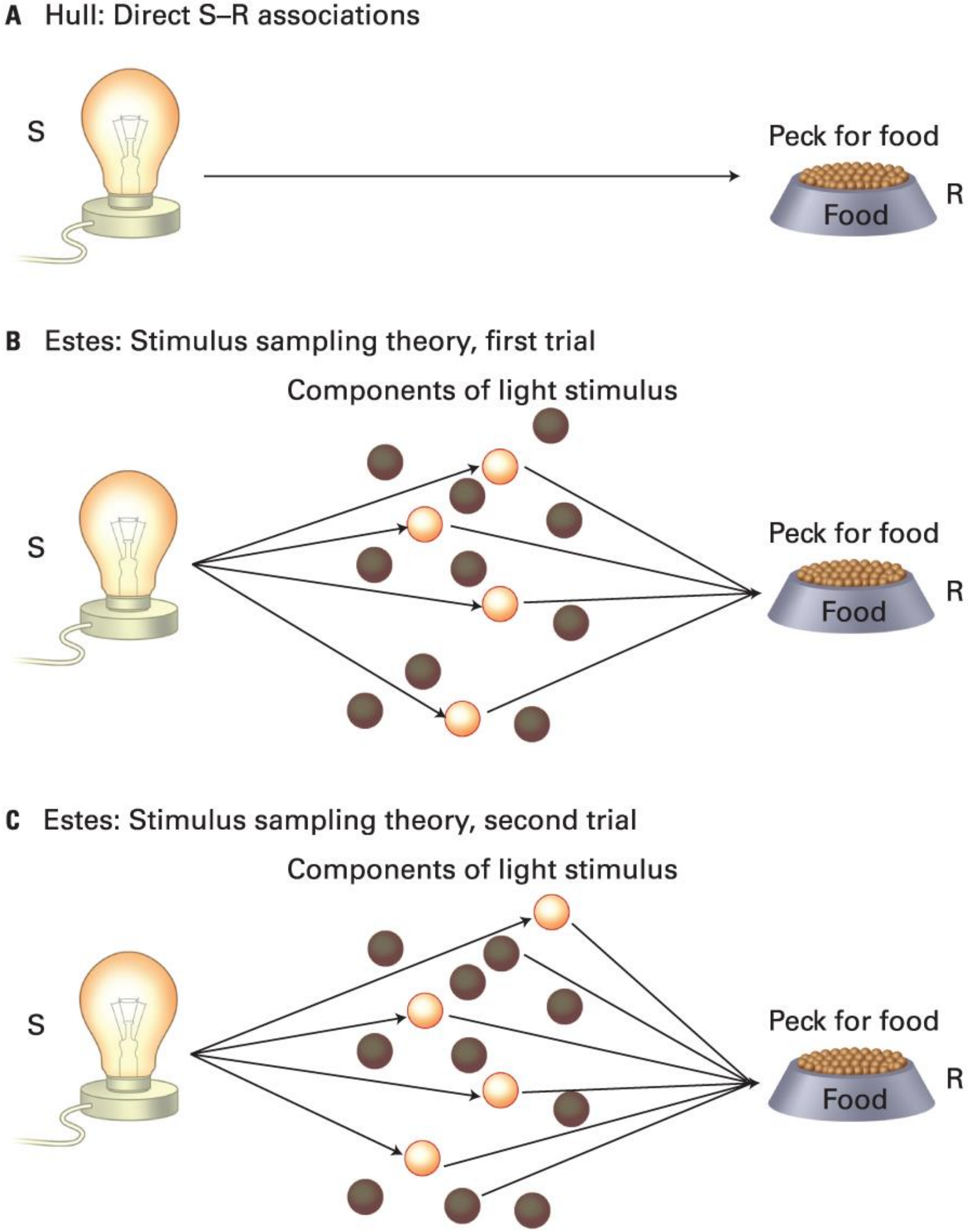
W. K. Estes and Mathematical Psychology

- William K. Estes (1919–2011) and his colleagues established a new subdiscipline of psychology, **mathematical psychology**
    - Stimulus Sampling Theory (SST). SST is a probabilistic model that provides a statistical explanation of how we learn a stimulus-response association in a single trial, but require more stimulus-response repetitions to build an evident unit of learning.

Stimulus-Response Models

HULL

ESTES



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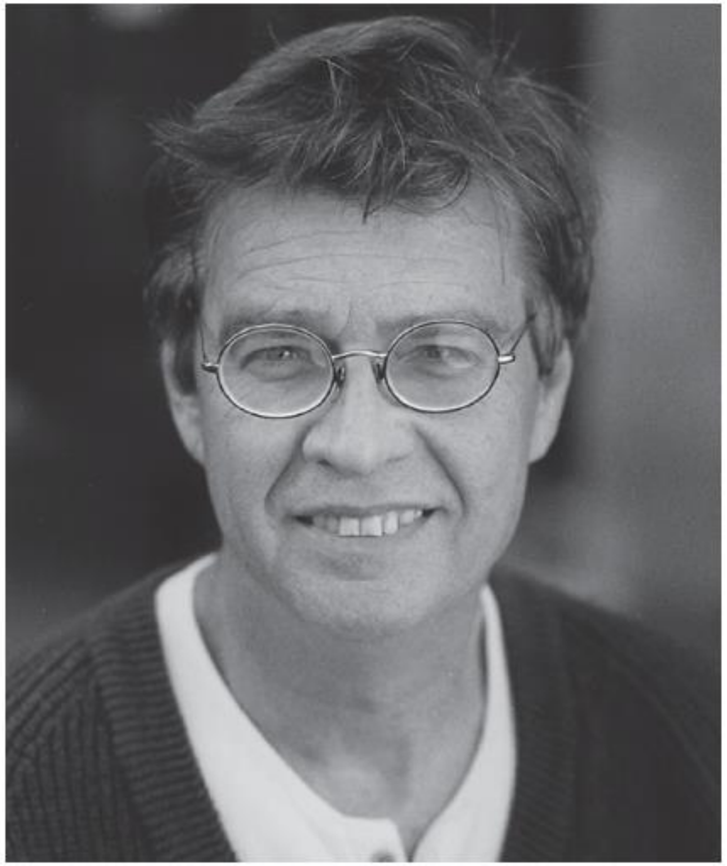
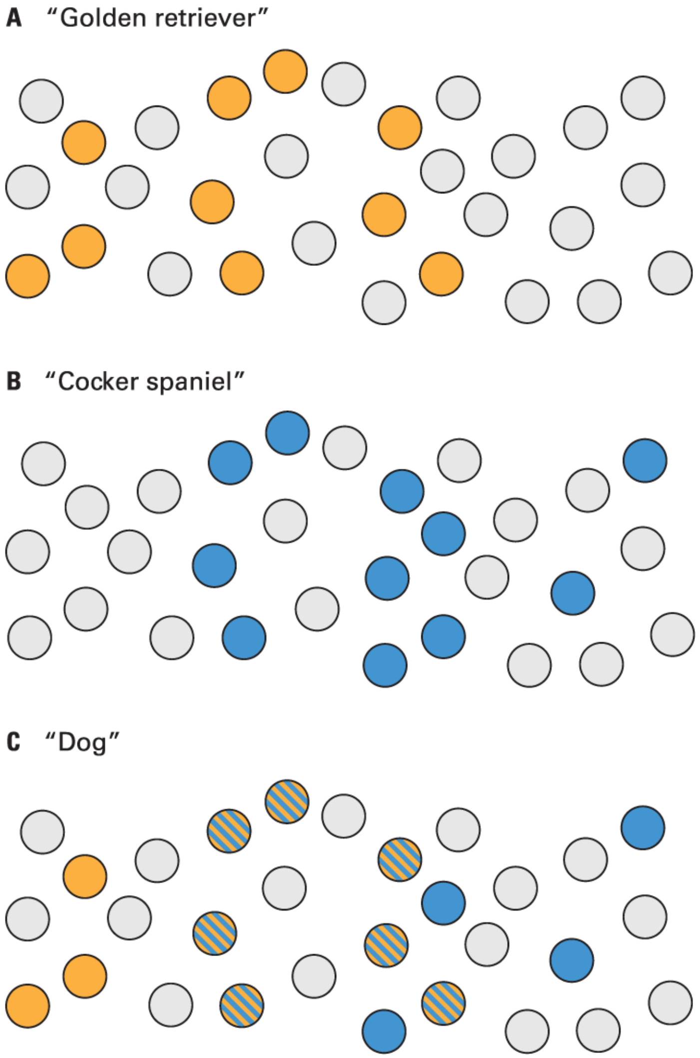
Connectionist Models - David Rumelhart



Linda A. Cicero/Stanford News Service

In **connectionist models**, ideas and concepts in the external world are not represented as distinct and discrete symbols but rather as distributed patterns of activity over populations of many nodes

(1942–2011)



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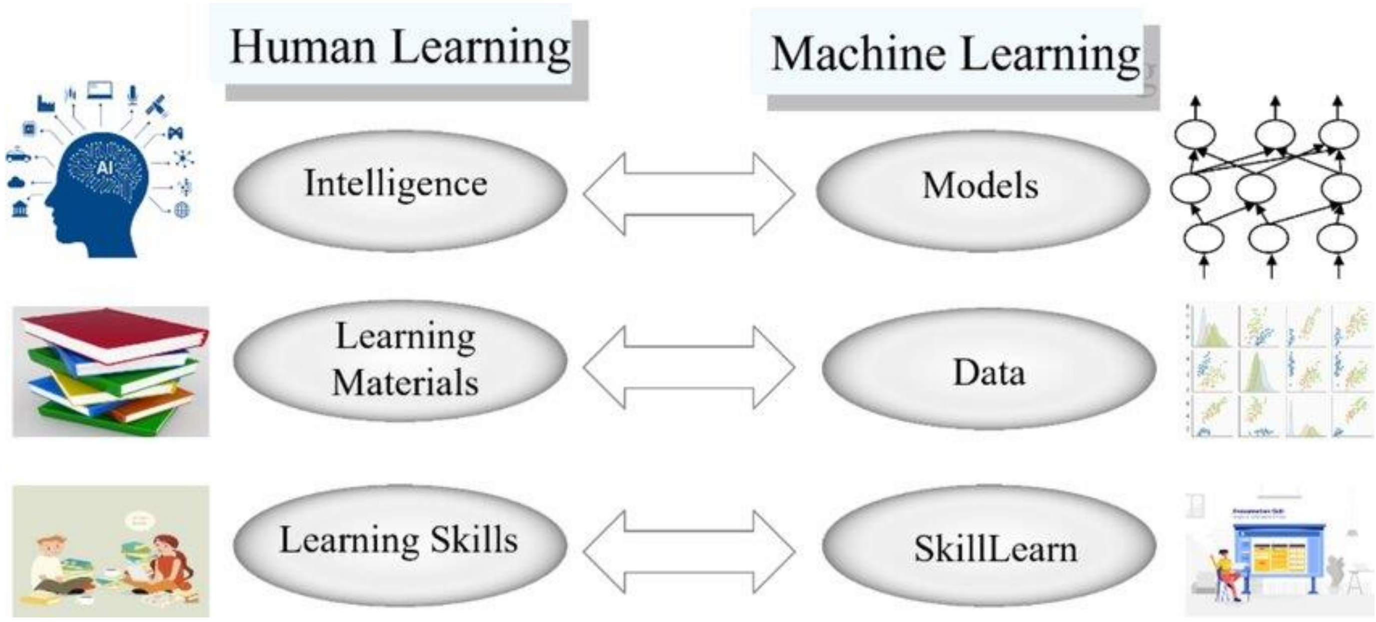
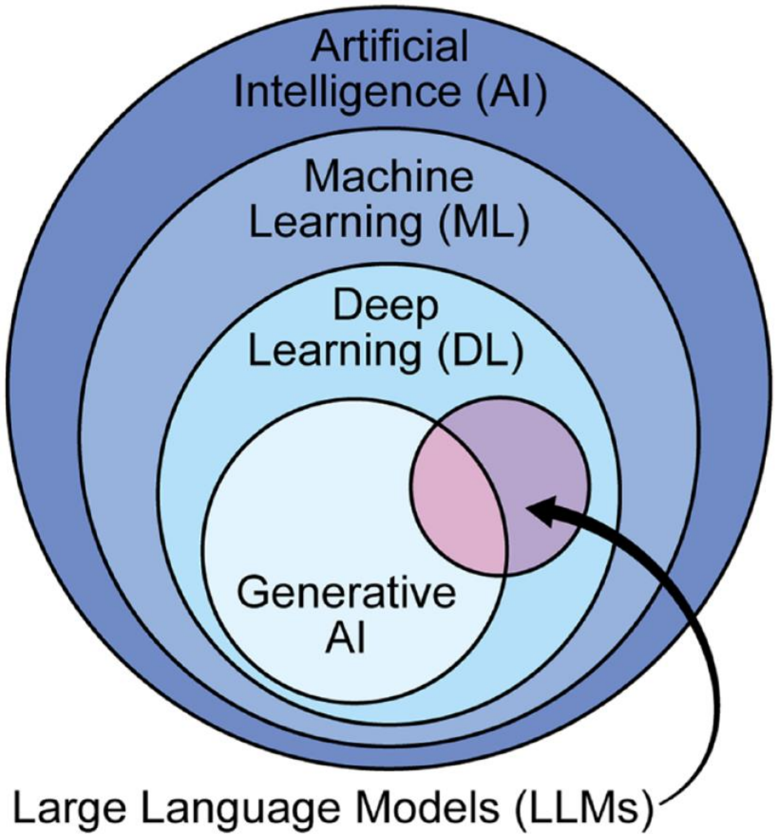
Developed models of learning and thinking that he described as "connectionist network models"

How do machines learn?
LLMs?
ChatGPT?





Journal of Cloud Computing

Which has the greater influence on our learning and memory abilities?

Nature Versus Nurture

Plato

(427–347 BC)

Nativism - that the bulk of our knowledge is inborn or innate (or native)

John Watson’s Behaviorism

(1878–1958)

Behaviorism: a school of thought that says psychology should restrict itself to the study of observable behaviors (such as lever presses, salivation, and other measurable actions) and not seek to infer unobservable mental processes

From his studies with rats, Watson came to believe that all behavior is learned and a product of our environments

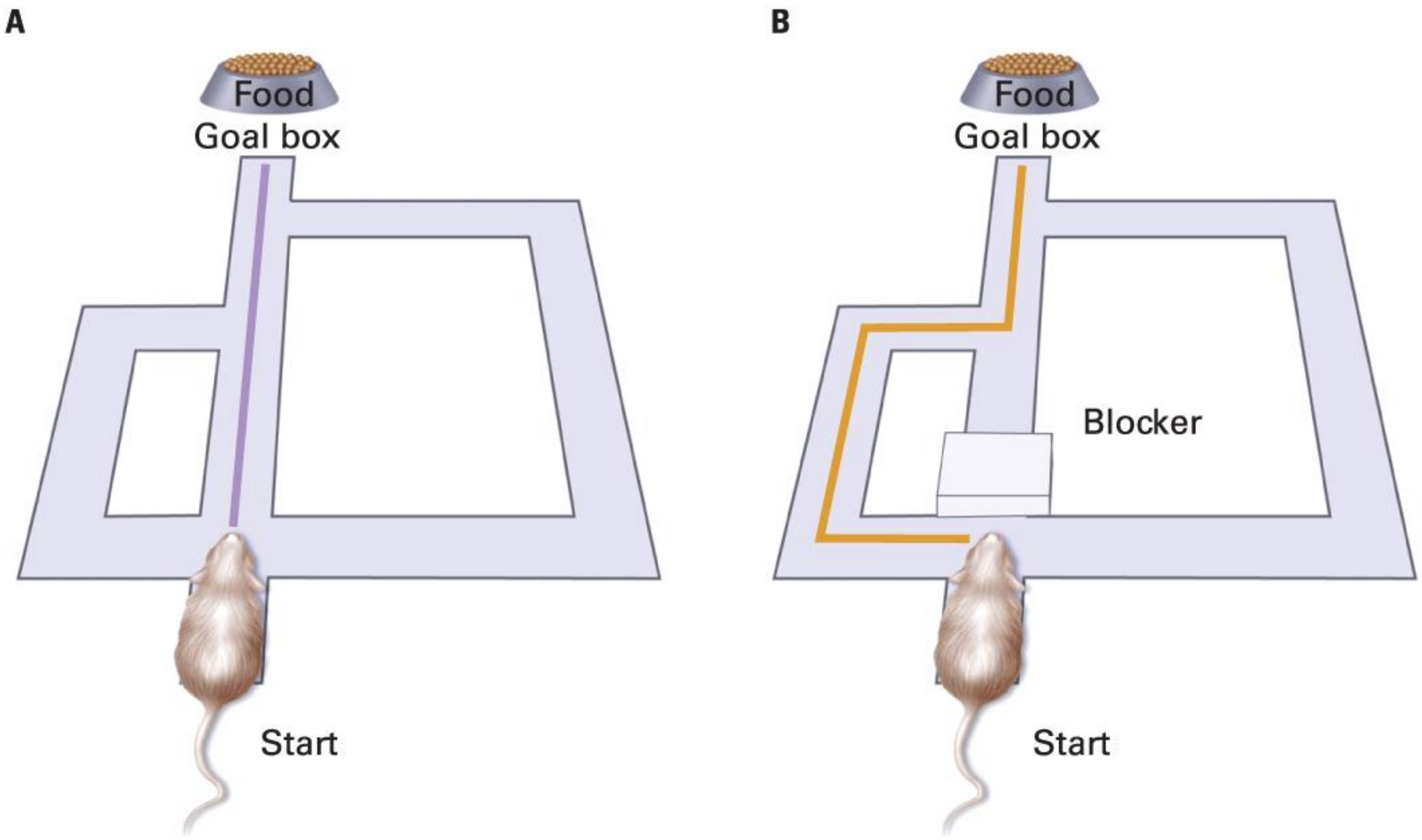
George Rinhart/Corbis Historical/Getty Images

The Neo-Behaviorism of Edward Tolman (1886–1959)

- Edward Tolman Argued that rats are like humans in that they are intrinsically motivated to learn the general layout of mazes by forming what he called a **cognitive map**, an internal psychological representation of the spatial layout of the external world
- “Behavior reeks of purpose”

The Drs. Nicholas and Dorothy Cummings Center for the History of Psychology, The University of Akron

Cognitive Maps in Rats



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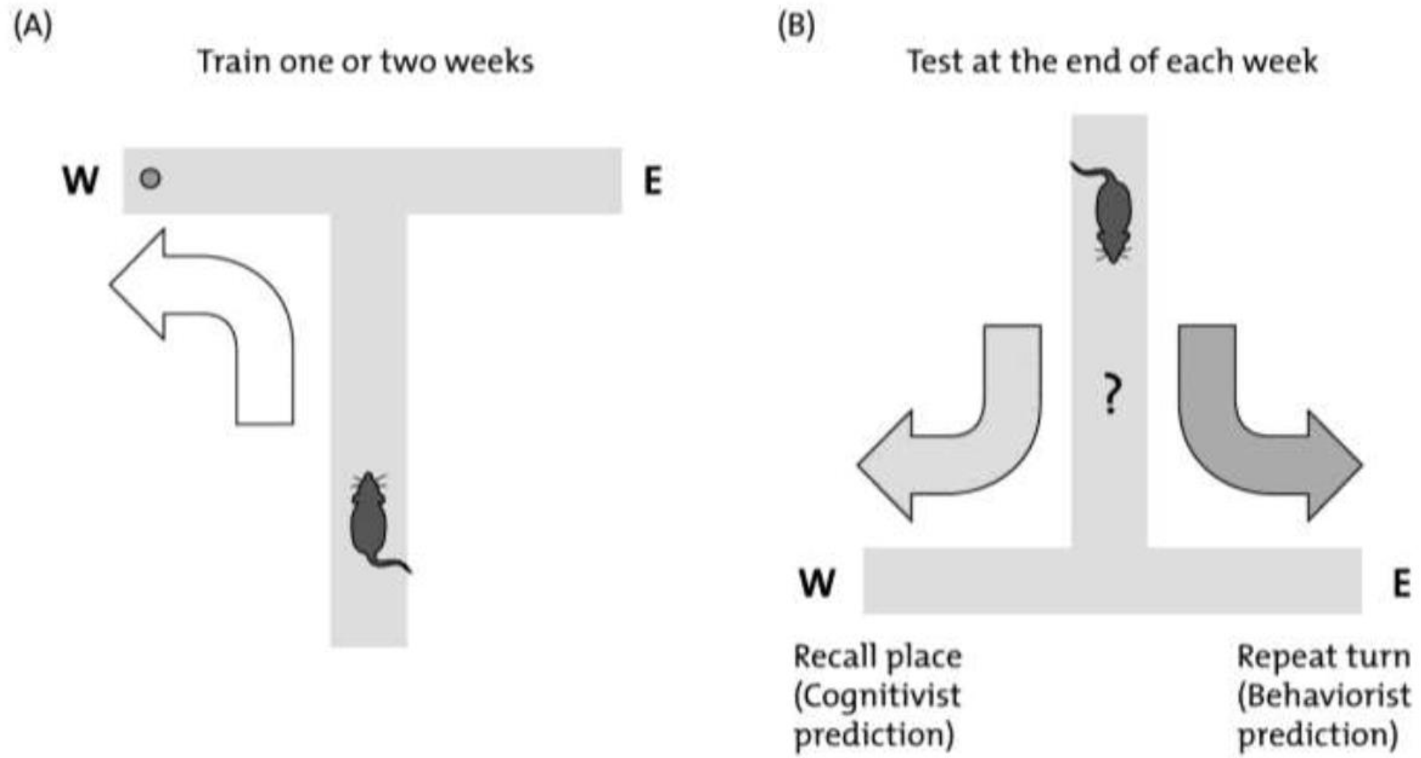
- Tolman showed the value of cognitive maps for understanding how rats can apply what they have learned in novel situations; rats, he showed, are able to find food in mazes by using alternative routes if their preferred route is blocked
- Tolman argued that during their free exploration, the rats were learning a cognitive map that they could exploit later (**latent learning**)
    - **Latent learning:** learning that is unconnected to a positive or negative consequence and that remains undetected (latent) until explicitly demonstrated at a later stage


(A)
Train one or two weeks
W
E
(B)
Test at the end of each week
?
W
E
Recall place
(Cognitivist
prediction)
Repeat turn
(Behaviorist
prediction)

Can the psychological study of the mind be rigorously scientific?

Can we uncover universal principles of learning and memory that can be described by mathematical equations and fundamental laws?

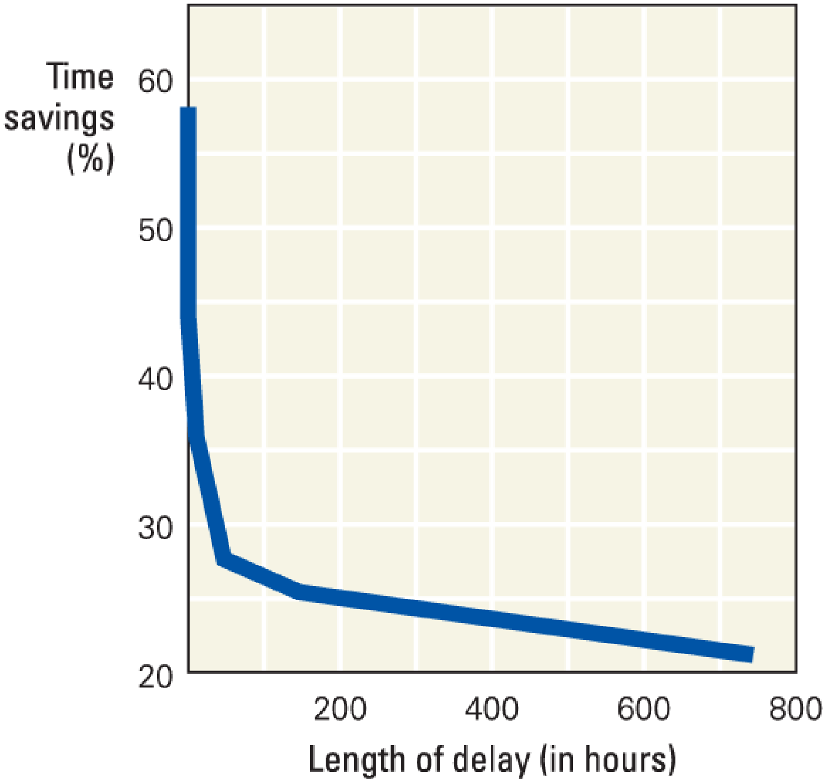
–Ebbinghaus, Watson, Hull, Skinner, Estes, and nearly everyone who followed.

Hermann Ebbinghaus and Human Memory Experiments

(1850–1909)

Bettmann/Getty Images

- conducted the first rigorous experimental studies of human memory
- Proposed that the psychology of memory could also become a rigorous natural science, defined by precise mathematical laws
- So he measured memory over time



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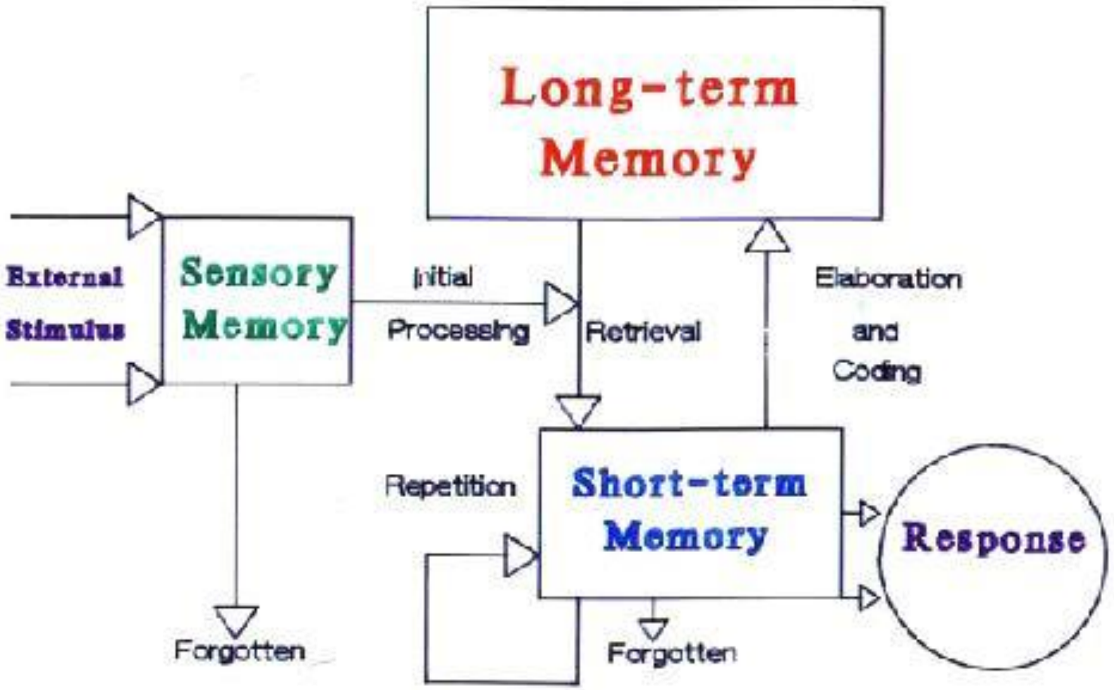
Plot of a **retention curve**, which measures how much information is retained at each point in time following learning

George Miller -- Information Processing Theory

- George Miller (1920–2012) adapted formal models of information theory to psychology to help us understand memory capacity



Miller's specific goal was to understand the information holding capacity – Short Term Memory (chunking) and other memory processes

https://web-archive.southampton.ac.uk/cogprints.org/730/1/miller.html

Many of the scientists who made important contributions did so by liberally borrowing from the methods and concepts of the physical and natural sciences.

Who…	Borrowed from…	To explain or do what?
1. René Descartes	Hydraulic engineering	How the body could function like a machine with input and output control pathways
2. John Locke	Physics (Newton), chemistry (Boyle)	How complex ideas could be formed from combinations of simpler and more elementary components
3. Hermann Ebbinghaus	Laws of perception (Fechner)	How psychology of memory could be a rigorous natural science, defined by precise mathematical laws
4. Ivan Pavlov	Telephone exchanges	The distinction between a direct fixed connection and a modifiable indirect connection, as when a switchboard operator makes the call
5. Edward Thorndike	Evolution by natural selection (Darwin)	That of all possible behavioral responses, the ones that are more successful and adaptive are more likely to be retained (i.e., learned)
6. Clark Hull	Theory of relativity (Einstein)	The search for simple, powerful equations that unify many disparate observations
7. George Miller	Information theory (Shannon)	How to measure the amount of information in a message or stored memory, independent of the content

- Several studies have shown what seems to be a genetic influence on some kinds of memory ability: parents with high memory ability are likely to have children who also have high memory ability. How would an empiricist account for such findings?

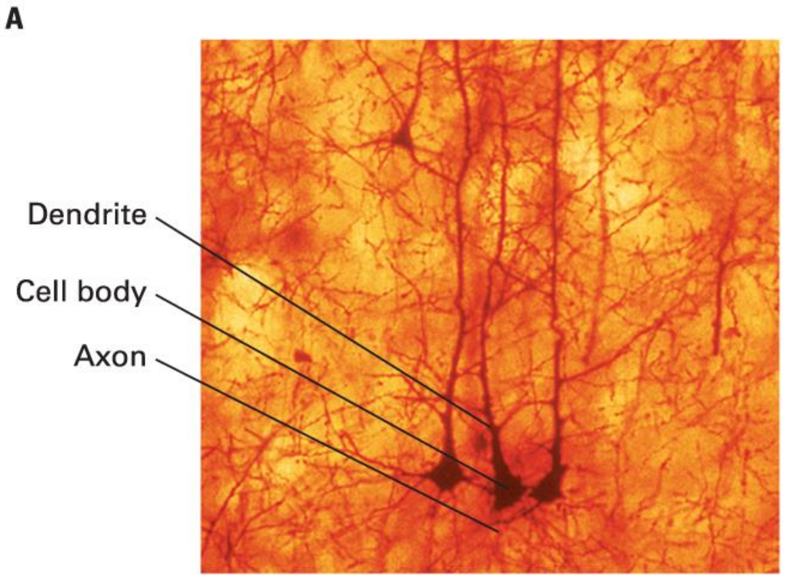
What we learn and remember, does it stay with us forever?

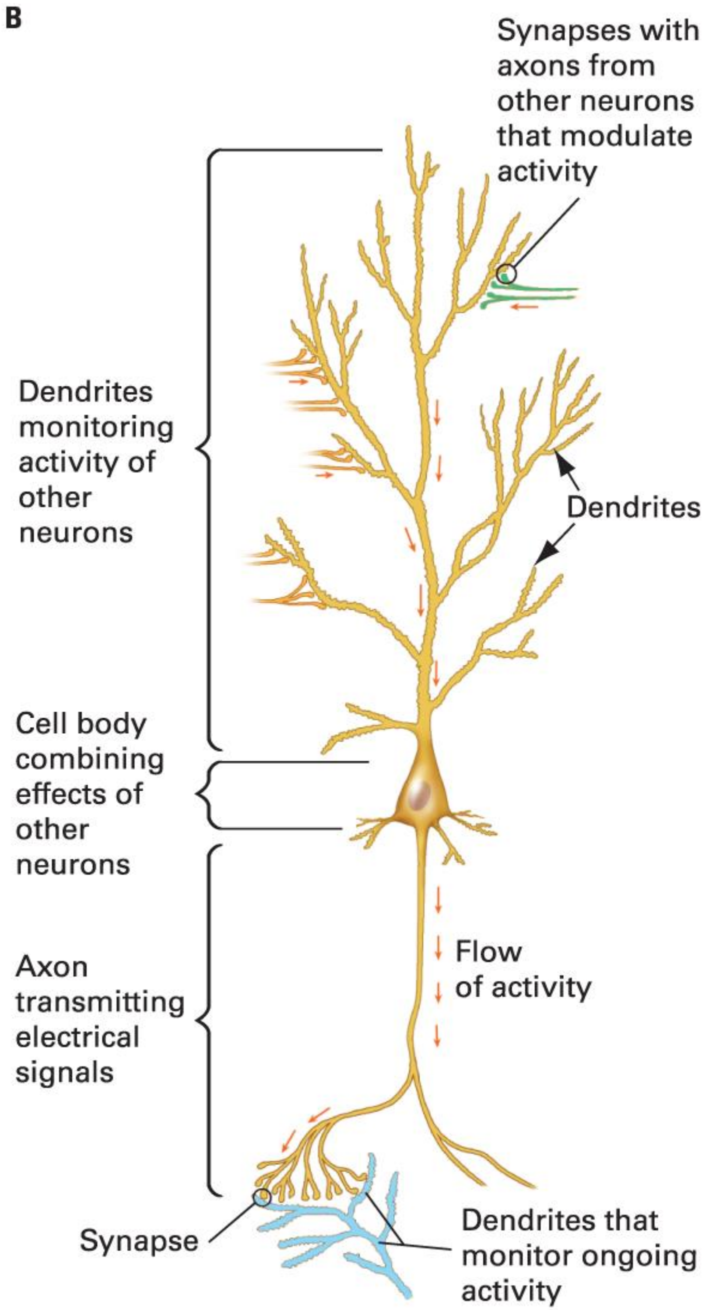
Can you remember things from a long time ago exactly as they were?

Anatomy of
Learning and Memory

Where is memory stored in the brain?

Neuron





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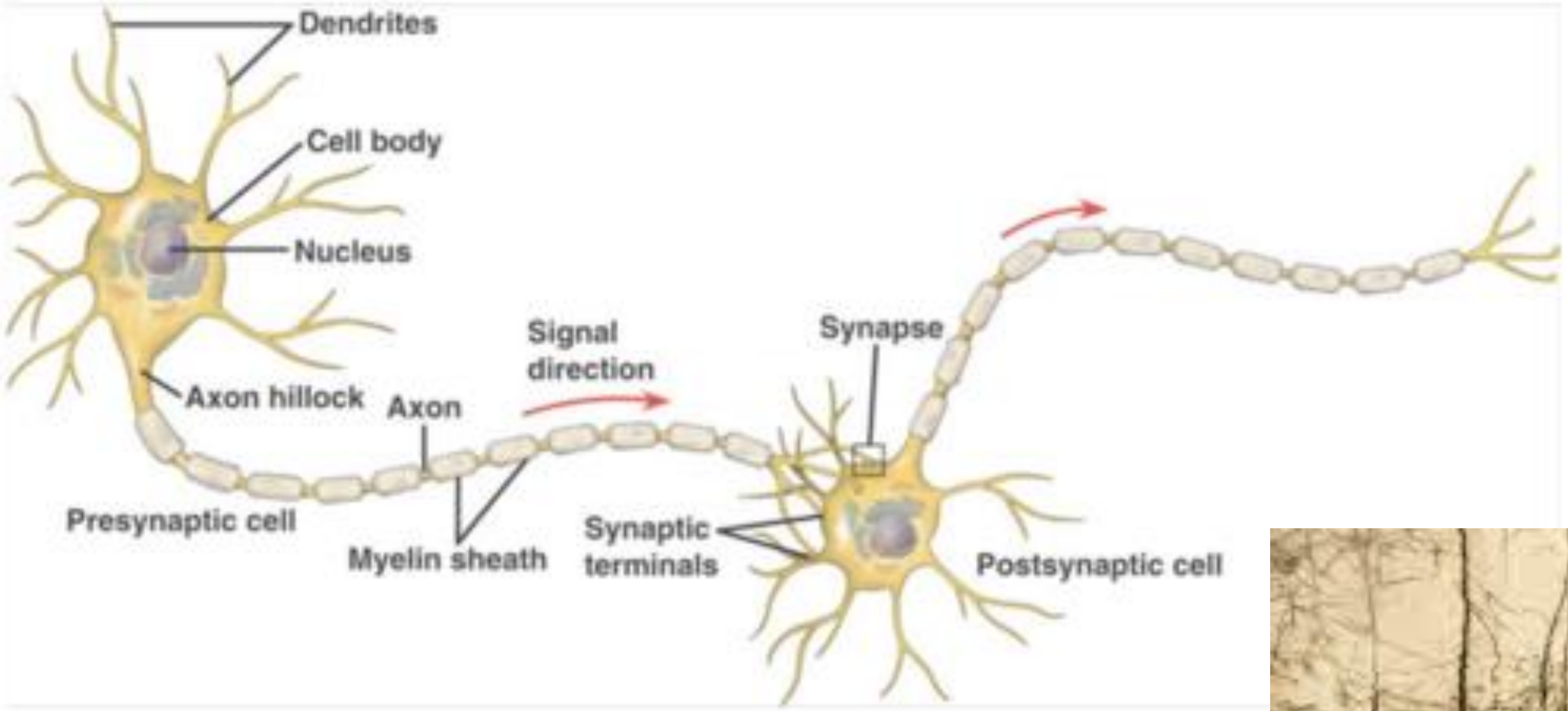
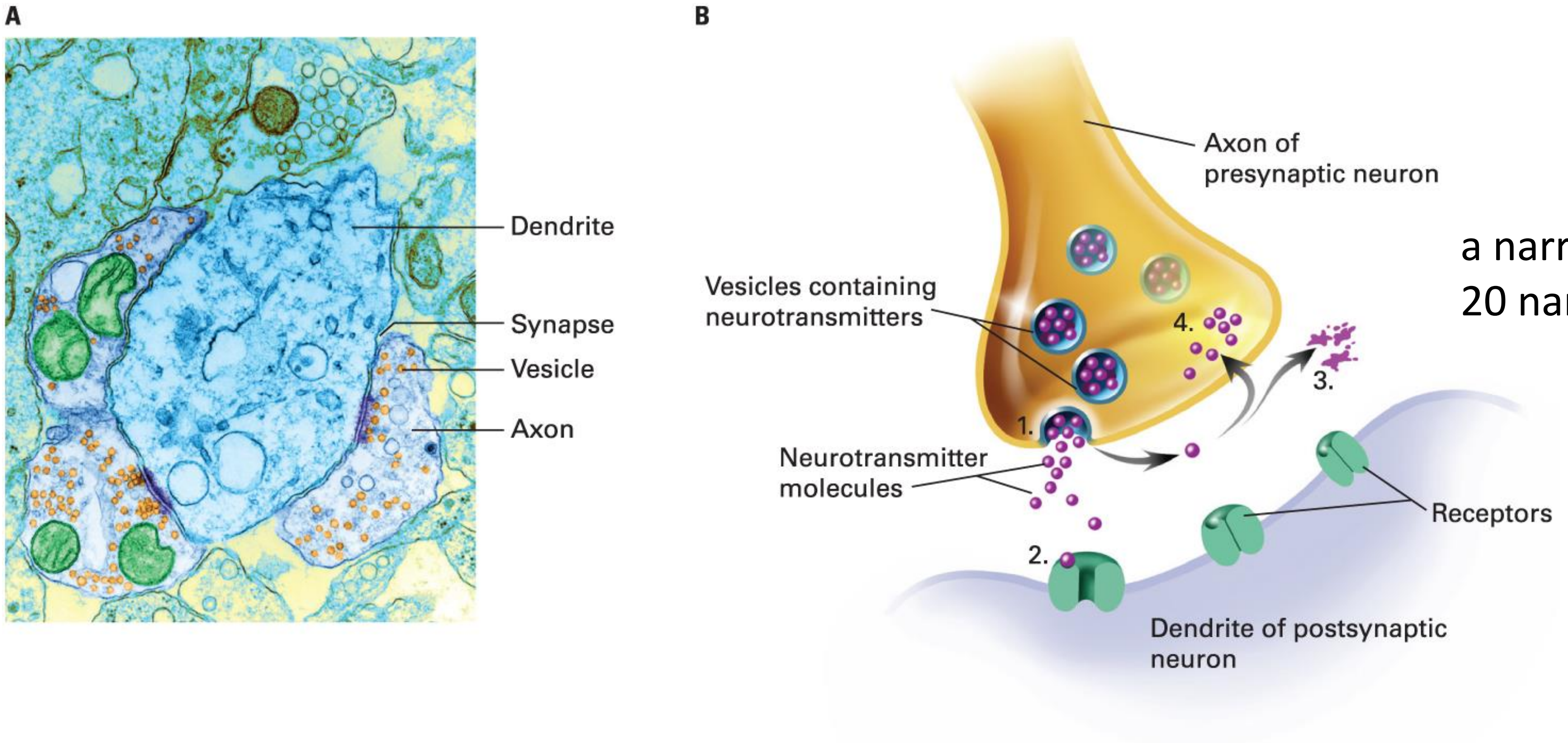
A: Biophoto Associates/Science Source


Dendrites
Cell body
Nucleus
Axon hillock
Axon
Signal direction
Synapse
Presynaptic cell
Myelin sheath
Synaptic terminals
Postsynaptic cell

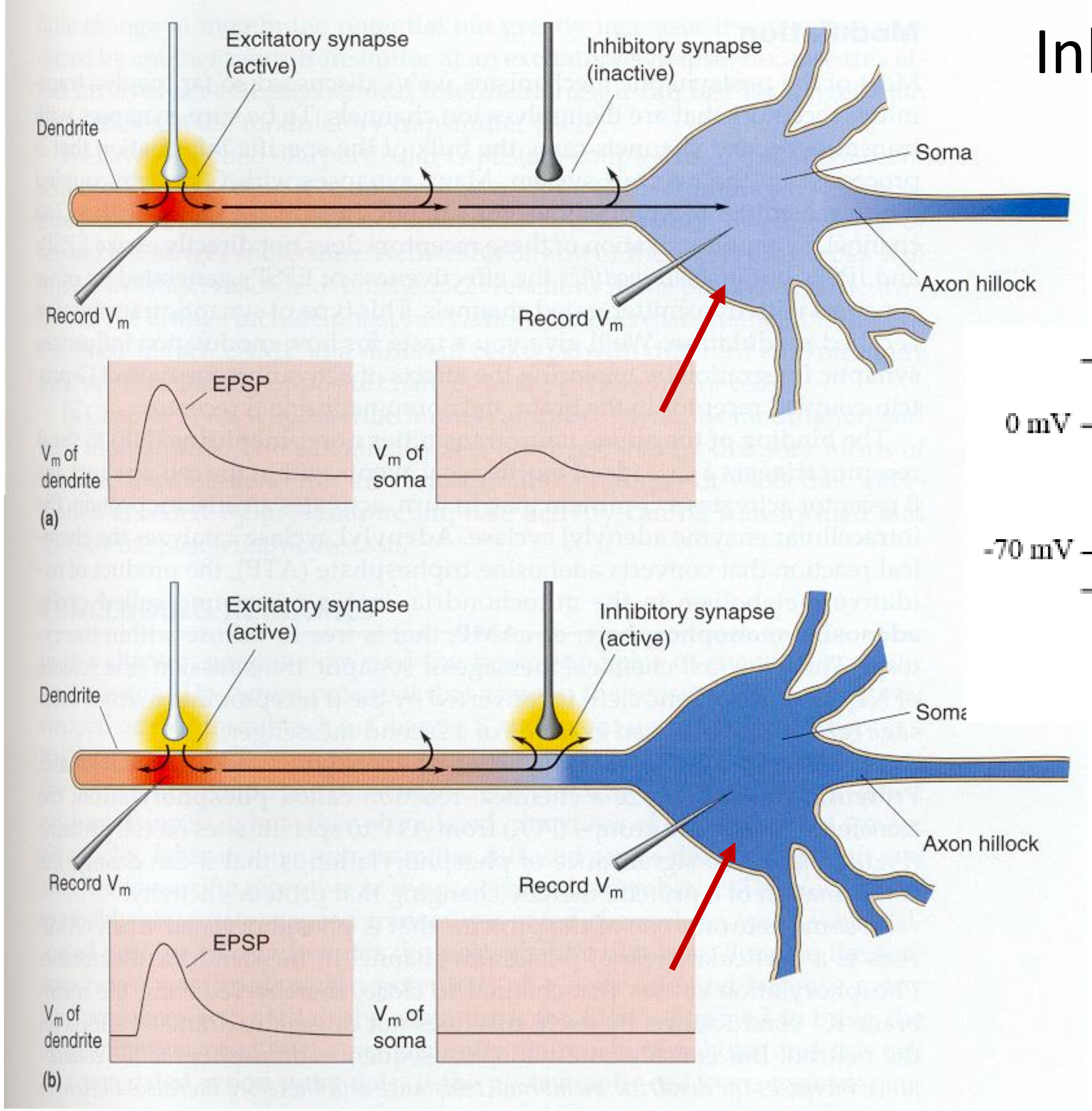
Synapse

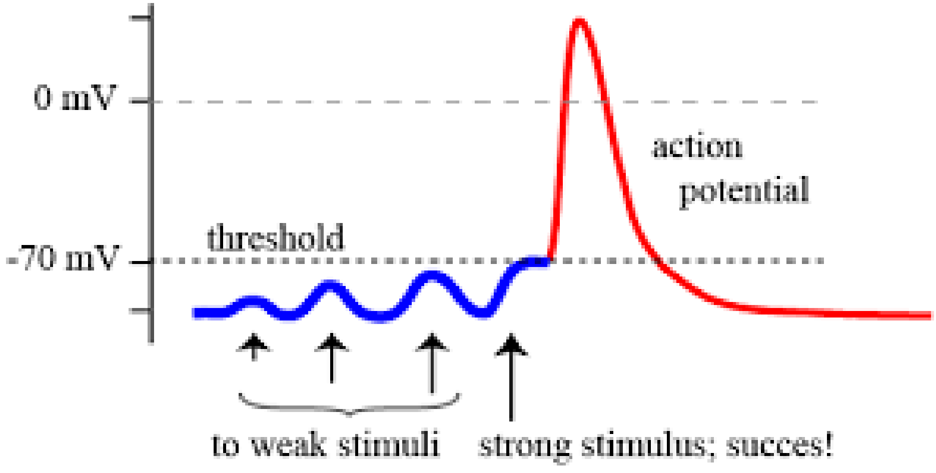


a narrow gap of about
20 nanometers

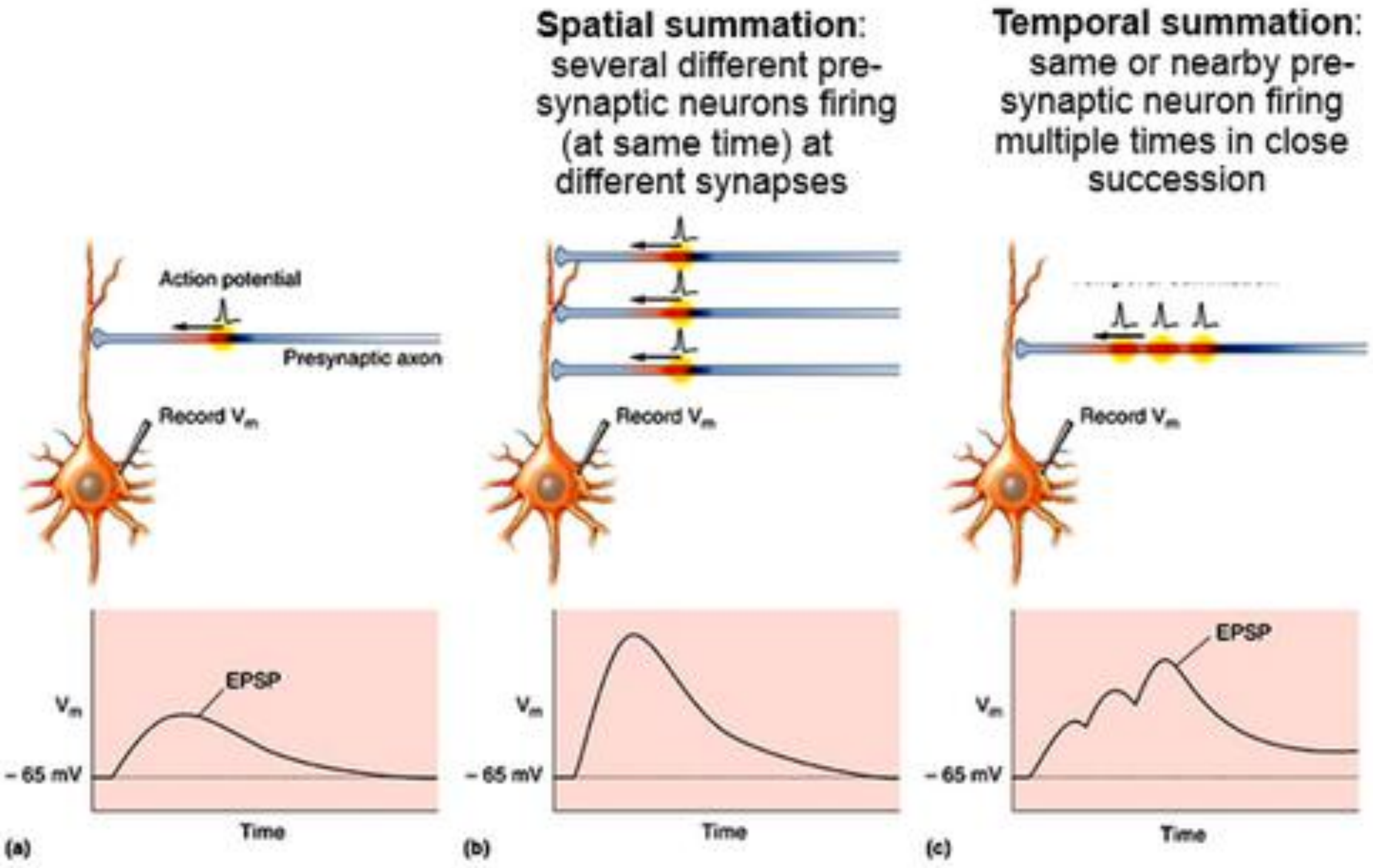
How does a neuron know when to fire?

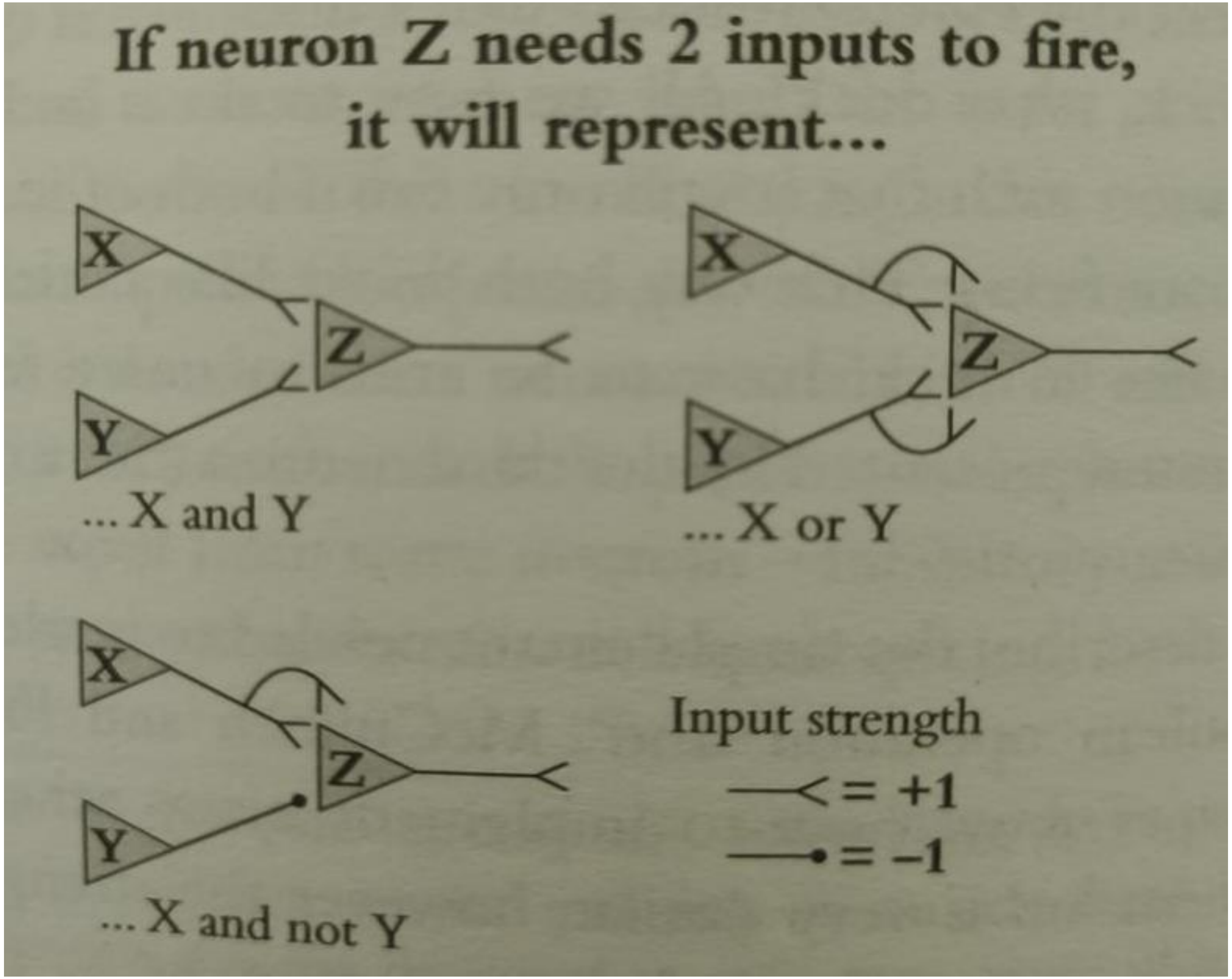
Inhibition and Excitation





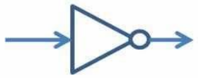
Temporal Vs Spatial Summation of PSP





NOT

x	F
0	1
1	0



AND

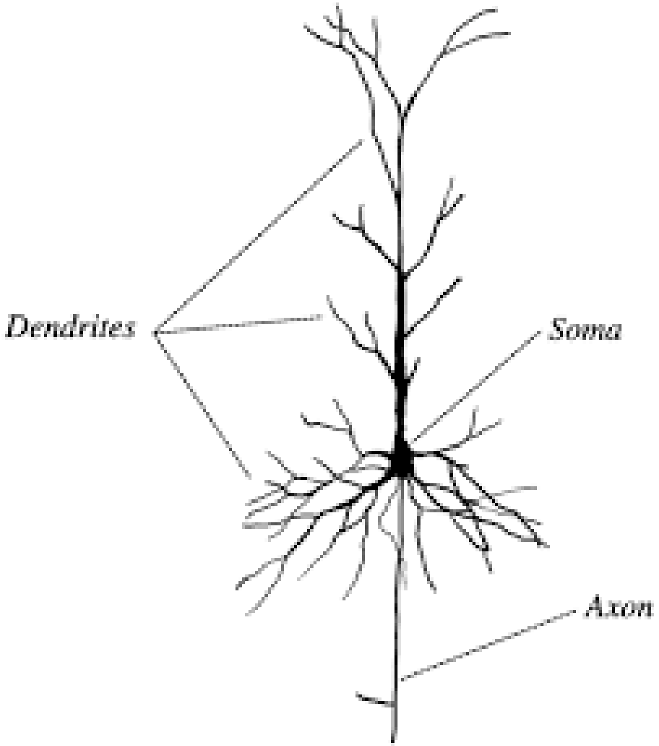
x	y	F
0	0	0
0	1	0
1	0	0
1	1	1

OR

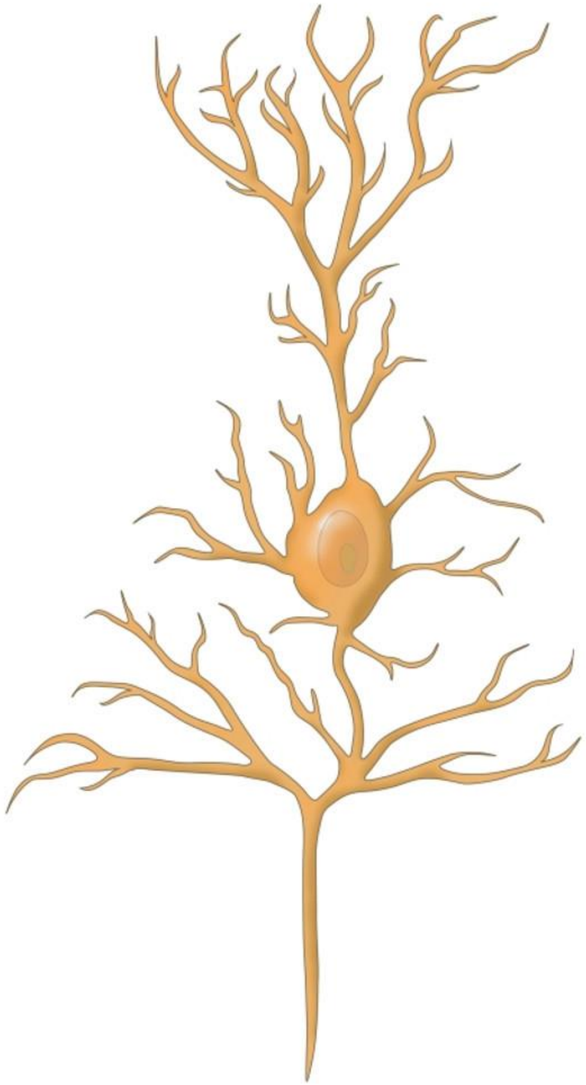
x	y	F
0	0	0
0	1	1
1	0	1
1	1	1

Neurons function similar to Boolean Operators

Neurons are not so simple –
thousands of inputs



NEURON TYPE



Pyramidal

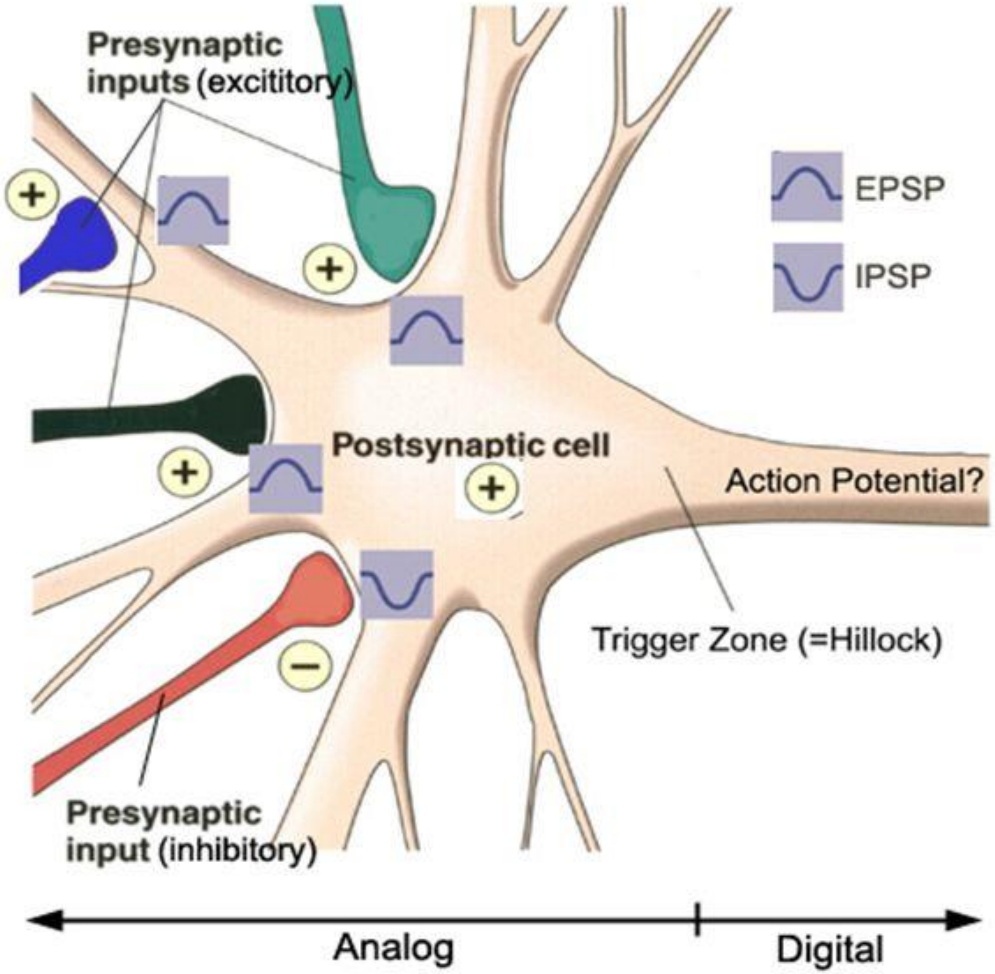
How does a neuron incorporate Boolean logic?

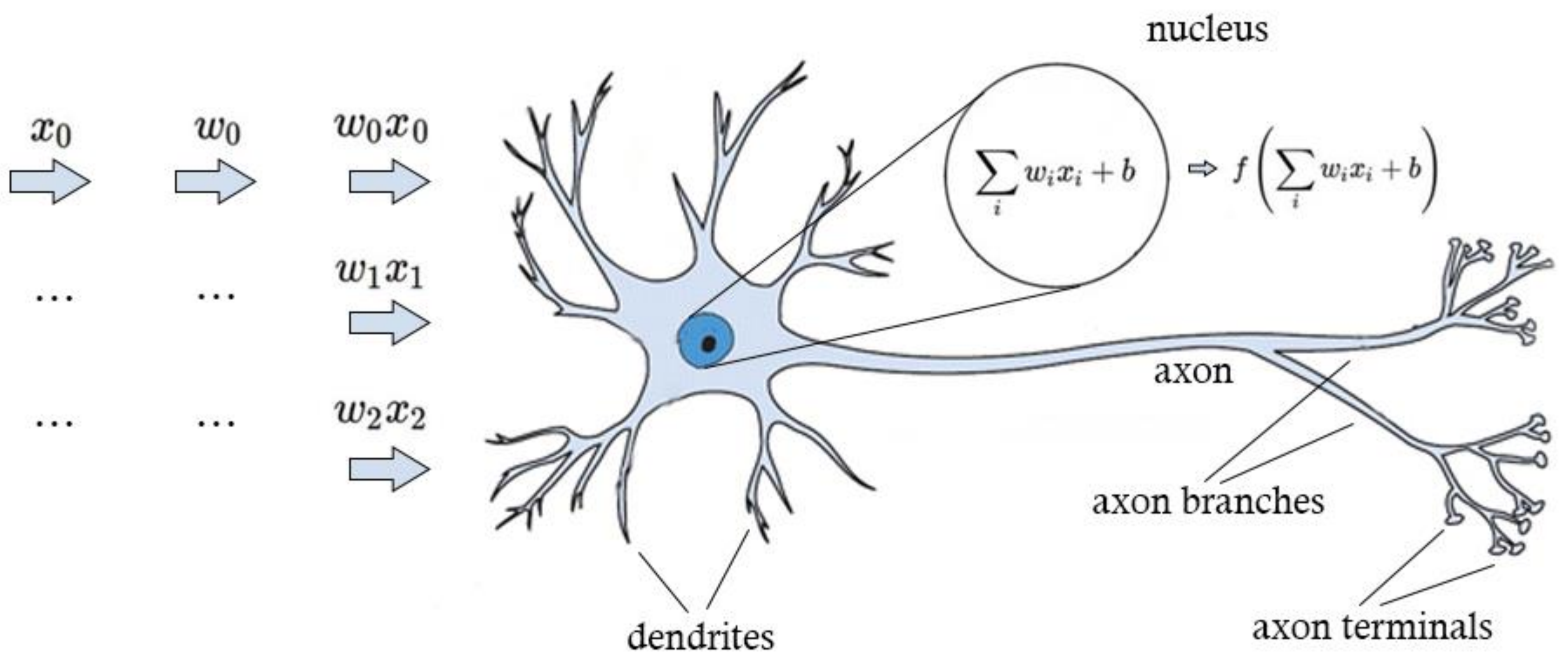
Spatial summation of PSP Post synaptic potential

Synaptic integration

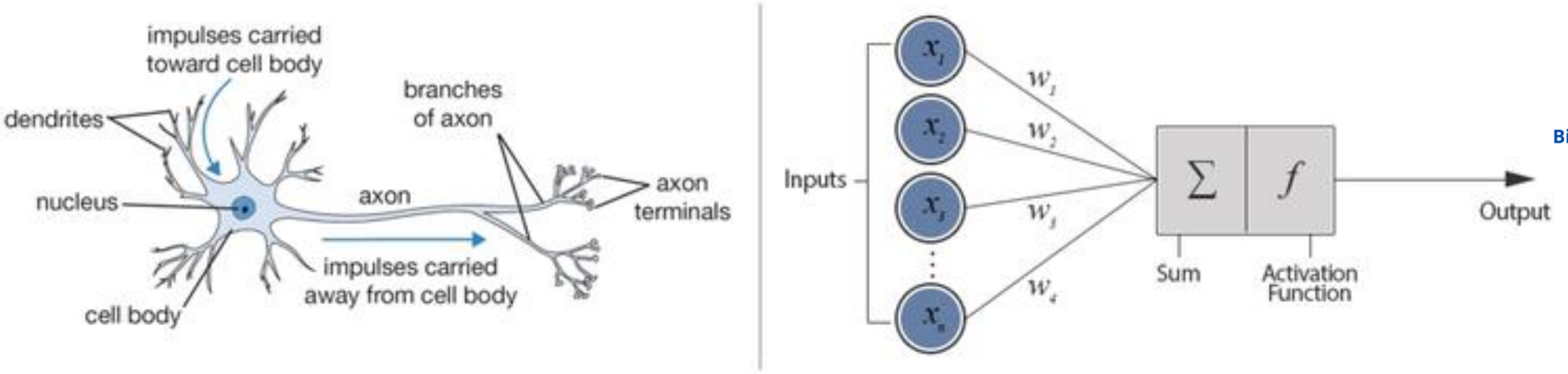
- The combining of excitatory and inhibitory signals acting on adjacent membrane regions of a neuron.

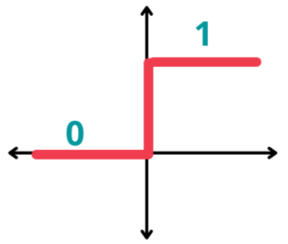
In order for an action potential to occur, the sum of excitatory and inhibitory postsynaptic potentials (local responses) must be greater than a threshold value.





Biological Neuron versus Artificial Neural Network

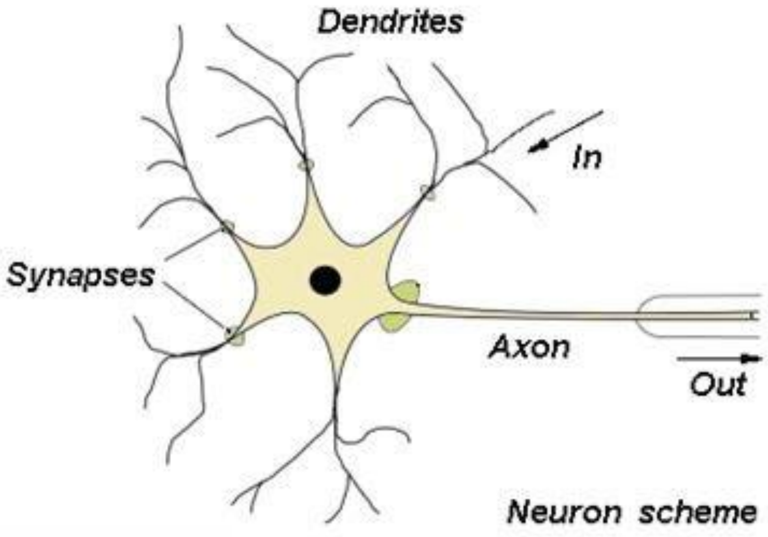


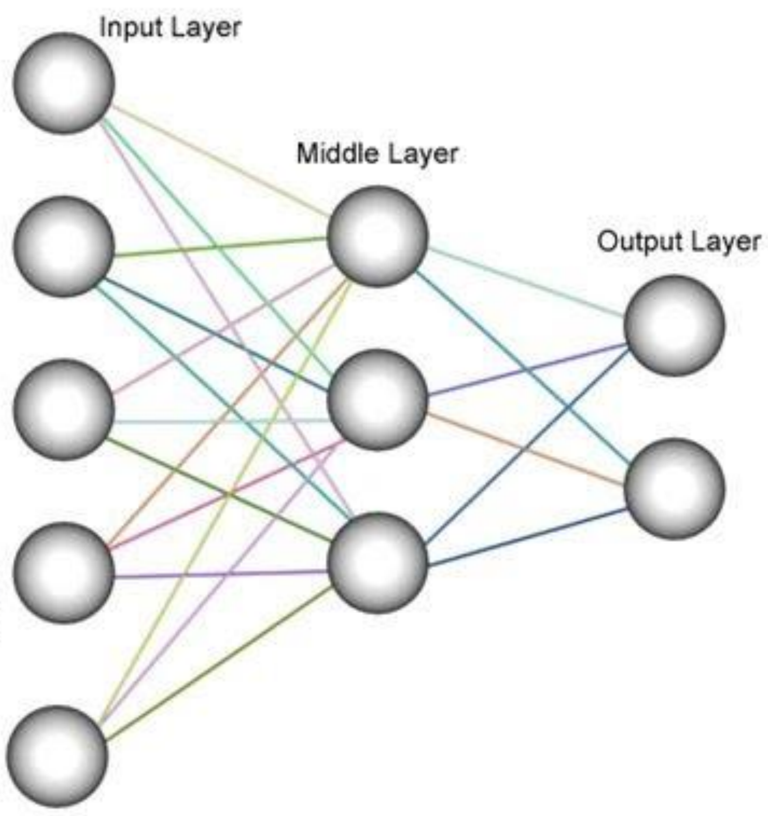


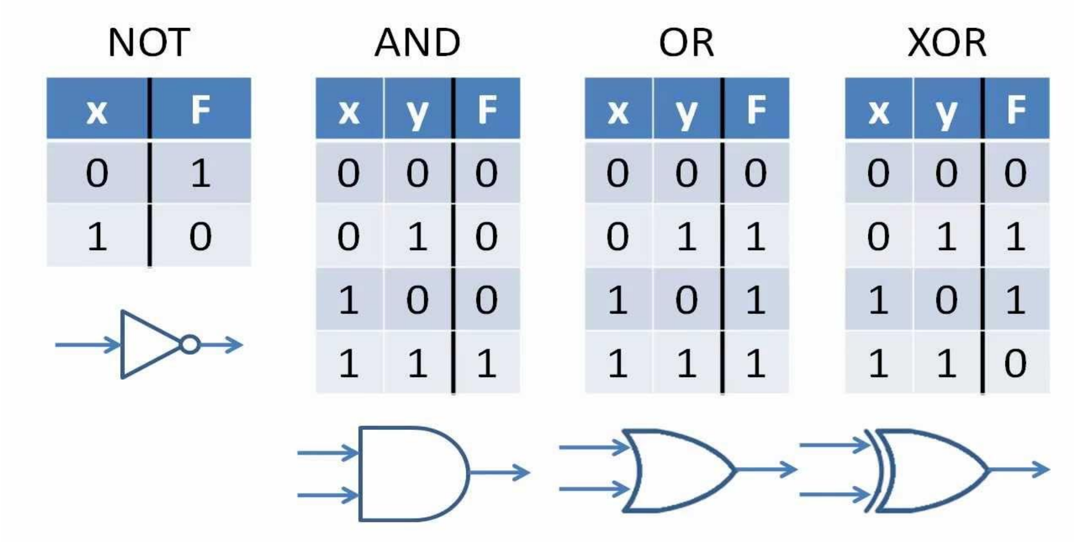
Binary Step Activation Function

When both inputs to a firing neuron are inhibitory, how does a neural network model incorporate that?

Inhibitory input does not mean absence of a signal – by inhibition the output has to be lowered by a certain magnitude







NOT

x	F
0	1
1	0

AND

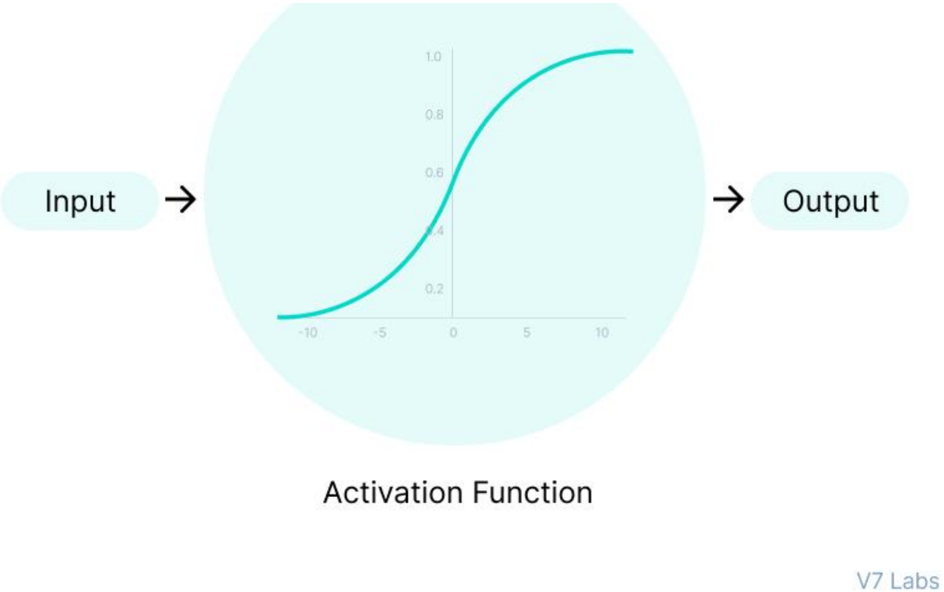
x	y	F
0	0	0
0	1	0
1	0	0
1	1	1

OR

x	y	F
0	0	0
0	1	1
1	0	1
1	1	1

XOR

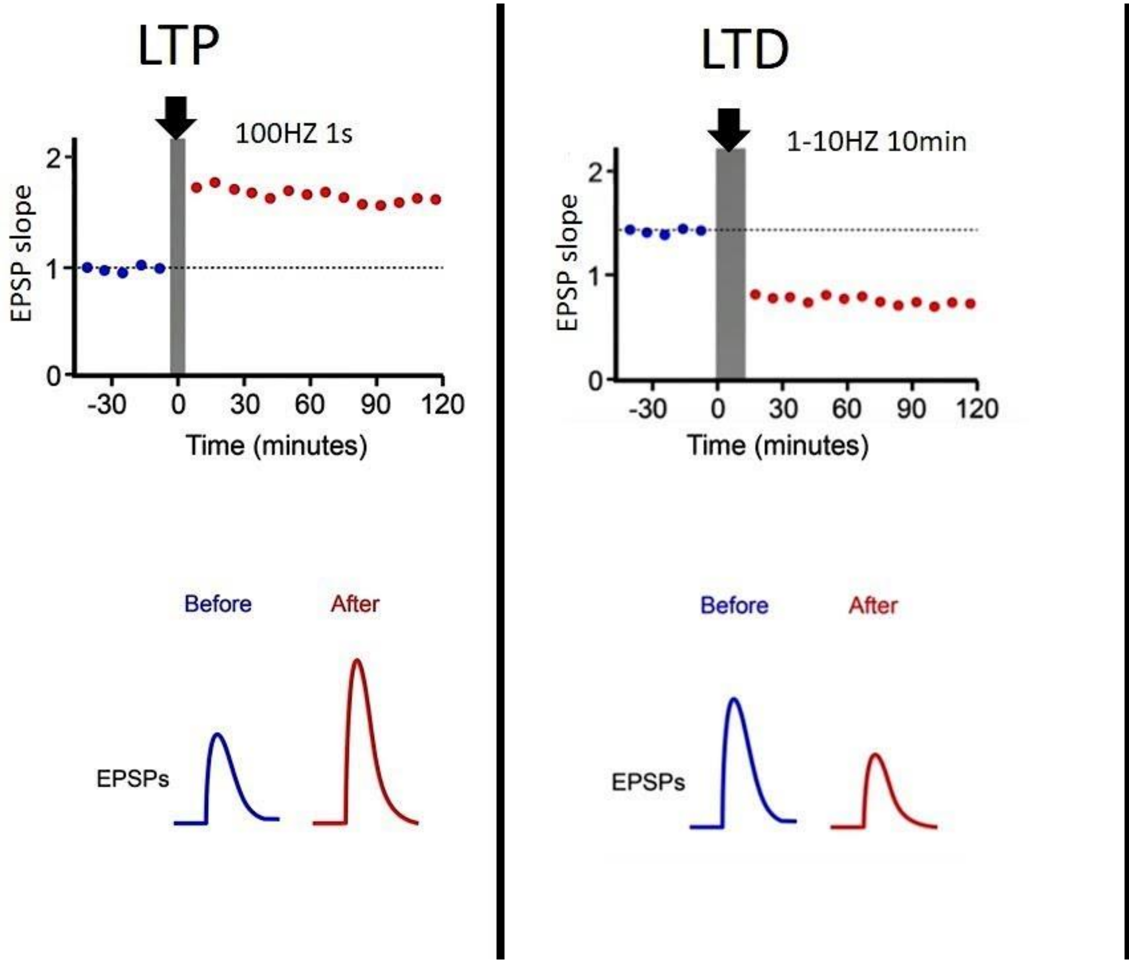
x	y	F
0	0	0
0	1	1
1	0	1
1	1	0



So how does a neuron store an experience?

Synaptic Plasticity

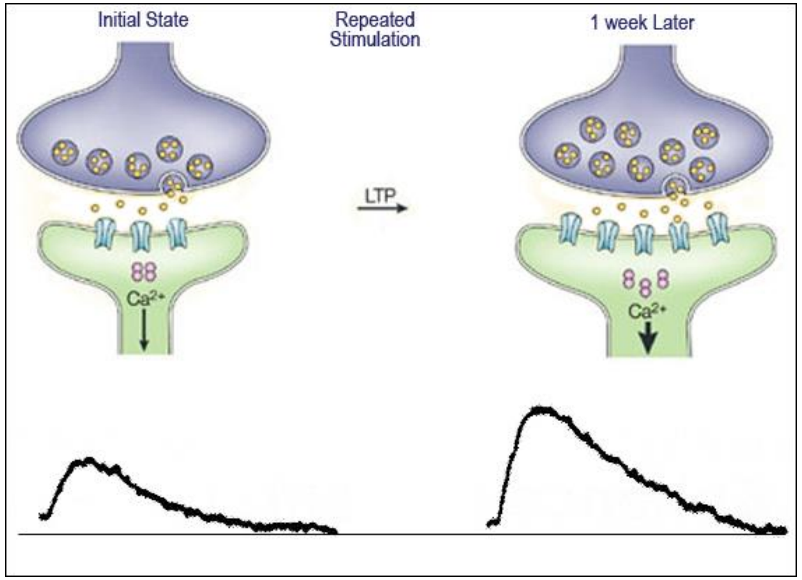
- **Long-term potentiation (LTP):** a process in which synaptic transmission becomes more effective as a result of recent activity
- **Long-term depression (LTD):** a process in which synaptic transmission becomes less effective as a result of recent activity

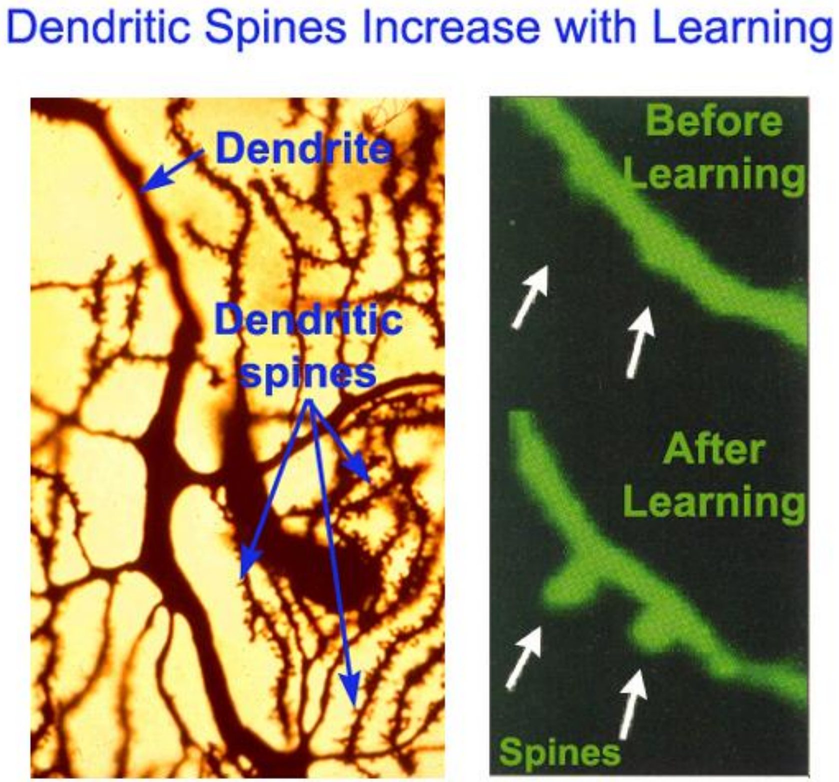


https://www.youtube.com/watch?v=4Hm08ksPtMo&ab_channel=AlilaMedicalMedia

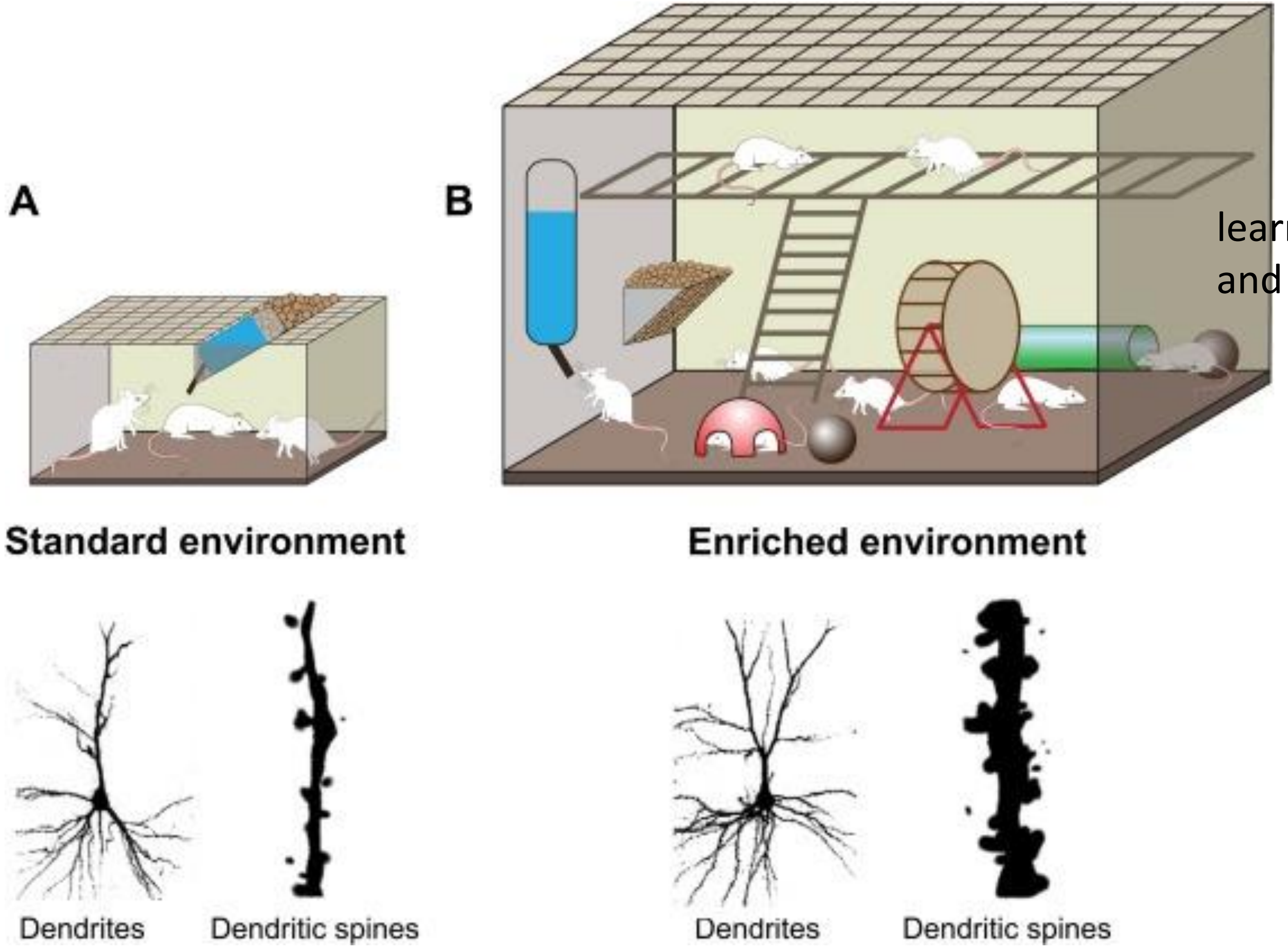
When synapses get strengthened, what changes occur in a neuron that increase magnitude of LTP?

More receptors on the postsynaptic membrane





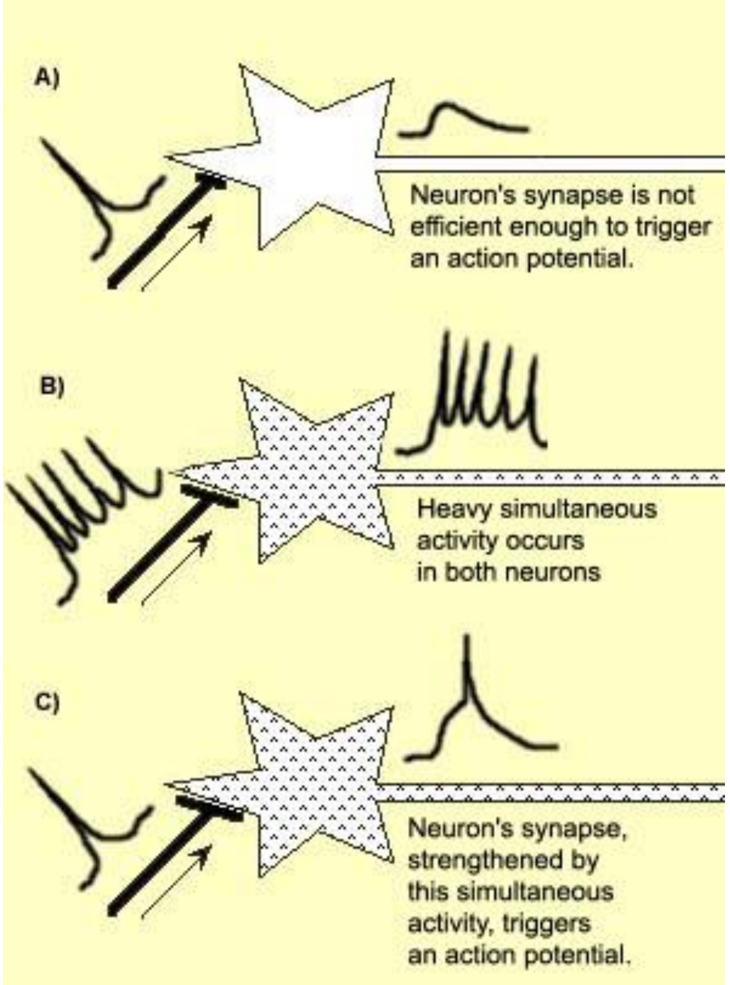
More dendrites



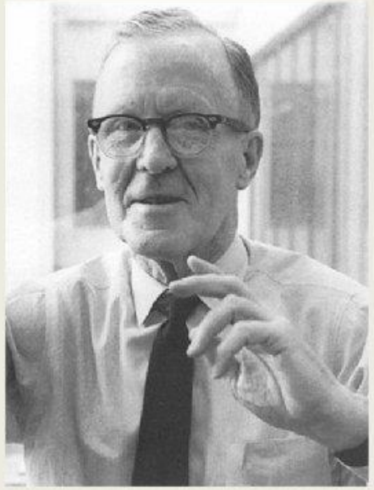
learning, social interactions, and exercise

Under what conditions does synaptic plasticity occur?

Hebbian Learning

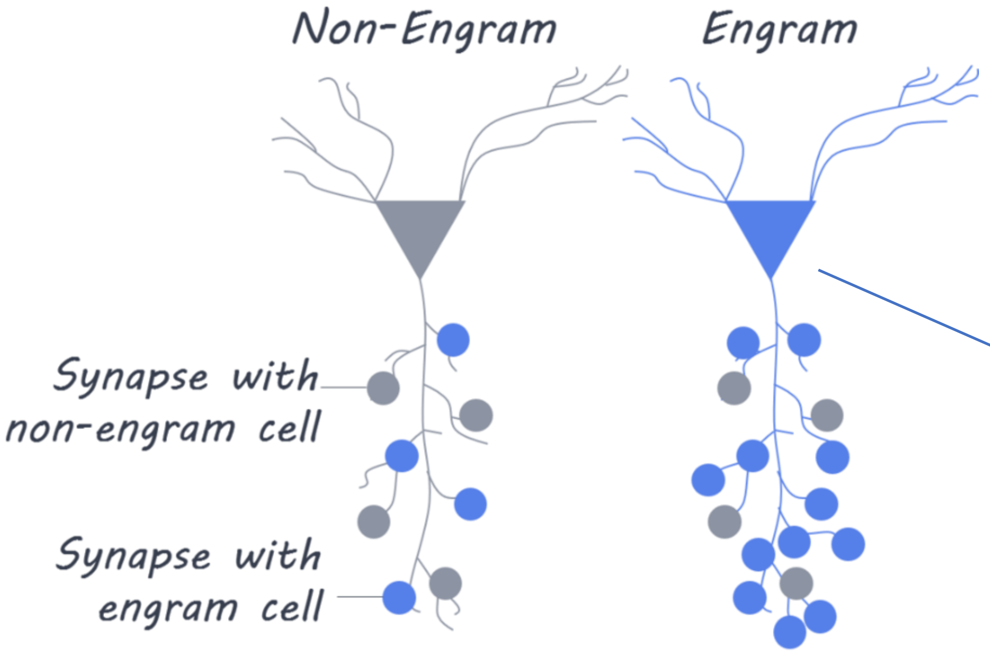


Donald Hebb

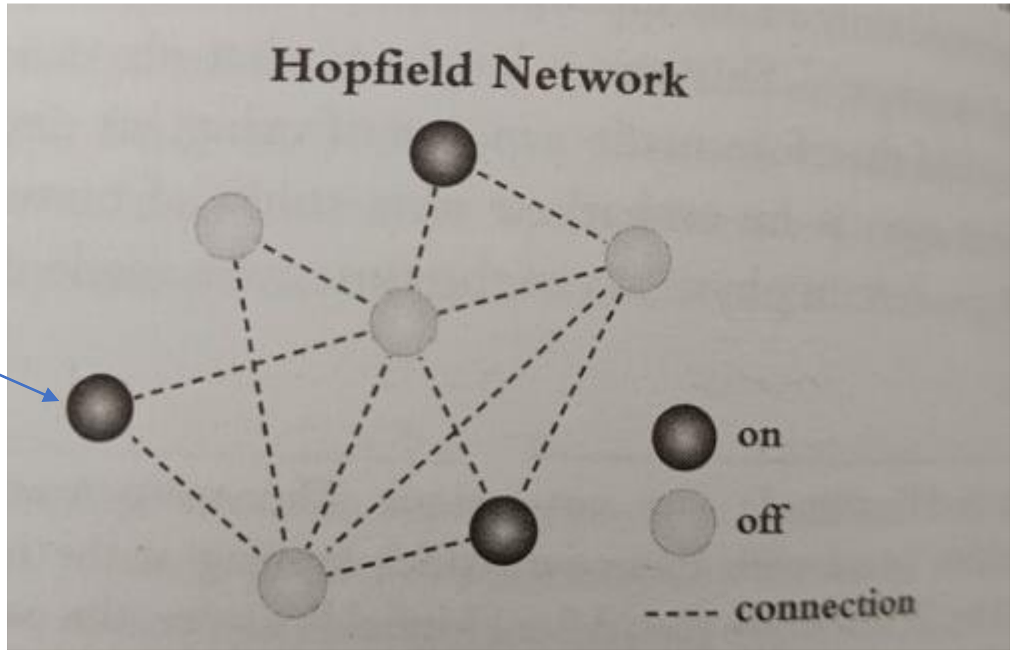


Neurons that fire together, wire together.

Engram?



Mathematical model of a memory network – John Hopfield (physicist)

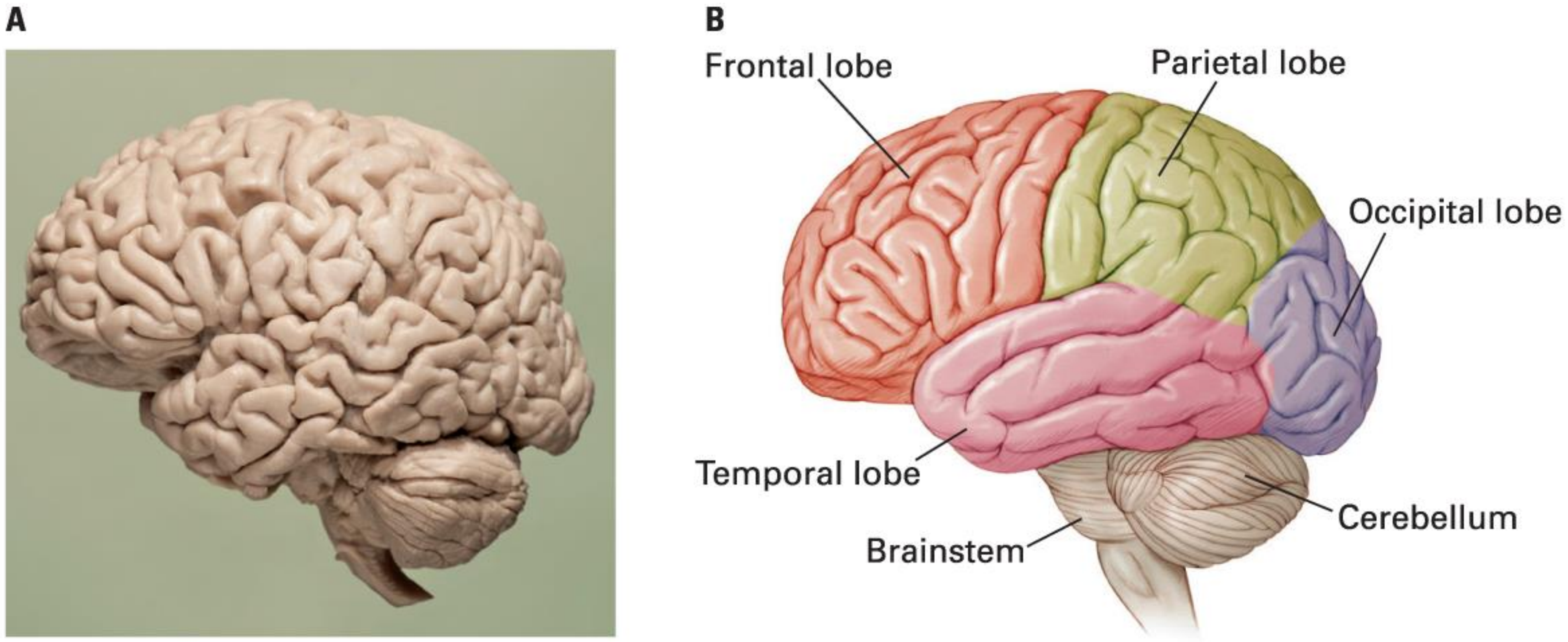


- Can learning related changes in a neuron be reversed?

Neurons are important units of information processing

Which is the most important region for helping the brain to form new memories?

The Human Brain



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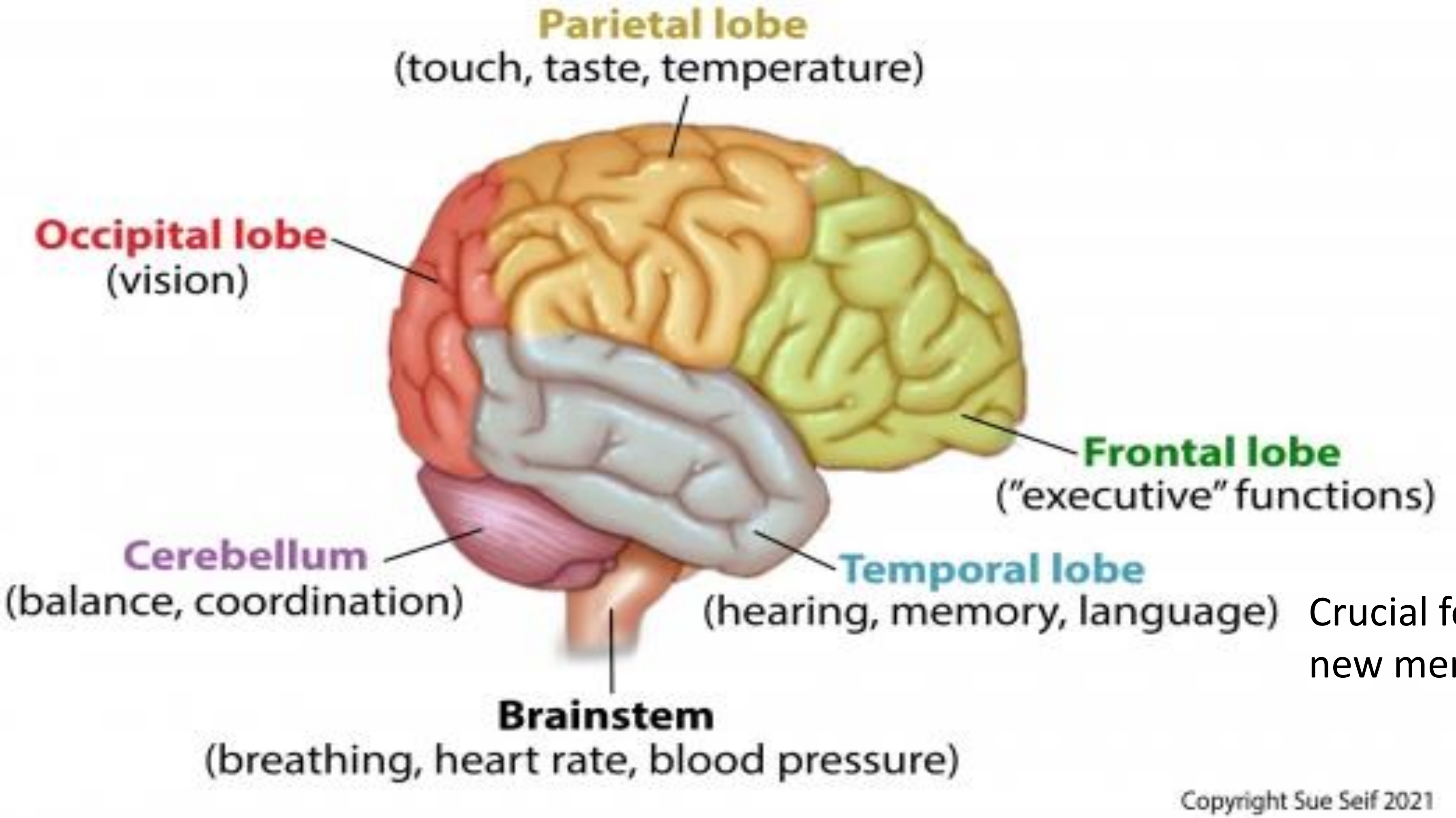
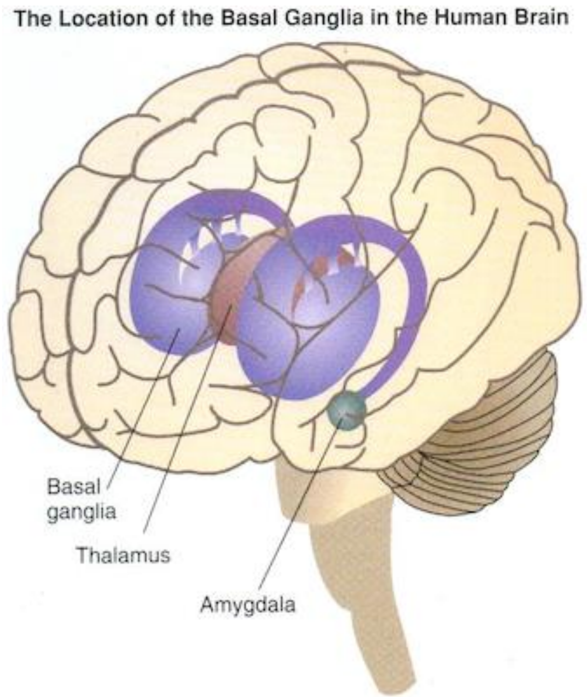
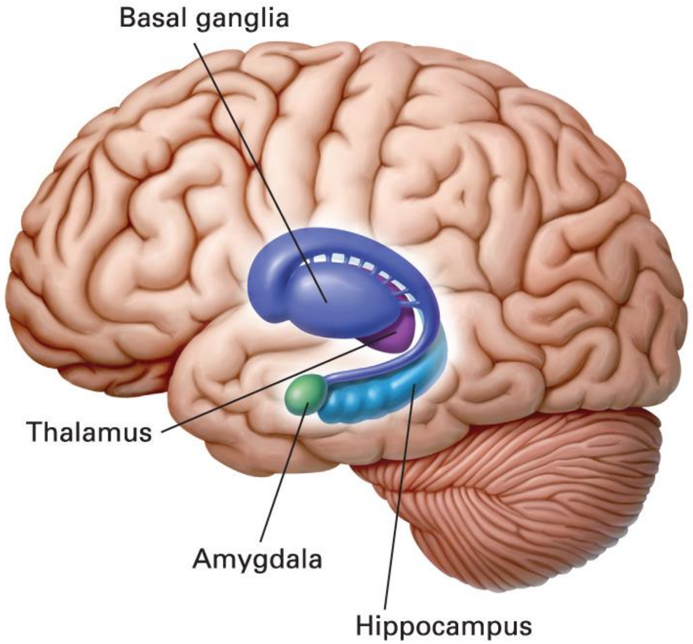


Crucial for forming new memories

Brain Regions Known to Contribute to Memory

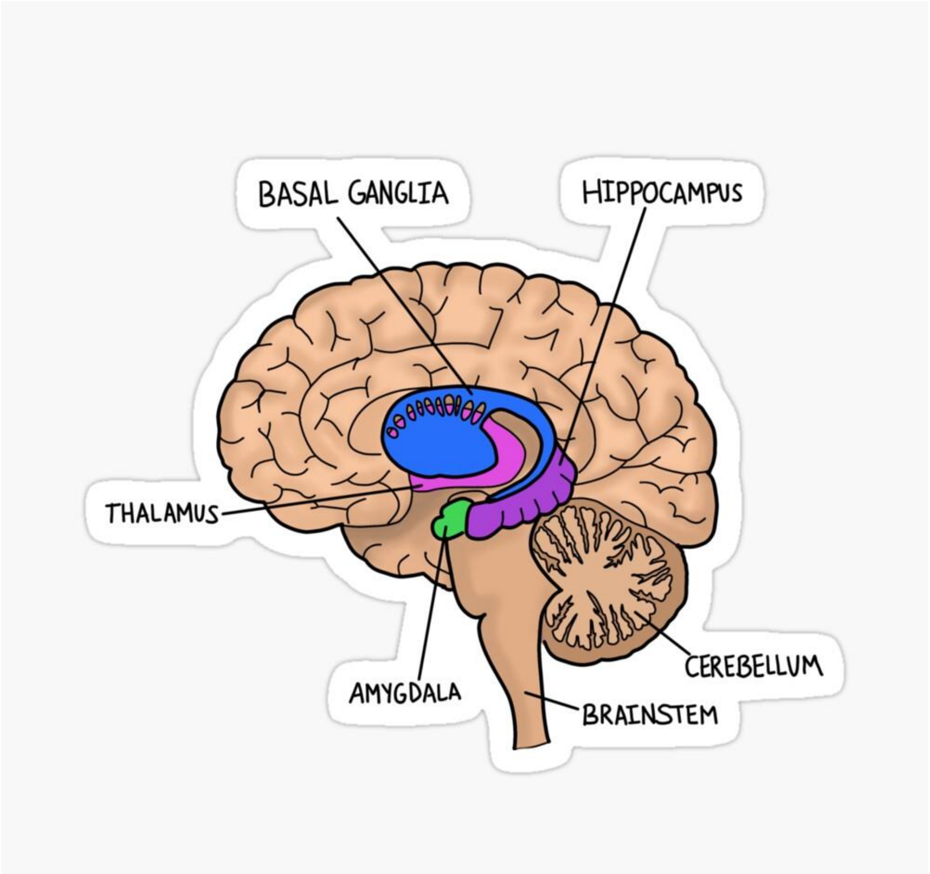


Habit based, motor memories



Gluck et al., *Learning and Memory*, 4e, © 2020 Worth Publishers

Declarative memories, knowledge networks



Surprise Quizzes – Laptops/phones

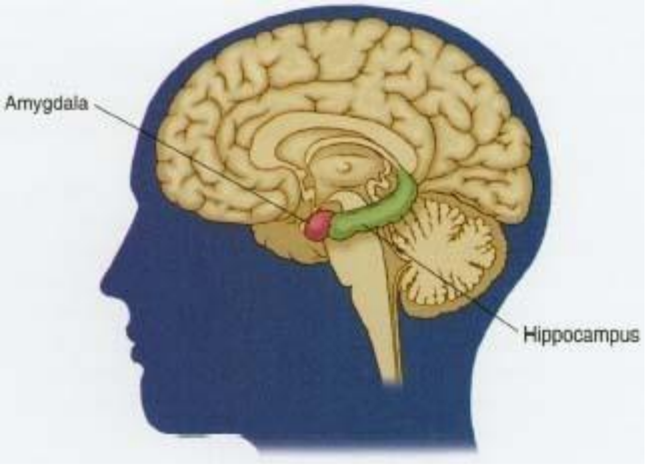

IT FEELS GOOD TO
BELONG!

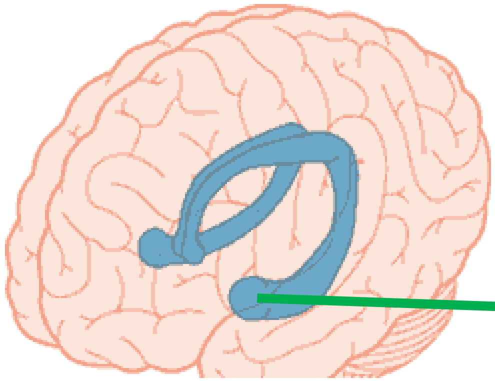
Old items - Target

Similar items - Lures

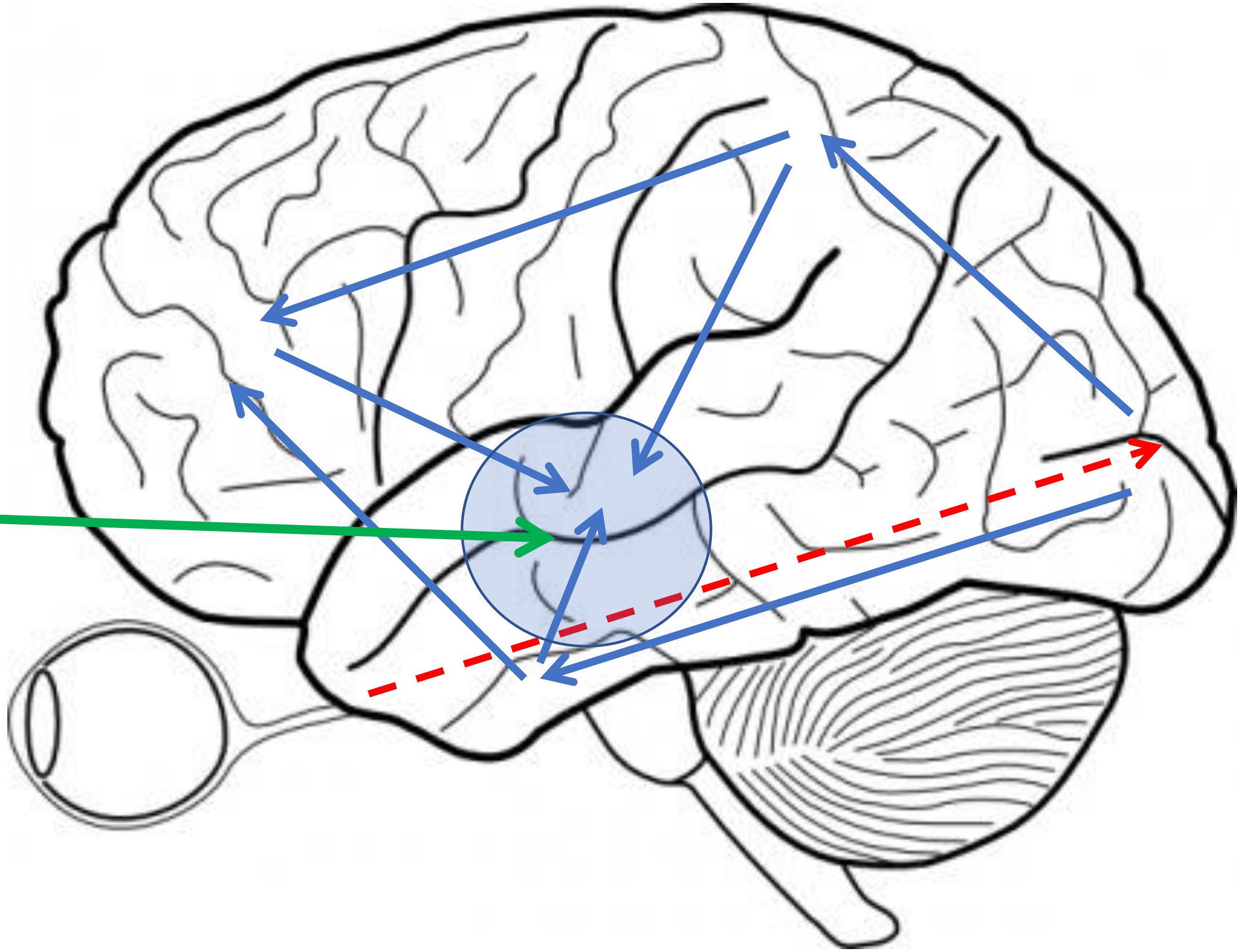
New items - Foils

- How does our brain achieve such a level of computation?

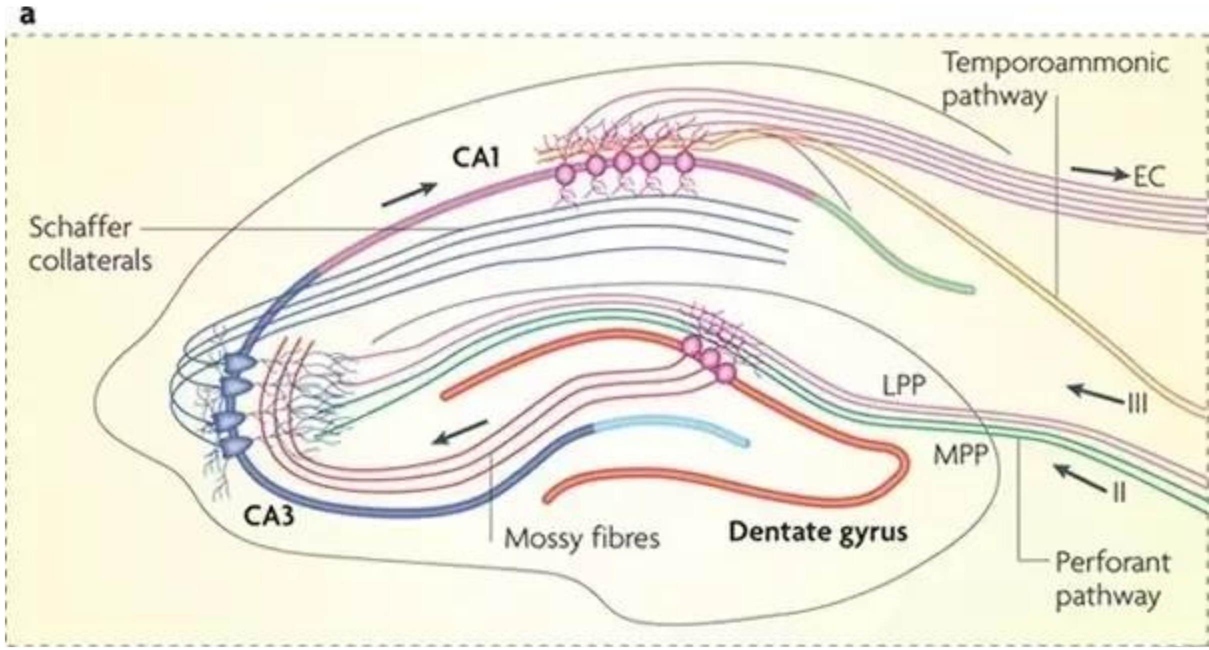


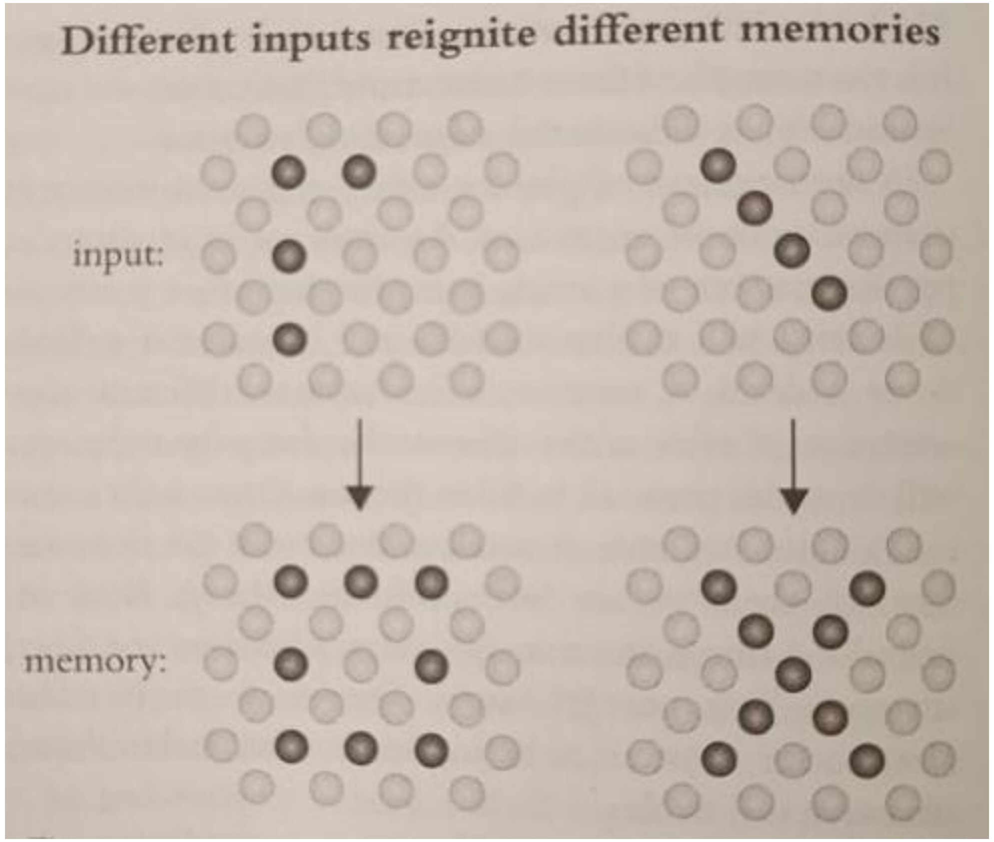


www.BrainCo
©1999 Scientific L

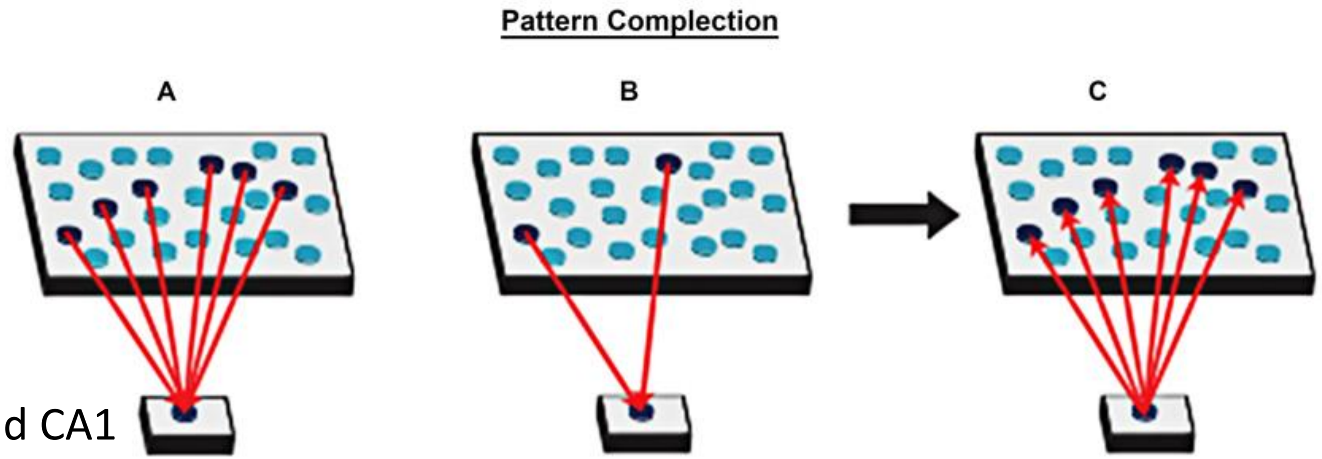


Unidirectional flow of information

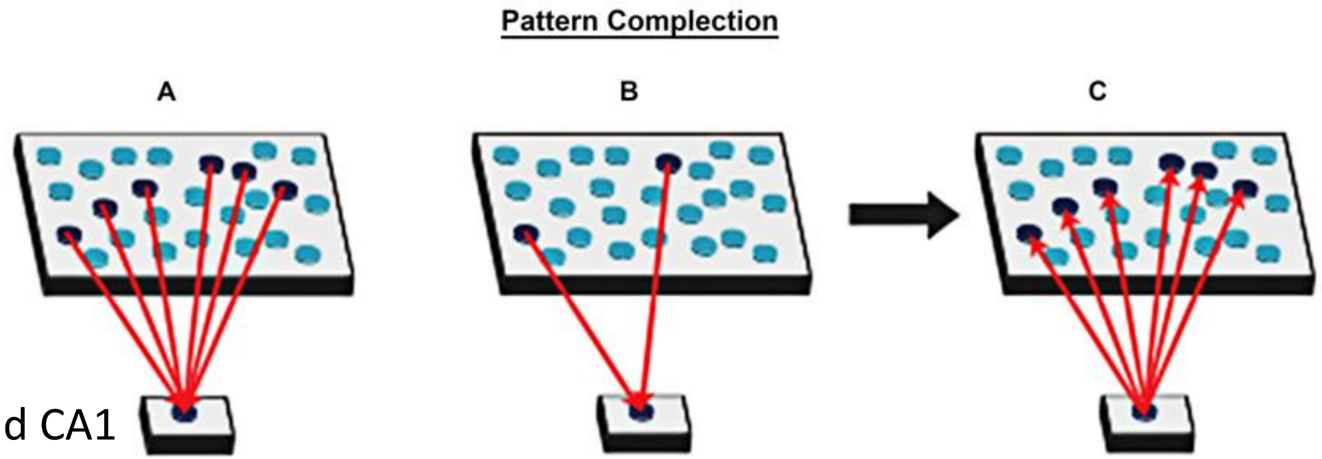




Nature Reviews | Neuroscience



CA3 and CA1
Subregions of the hippocampus



CA3 and CA1
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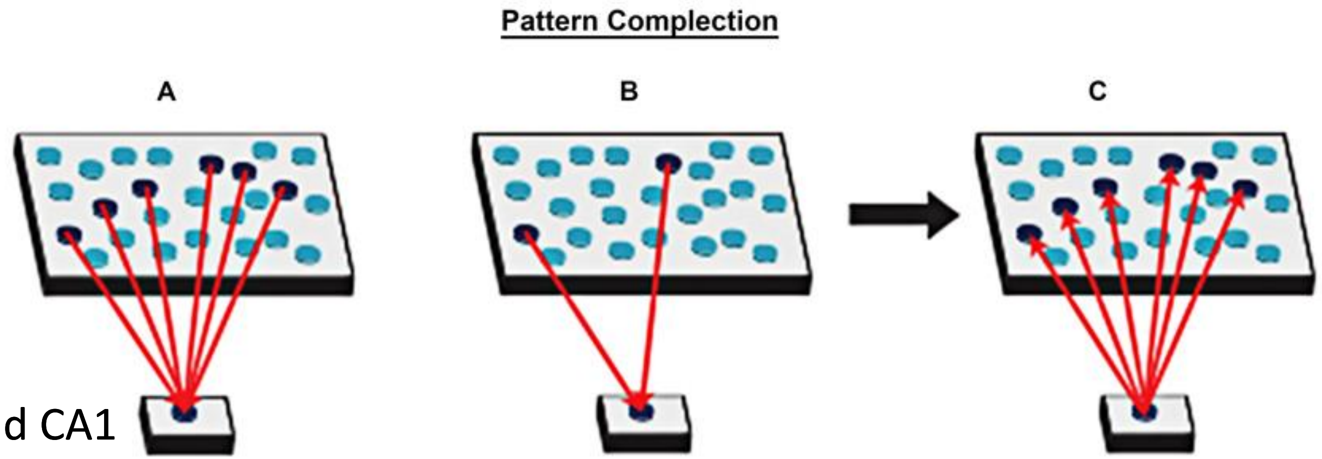
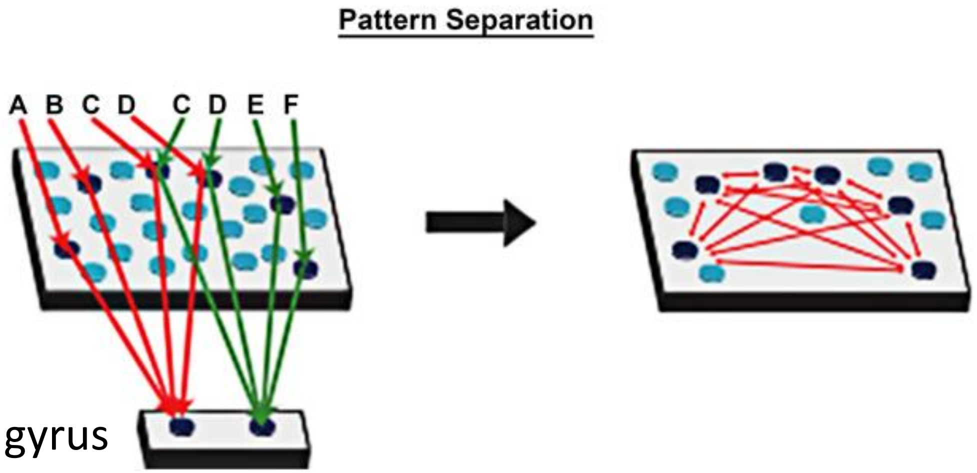


CA3 and CA1
Subregions of the hippocampus



Dentate gyrus
Sub-region of the hippocampus

Pattern discrimination and completion are recognized as complementary processes, requiring a fine balance between establishing and dissociating new memories and reconstructing old ones

- What if somebody loses their hippocampus?

Learning about repeated events

Continuous occurrence of …..

- Clouds thundering
- Fire alarm at a distance (far)
- Exhaust fan
- New ring tone

- Can you feel your clothes?

- What behaviour do you exhibit?

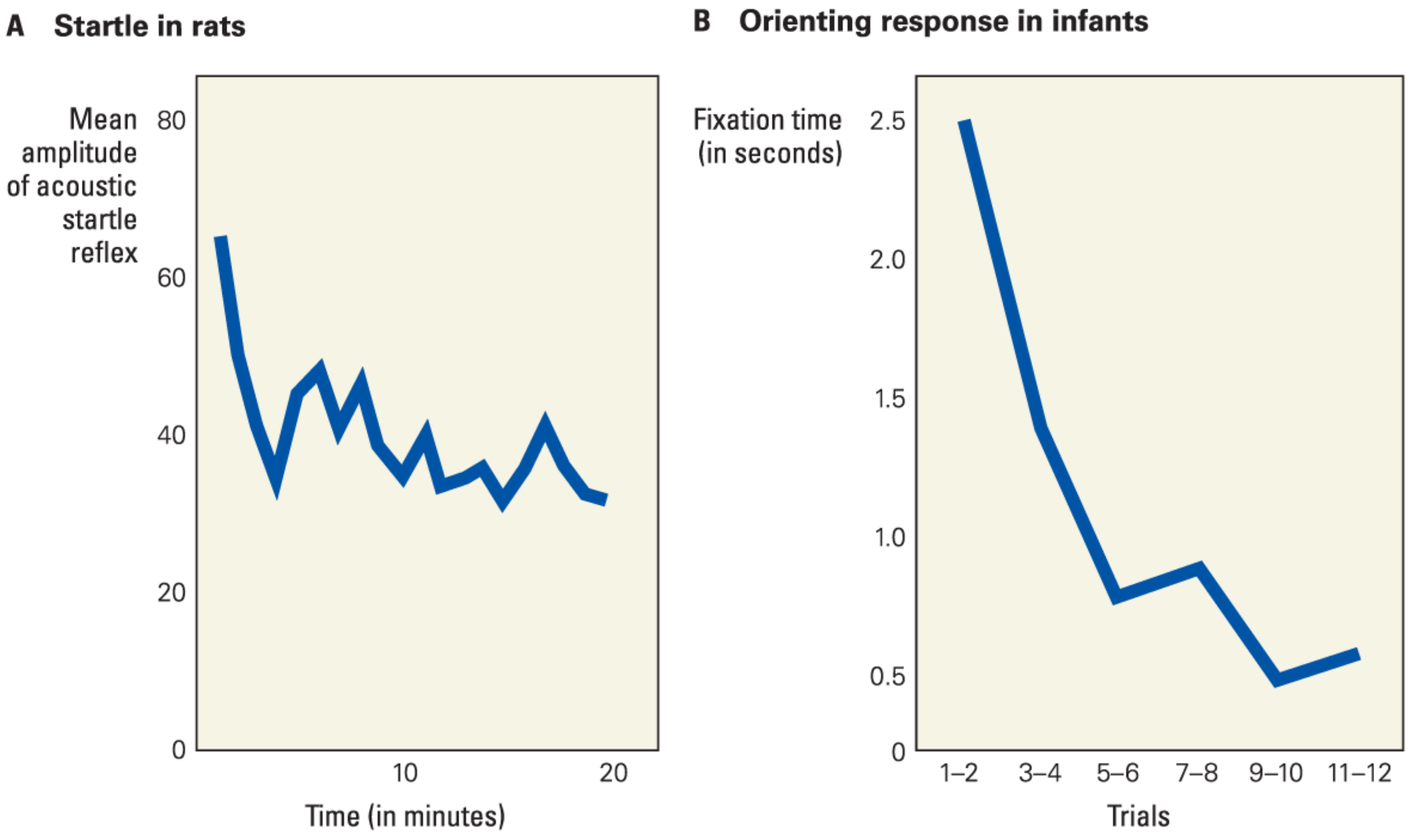
- How long can you smell a flower?
- How long does taste last in your mouth?
- How long can you feel a tight watch around your wrist?
- Do you become used to the darkness in a room?
- Can you feel the temperature of the room after 15-20mins of entering it? (or swimming pool)

- What kind of behaviour do you exhibit?

General Features of Habituation

In the laboratory, researchers examine simpler examples of habituation that they can describe in terms of a single, easily controlled stimulus and a single, easily measurable response

Acoustic startle reflex: a defensive response (such as jumping or freezing) to a startling stimulus (such as a loud noise)



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Orienting response: an organism's innate reaction to a novel stimulus

- **Adaptation (Sensory)**
  - Environmental stimuli is filtered out over time – response stimuli dies out (smells, taste, tactile)
  - The receptors reduce or stop responding to the stimuli
  - A short sensory interval is necessary to perceive the stimulus again
  - You cannot perceive the signal, we don't have much control over it
  - No conscious control

vs

- **Habituation**
  - Novelty related startle in the beginning but gradually response to repeated (harmless) stimuli decreases
  - The receptors respond to the stimuli but the signal is not relayed to higher cortical regions for processing.
  - Stop noticing the signal but if you shift your attention to the stimulus you can perceive it (Conscious control)
  - It is a temporary lowering of response – decrease stimulus related arousal.

- Why do we habituate or adapt?
  - Helps to prevent being exhausted by repeatedly responding to unimportant stimuli
  - E.g. Living near railway station or airport or noisy market

If you

- Feel an earthquake
- Living in war zones
- See a stray dog (for those who fear one)

What behaviour do you exhibit?

Why?

Survival? Unpleasant response or consequence in the past?

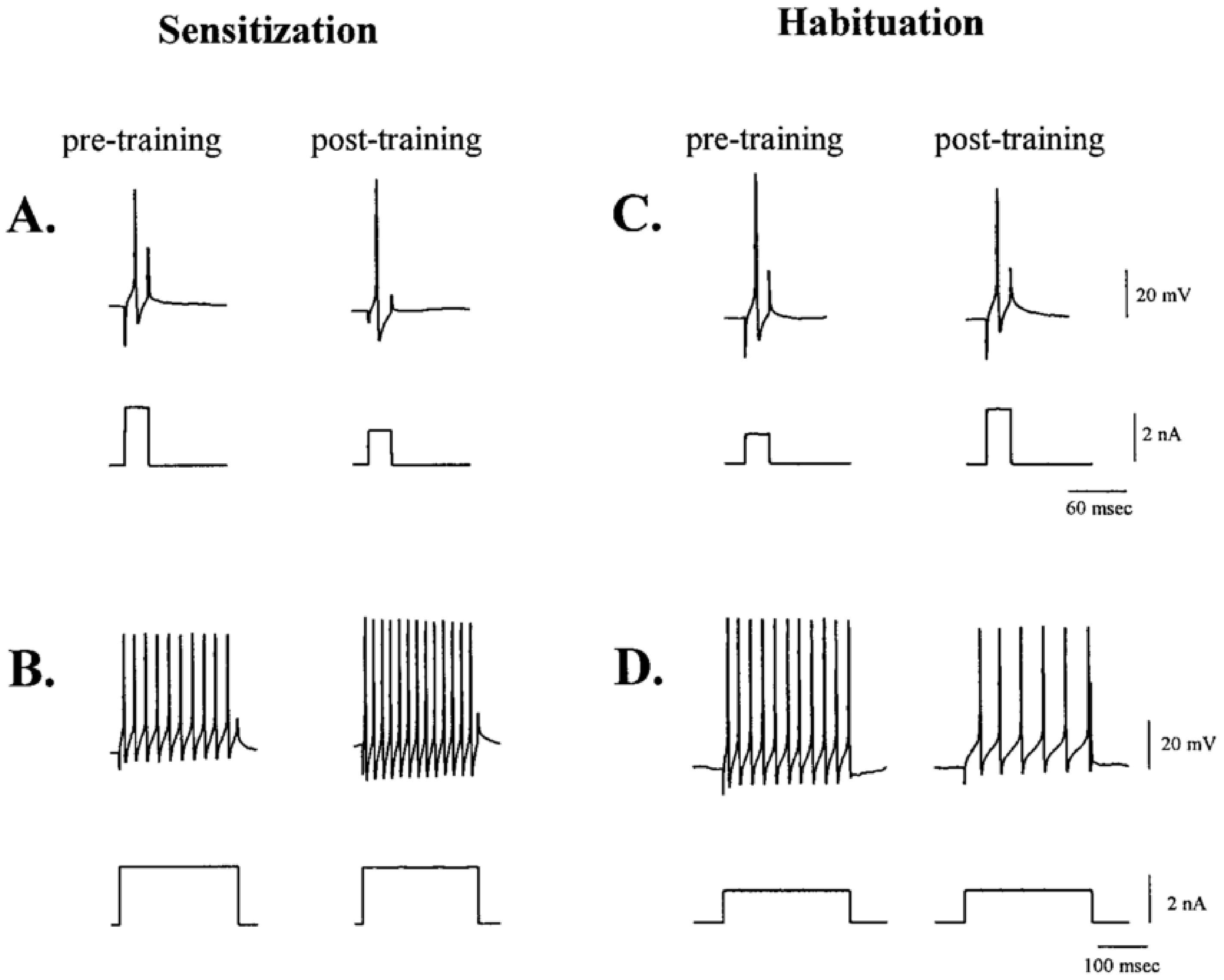
Sensitization

- Increased reaction/response to a stimulus after repeated exposure
- The receptors generate a greater response to the stimuli
- Increases stimulus-related arousal

Learning at a cellular level

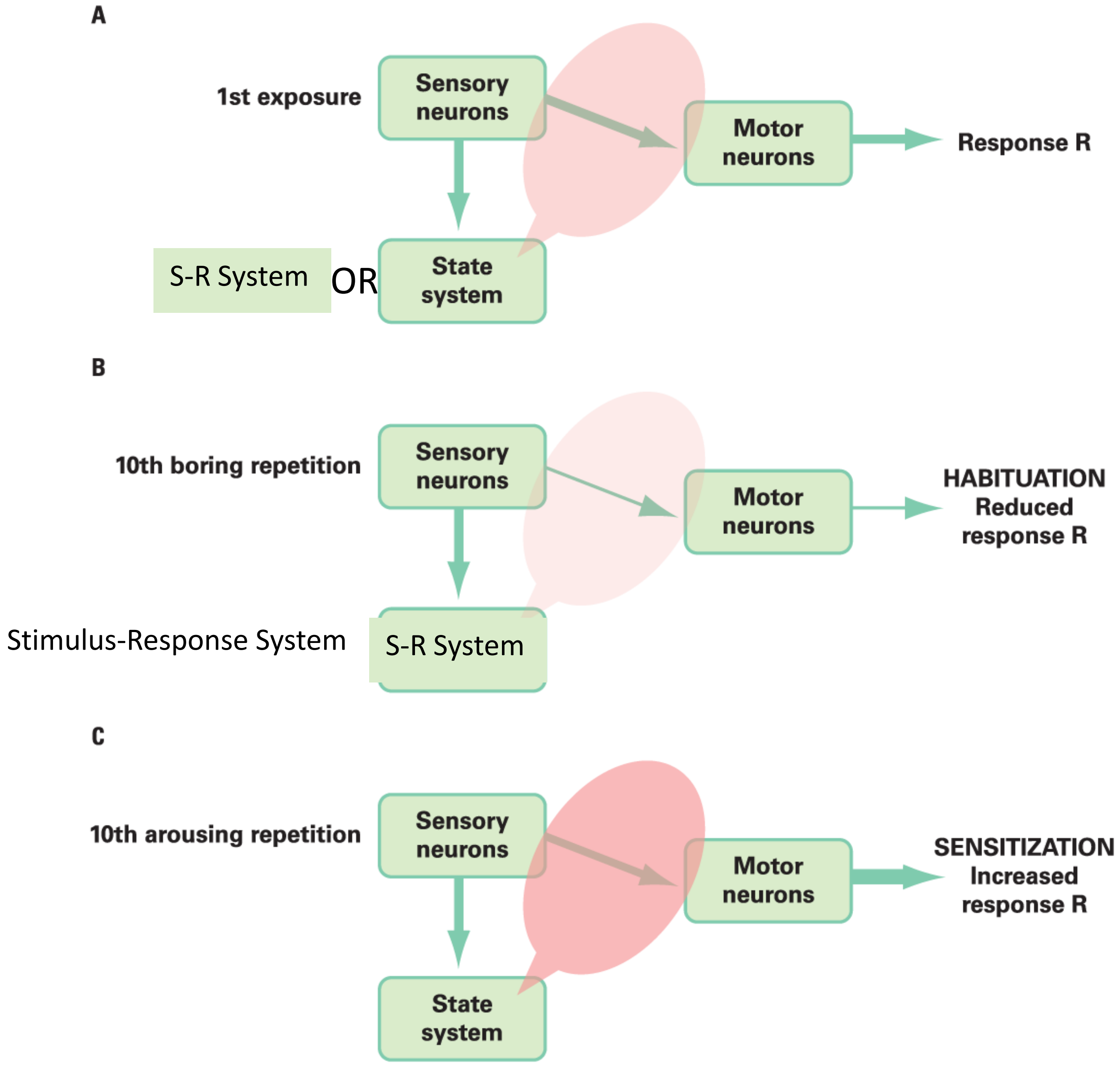
Sensitization (A) decreases the initiation threshold (measured as the amount of current necessary to produce a single action potential) and (B) increases the number of action potentials produced by a long current pulse.

Habituation (C) increases the initiation threshold and (D) decreases the number of action potentials elicited by the long stimulus pulse.



https://www.jneurosci.org/content/21/4/1401

Dual Process Theory



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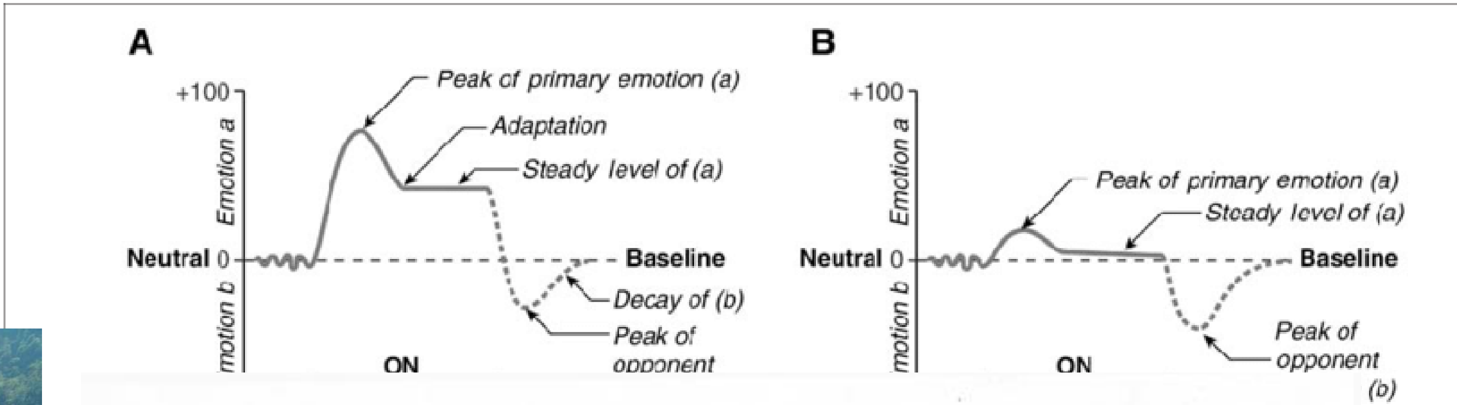
Habituation vs Sensitization

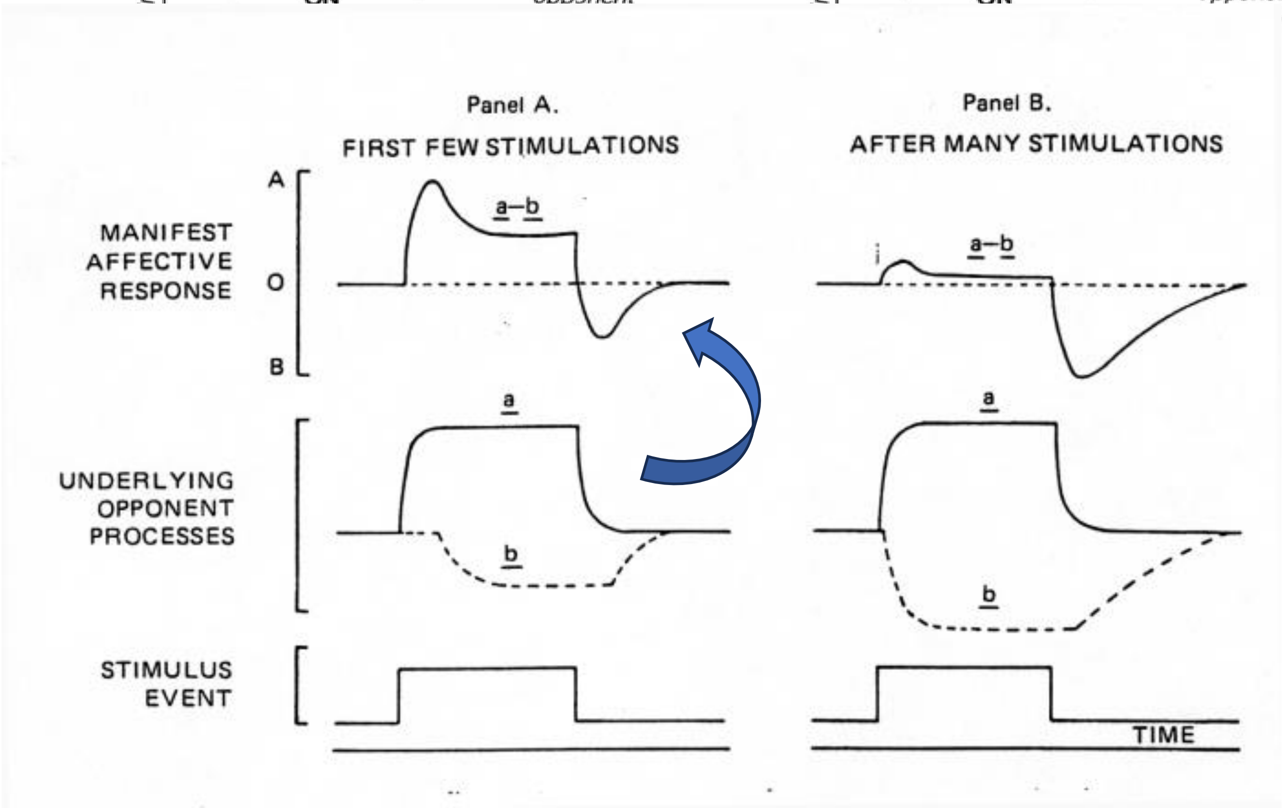
Which one?
Why?

- Past negative experience – sensitization
- Past neutral experience – habituation
- Illness/Health condition - sensitization

Opponent Process Theory

- Builds on Dual Process Theory
- Initial unpleasant experience can gradually turn to a pleasant experience or vice-versa





Complex Behavioural outcomes?

Habituation	Sensitization
Pros	Pros
Cons	Cons
Examples?	Examples?

Simple non-associative learning

- Habituation –
  - Specific to a stimulus
  - With repetition, response decreases
  - Can be localized in the brain

- Sensitization –
  - Similar stimuli may also trigger the same behavioural response -
  - With repetition, response is sustained or increases
  - Not localized, involves many regions in the brain.

At a behavioural level

- Habituation –
  - IIIT campus was exciting for the first few days……….
  - Ignoring inflation
  - Apathy/Indifference towards politics
  - Indifference of police towards criminals (inhuman treatment)

- Sensitization – become more sensitive to people or context
  - Bullying
  - Domestic violence / Abuse/ Sexual harassment
  - Financial setback – more cautious with transactions
  - PTSD
  - A timid child with angry parents that cries at school if the teacher uses a stern tone of voice

Sensitization to Stress

- *"individuals become sensitized to stress over time, such that the level of stress needed to trigger episode onsets becomes increasingly lower with successive episodes"* (Stroud, 2020, p. 349).

- If stressful experiences occur too often, too intense, more than what an individual can cope.

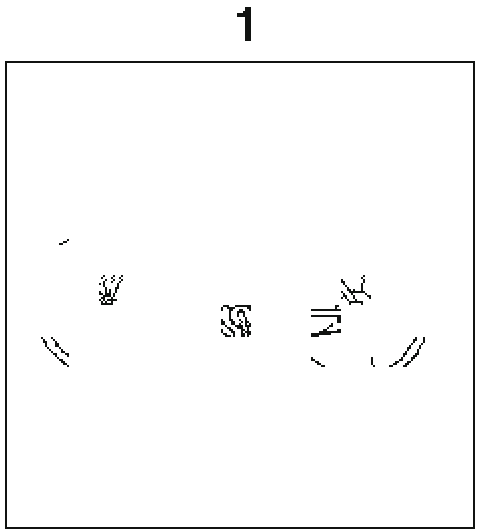
- Stress-related psychopathology can include major depression and bipolar disorder.

- Stress/adversity in early years/childhood can also result in psychiatric disorders

http://www.uclastresslab.org/pubs/Stroud_Stress%20Sensization_Oxford%20Handbook_2019-in%20press.pdf

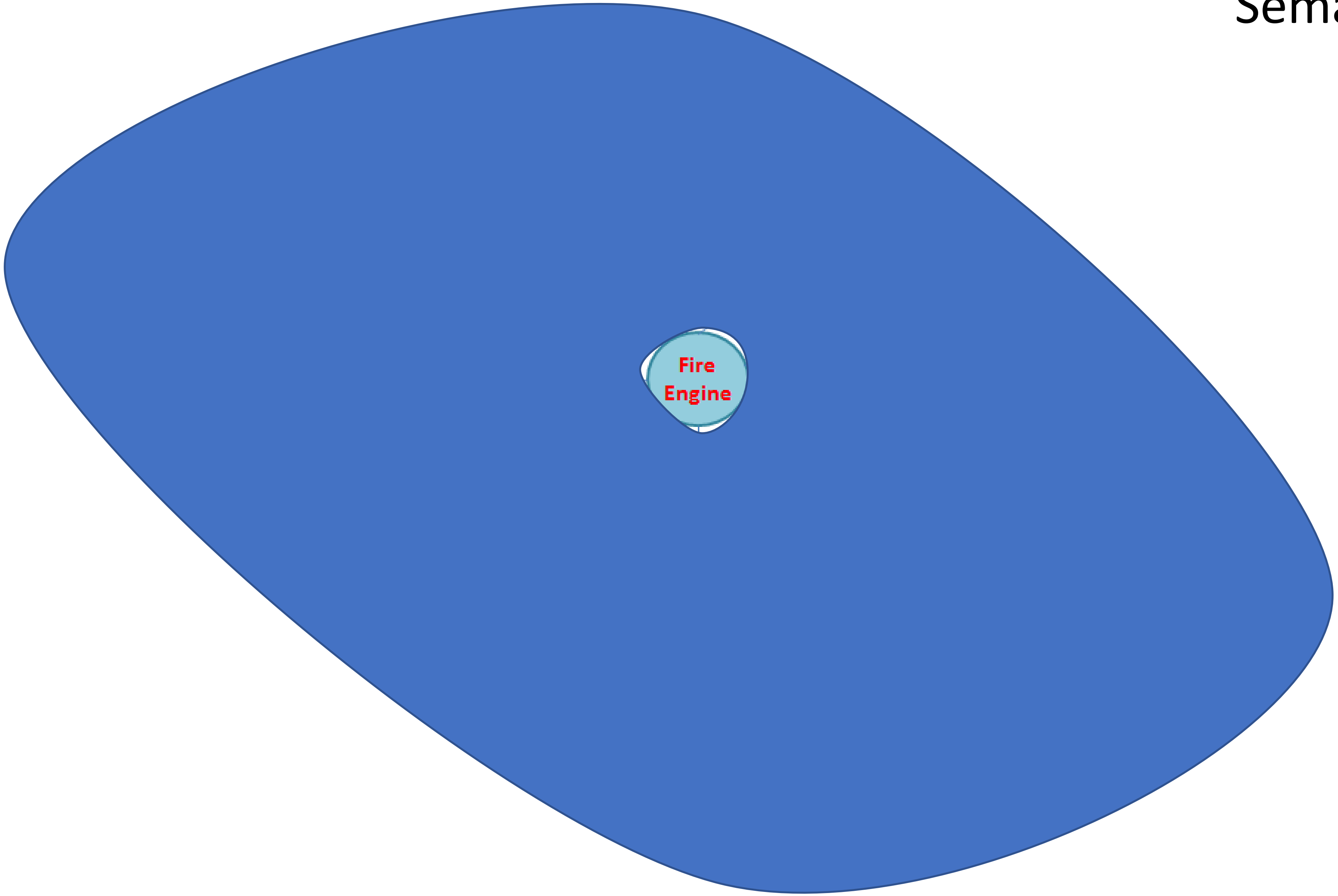
- Other repeated events?

Visual Priming



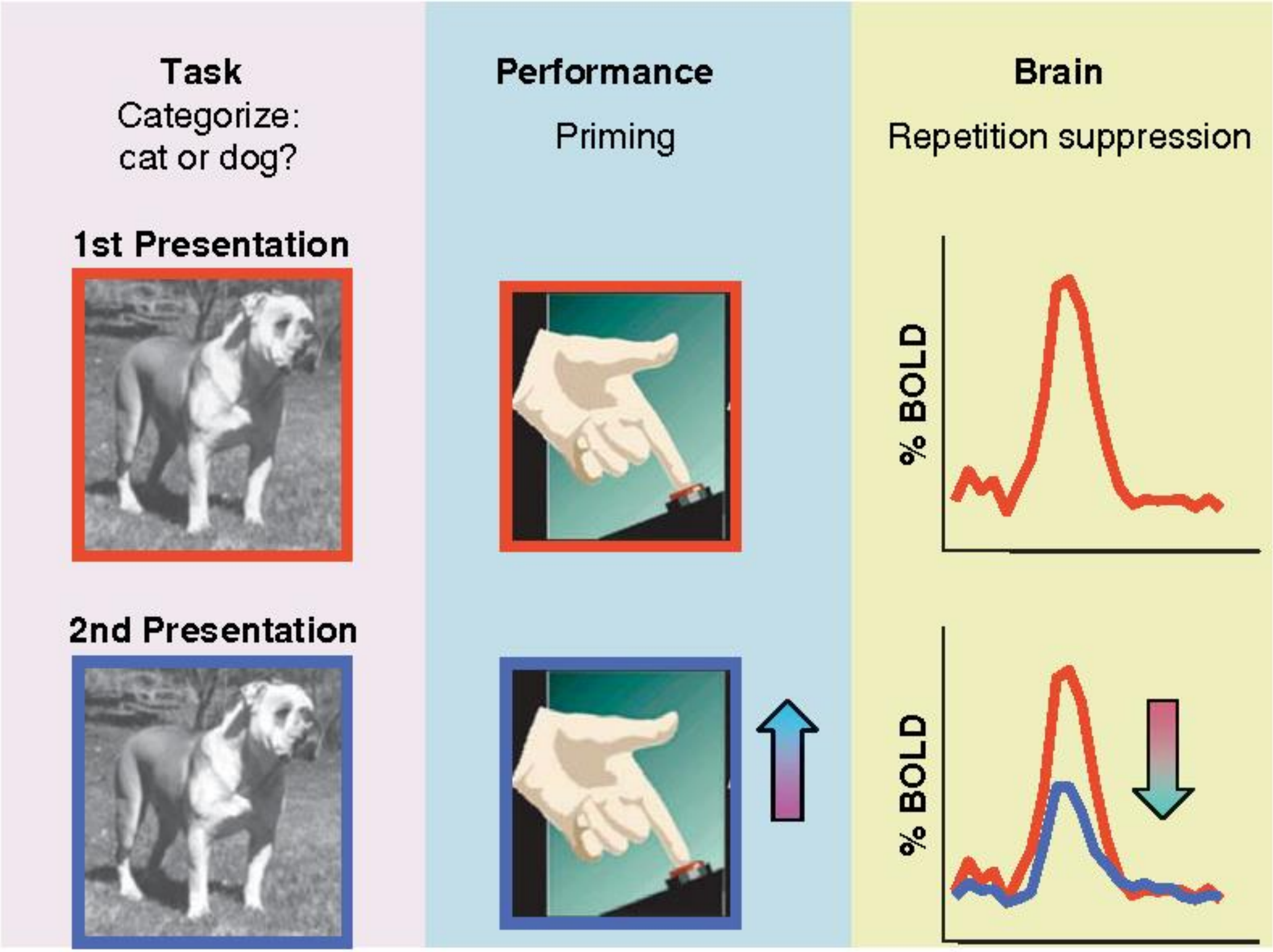
RED
BLUE
ORANGE
YELLOW
GR___

Semantic Priming



Priming

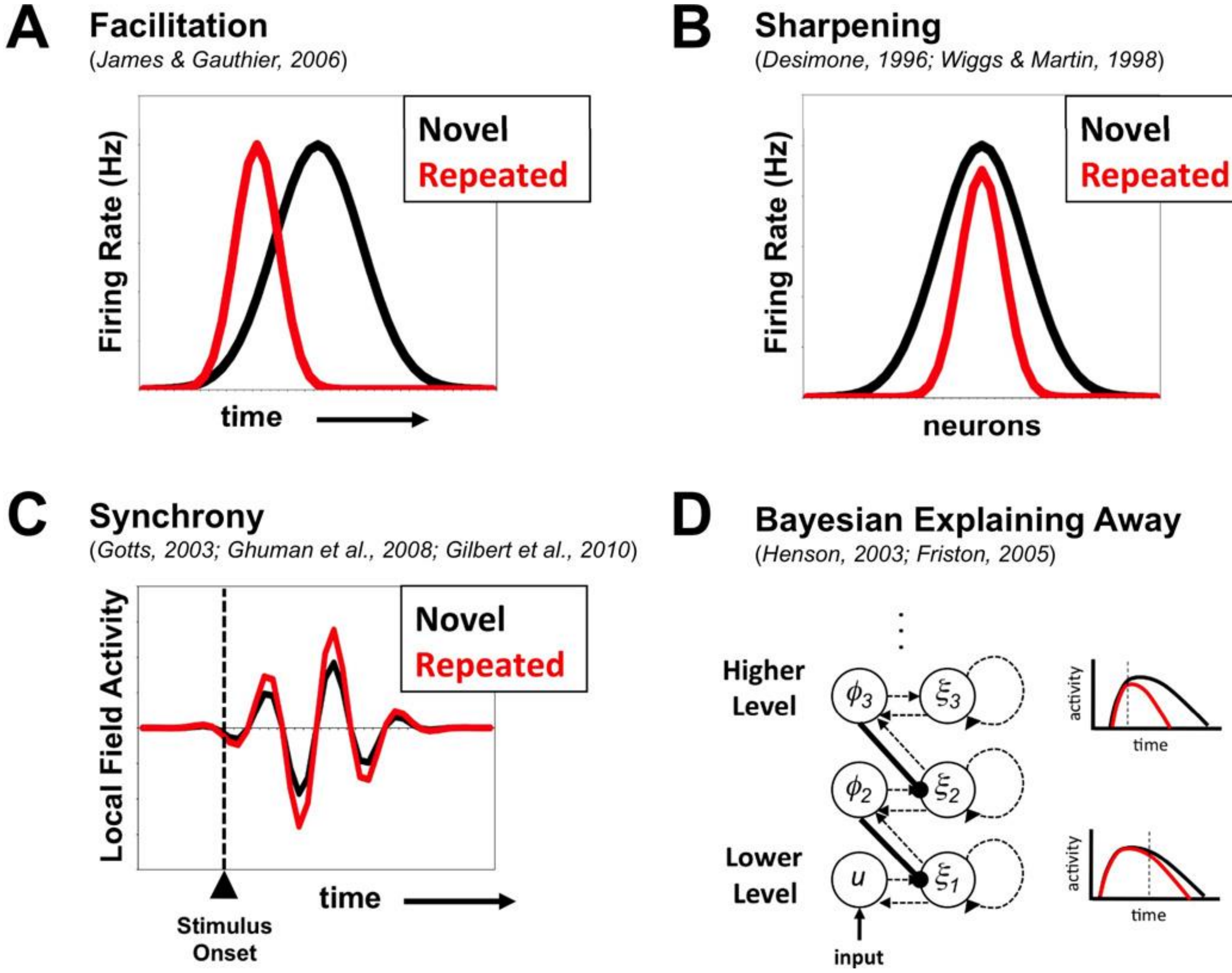
- **Priming:** a phenomenon in which prior exposure to a stimulus can improve the ability to recognize that stimulus later
- Priming can occur even in the absence of any feelings of familiarity or recognition that a stimulus was previously experienced
- Priming effects may persist much longer than recognition of past encounters



novelty

repetition

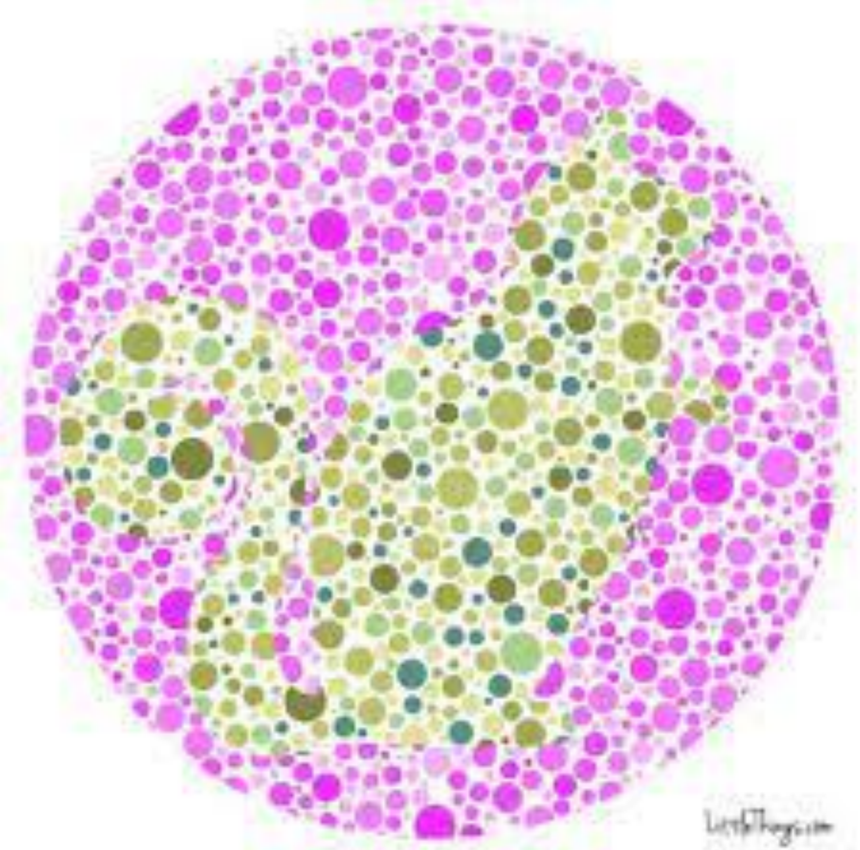
atic illustration of priming and repetition suppression/adaptation. *Left:* subjects are ask



[Repetition Priming and Repetition Suppression: A Case for Enhanced Efficiency Through Neural Synchronization]()

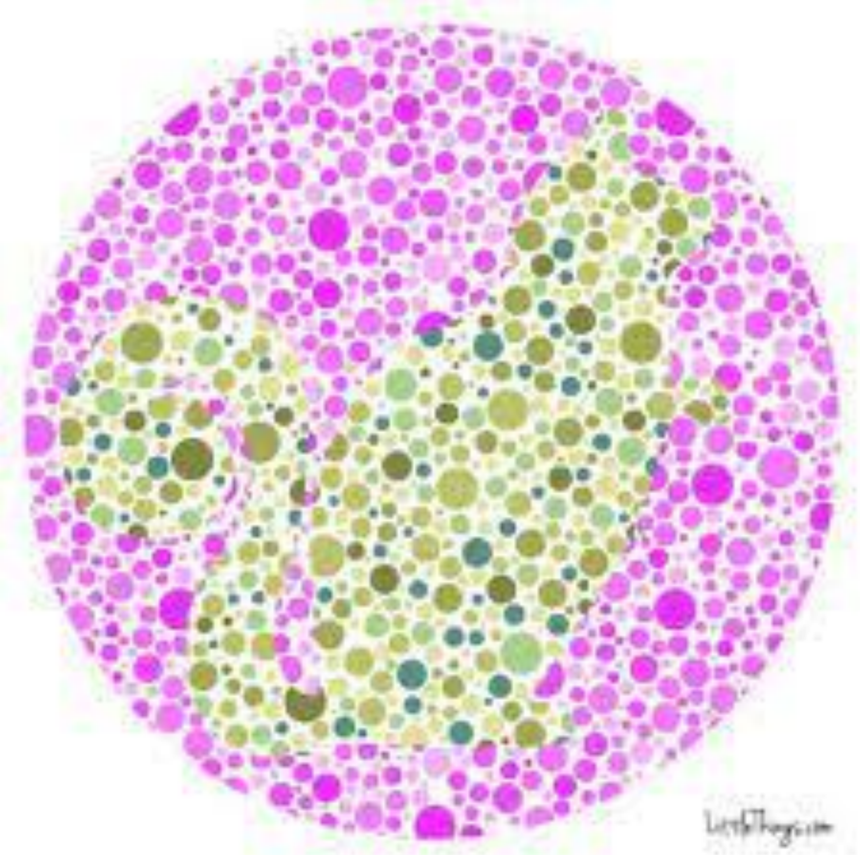
Familiarity to the stimulus or content is important for priming

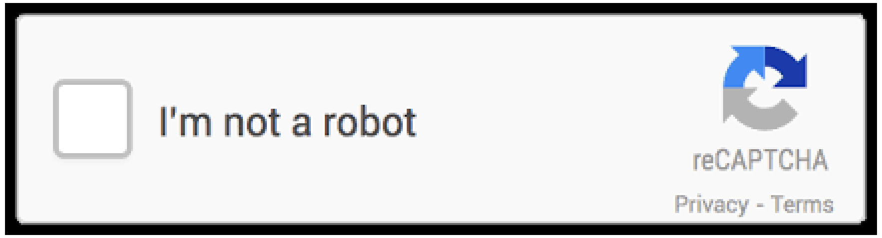
- Developing skills through repeated exposure?



Perceptual Learning

- Learning in which repeated experiences with a set of stimuli make those stimuli easier to distinguish is called **perceptual learning**

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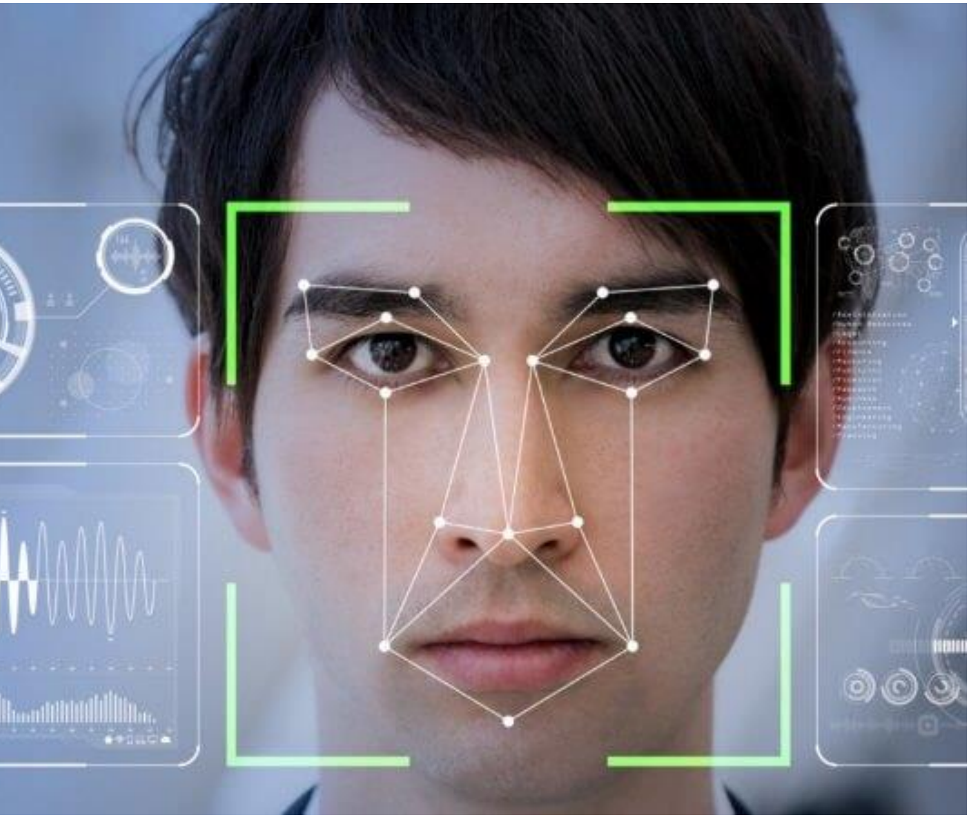
Click 3 pictures of kittens to submit

- Perceptual learning that happens without explicit training is sometimes called **statistical learning** because the percepts that individuals learn the most about are those that are experienced most frequently and consistently

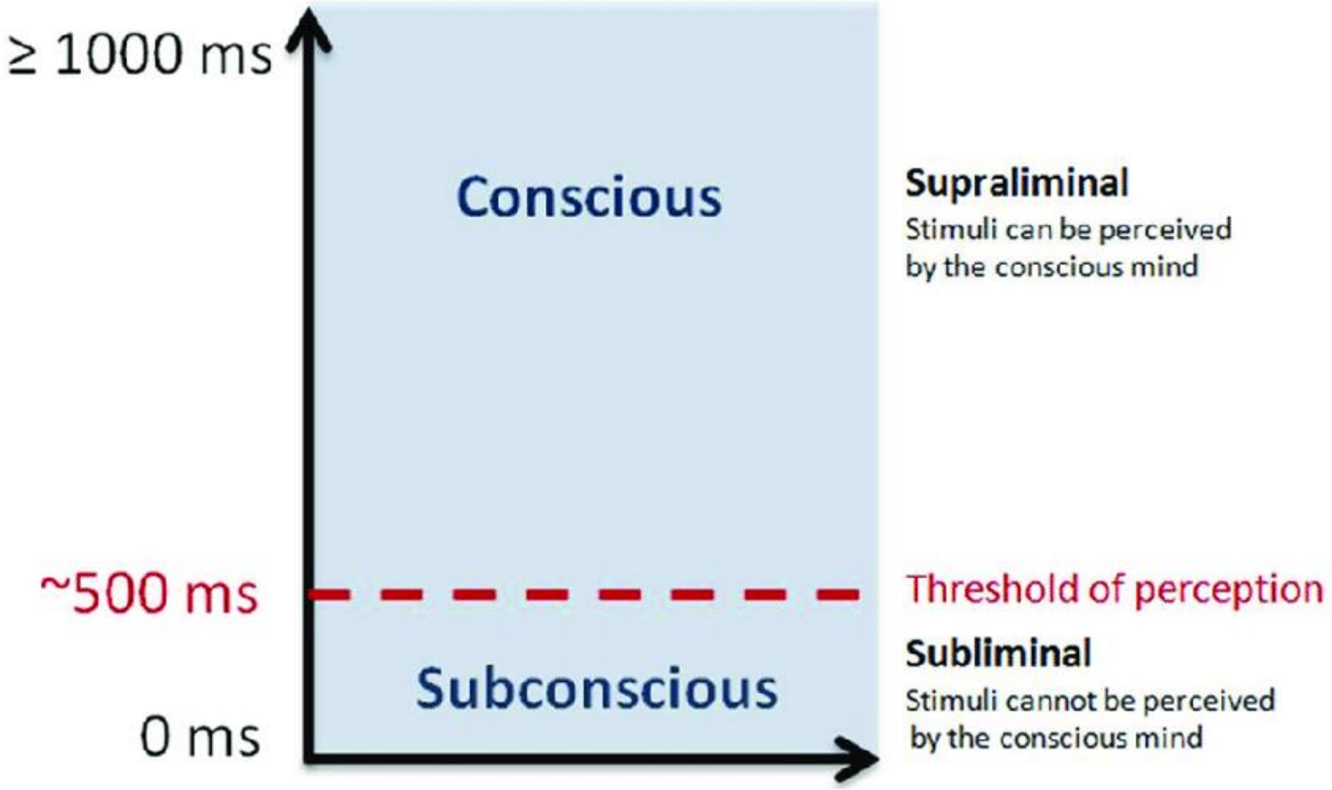
Identifying sounds, smells, visual, and tactile information

Learning through repeated exposure



- Is there a common underlying phenomenon in the types of learning discussed so far?

Repetition learning works in our subconscious, and these processes are almost always unnoticeable to the subject.



Learning to predict events

- Reaching for your phone every time you hear a ringtone like yours
- Fear of needles (vaccination, blood test)
- Disliking a subject because of …..
- Wild animals trained to dislike a certain type of meat

Ian Pavlov

Saliva measuring apparatus

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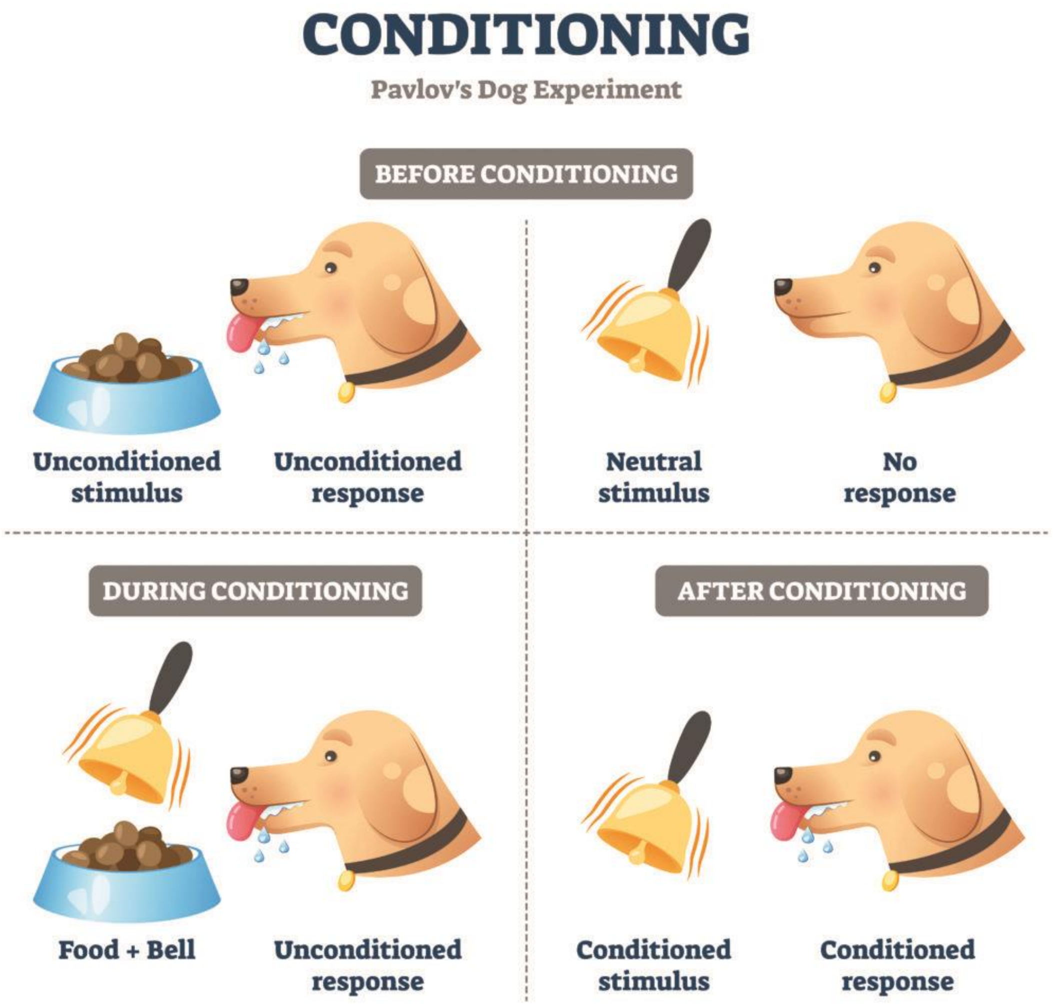
- Pavlov was originally studying effects of salivation on digestion (Nobel Prize 1904)
- He showed that salivation was necessary to start the process of digestion in the stomach
- He also started to test salivation to different types of food and stimuli
- Footsteps → salivation (accidental discovery)

What Is Classical Conditioning?

- **Classical (Pavlovian) conditioning:** a form of learning in which an animal/individual acquires the expectation that a given stimulus predicts a specific upcoming important event

Basic Concepts of Classical Conditioning

- **Unconditioned stimulus (US):** a cue that has some biological significance and that, in the absence of prior training, naturally evokes a UR
- **Unconditioned response (UR):** the naturally occurring physiological response to an unconditioned stimulus (US)
- **Conditioned stimulus: (CS)** a cue that is paired with an unconditioned stimulus (US) and comes to elicit a CR
- **Conditioned response (CR):** the trained response to a conditioned stimulus (CS) in anticipation of the unconditioned stimulus (US) that the CS predicts



Appetitive and Aversive Conditioning

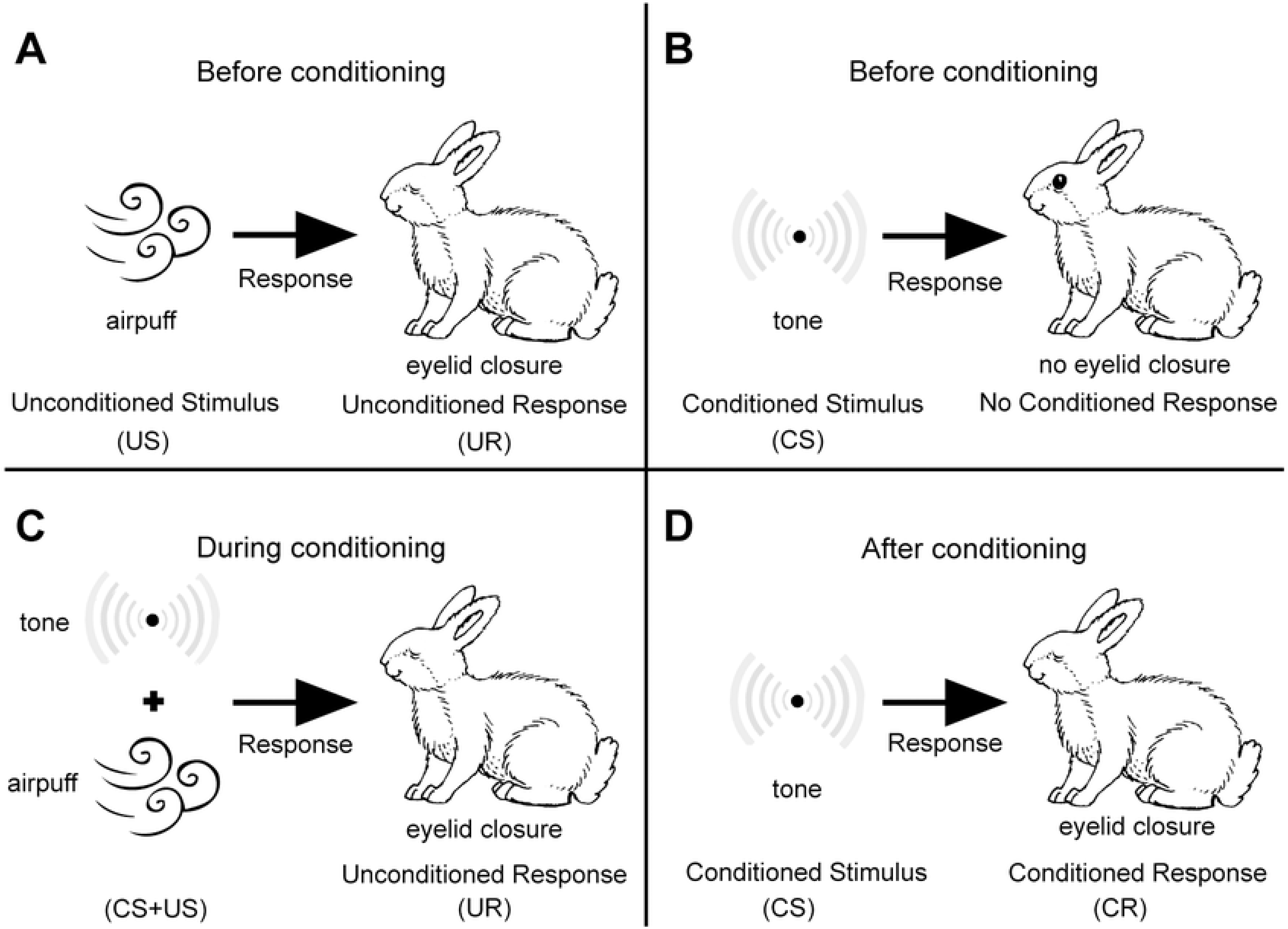
- **Appetitive conditioning:** conditioning in which the US is a desirable event
- E.g. food, sex, pleasurable events

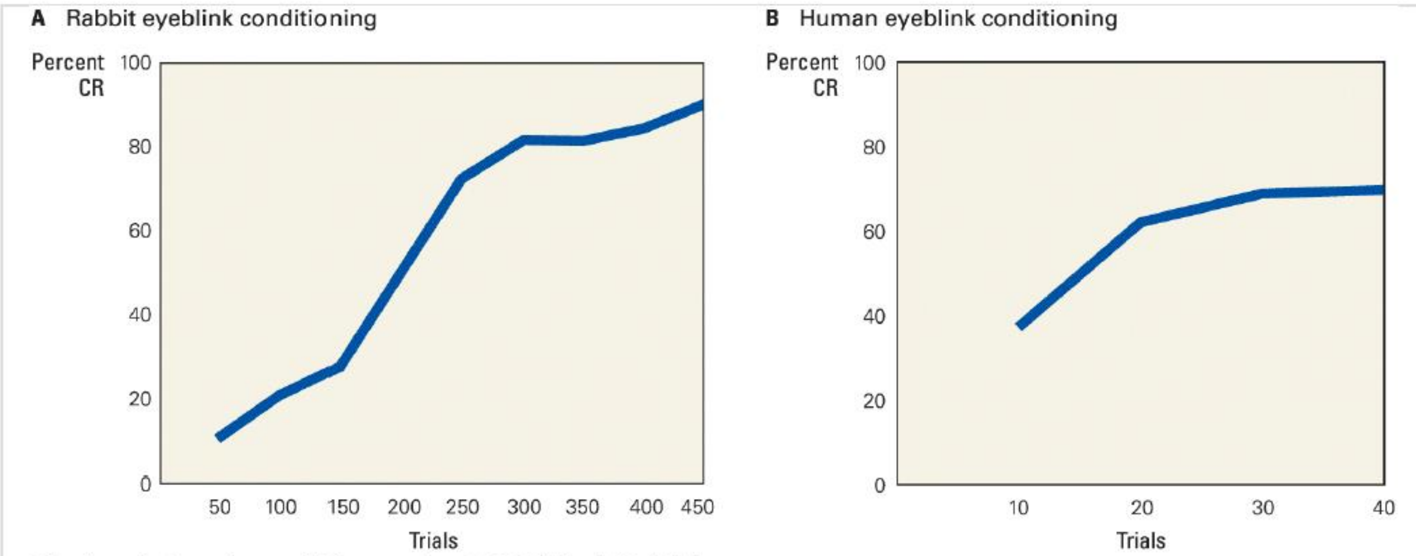
- **Aversive conditioning:** conditioning in which the US is a disagreeable event
- E.g. eyeblink conditioning
- E.g. fear for insects, spiders, phobias

CS, US, UR/CR – defined by the roles the cues play in a particular learning situation

- Cigarette Smoke(US) → headache (UR)
- Party → smoke → headache
- Party (CS) → headache (CR) (anticipating smoke)

- Boss harasses (US) → anxiety/heart rate increases (UR)
- Meetings → boss harasses → anxiety
- Meetings (CS) → anxiety (CR) [anticipating the boss's harassment]


A
Before conditioning
Response
airpuff
eyelid closure
Unconditioned Stimulus
(US)
Unconditioned Response
(UR)
B
Before conditioning
Response
tone
no eyelid closure
Conditioned Stimulus
(CS)
No Conditioned Response
C
During conditioning
tone
airpuff
Response
eyelid closure
(CS+US)
Unconditioned Response
(UR)
D
After conditioning
Response
tone
eyelid closure
Conditioned Stimulus
(CS)
Conditioned Response
(CR)



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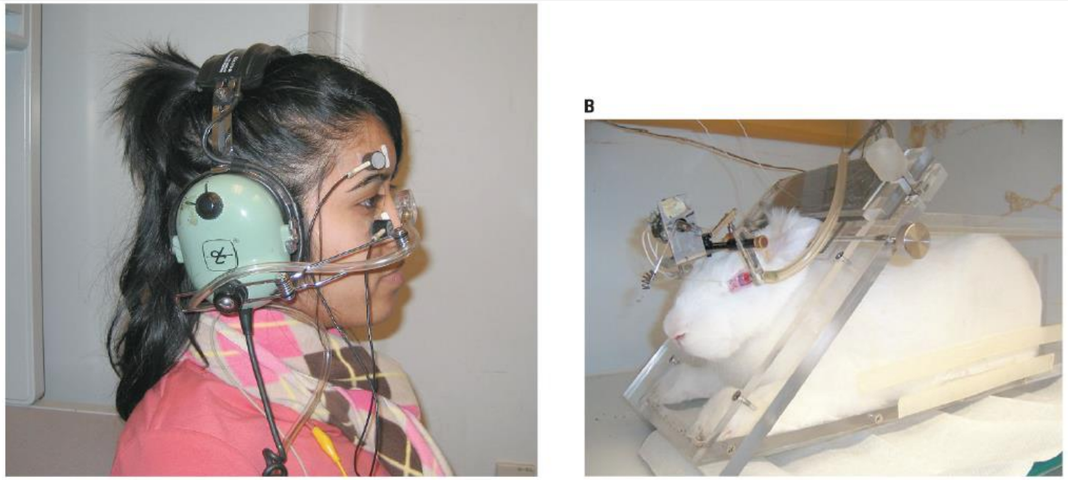
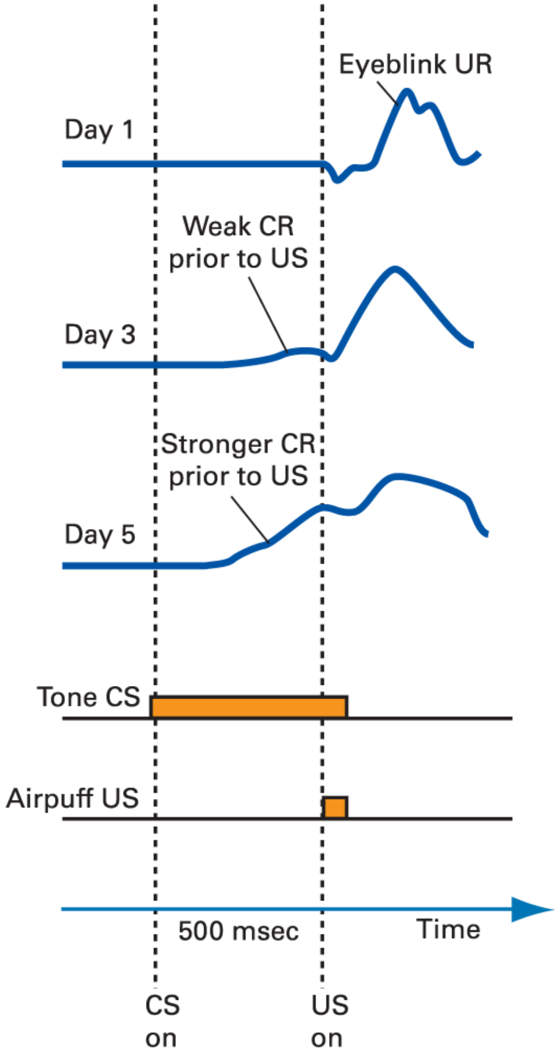


A: Mark Gluck; B: Richard F. Thompson

FIGURE 4.5 Eyeblink conditioning in humans and rabbits (A) In human eyeblink conditioning, a tone CS is delivered through headphones. The US is a puff of air delivered through the rubber tube. The eyeblink CR is recorded by EMG electrodes placed above and below the eye. (B) In rabbit eyeblink conditioning, a similar rubber tube delivers the airpuff US to the rabbit in the restraining acrylic glass case; a photobeam measures the CR and UR.

Airpuff → eyeblink
Tone → Airpuff → eyeblink
Tone → eyeblink



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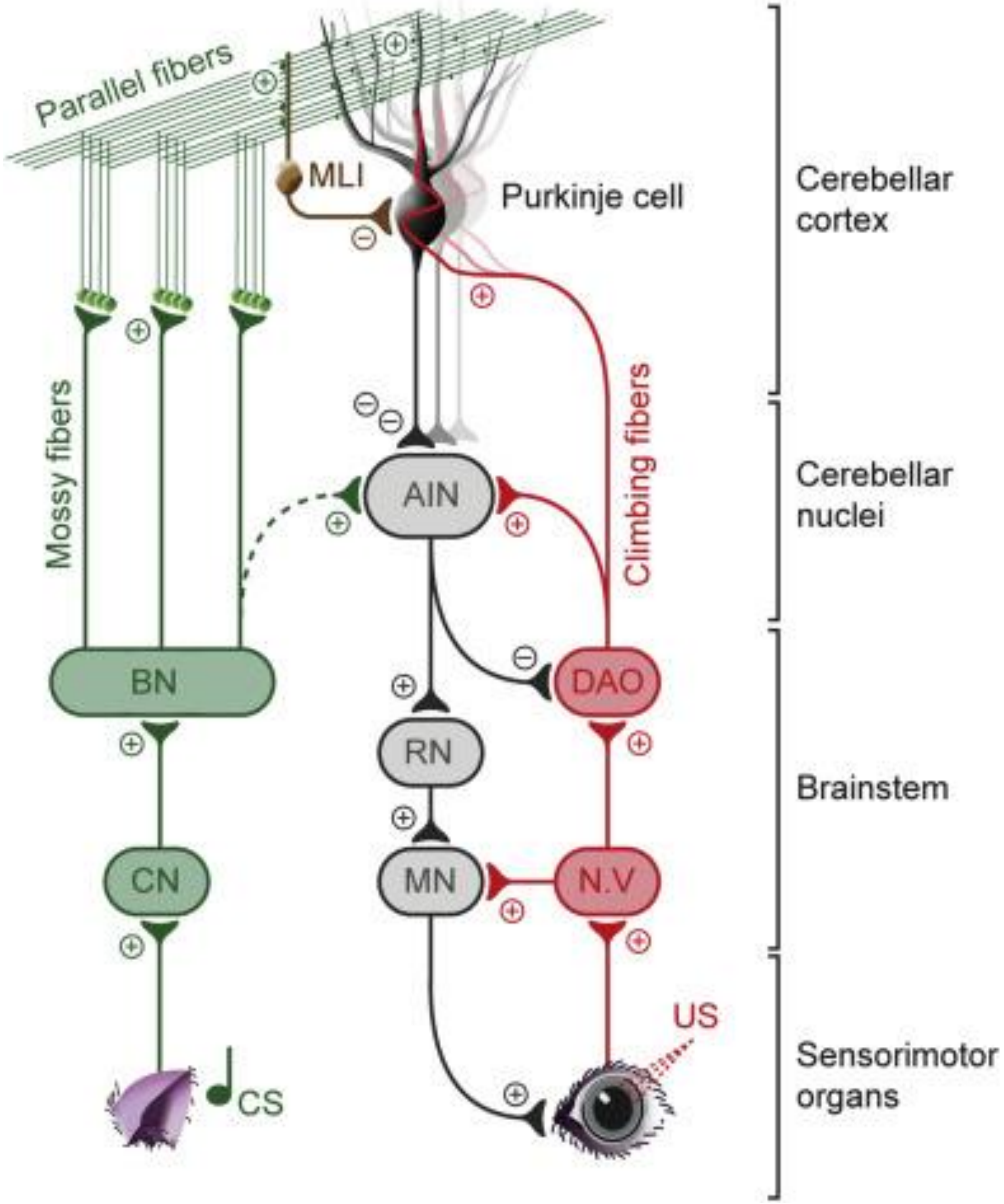

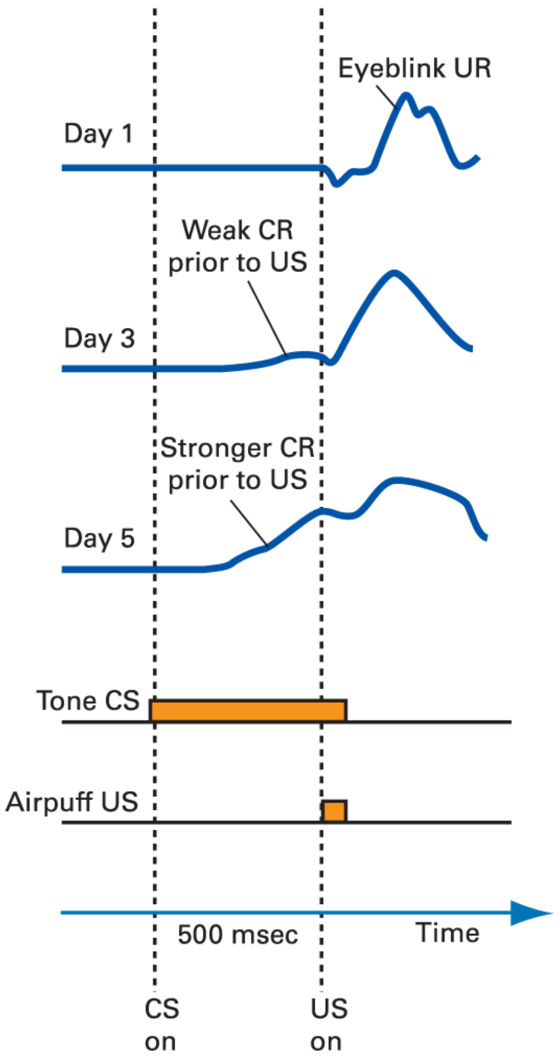

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Conditioned Compensatory Response (CCR)

- E.g. swimming pool overflow

- E.g. Context - Adrenaline – heart rate experiment in dogs (Subkov & Zilov, 1937).
  - dogs' heart rate increased less and less with each subsequent injection – ***tolerance***
  - *Homeostasis* - the researchers placed their dogs on injection stands, where the dogs normally received the drug injection, but they administered a neutral, inert substance rather than the adrenaline. The researchers observed that this caused the dogs' heart rate to decrease.
  - *CCR -* Apparently, the various cues (the stand, the injection) that predicted the adrenaline injection triggered a conditioned compensatory response that lowered the dogs' heart rate in anticipation of the adrenaline's causing an increase in heart rate.

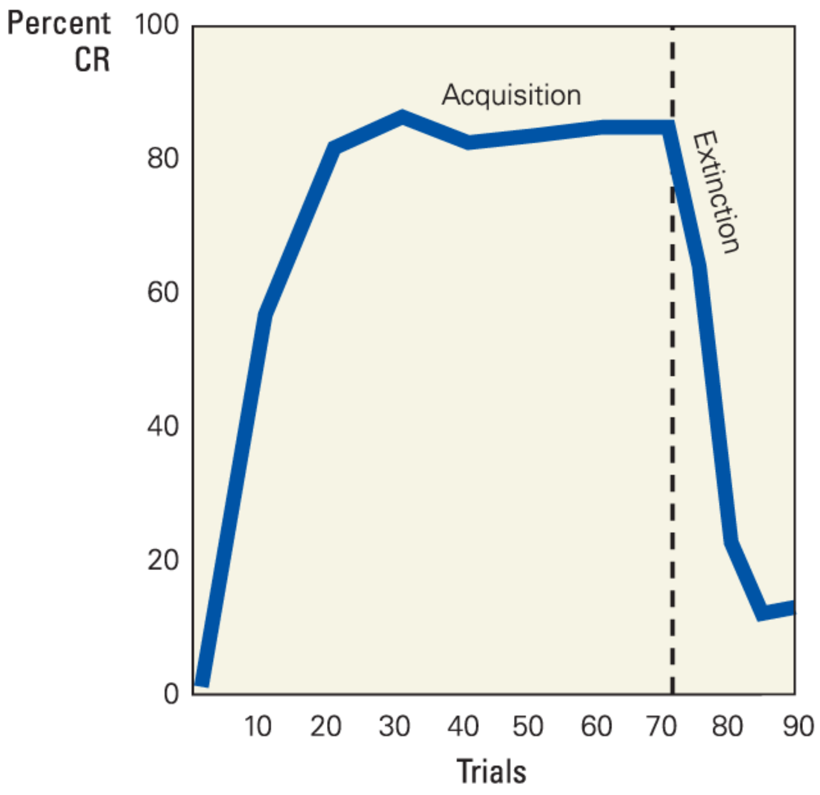
- Body adapts to the dose of the drug - **Homeostasis -** The tendency of the body (including the brain) to gravitate toward a state of equilibrium or balance
- **Is drug tolerance an example of CCR?**

Extinguishing an Old Association

1. What if the boss stops harassing during meetings ? (someone filed a complaint)
   How long will it take to stop becoming anxious?

   Association becomes dormant?

- **Extinction:** in classical conditioning, the process of reducing a learned response to a stimulus by ceasing to pair that stimulus with another, previously associated stimulus



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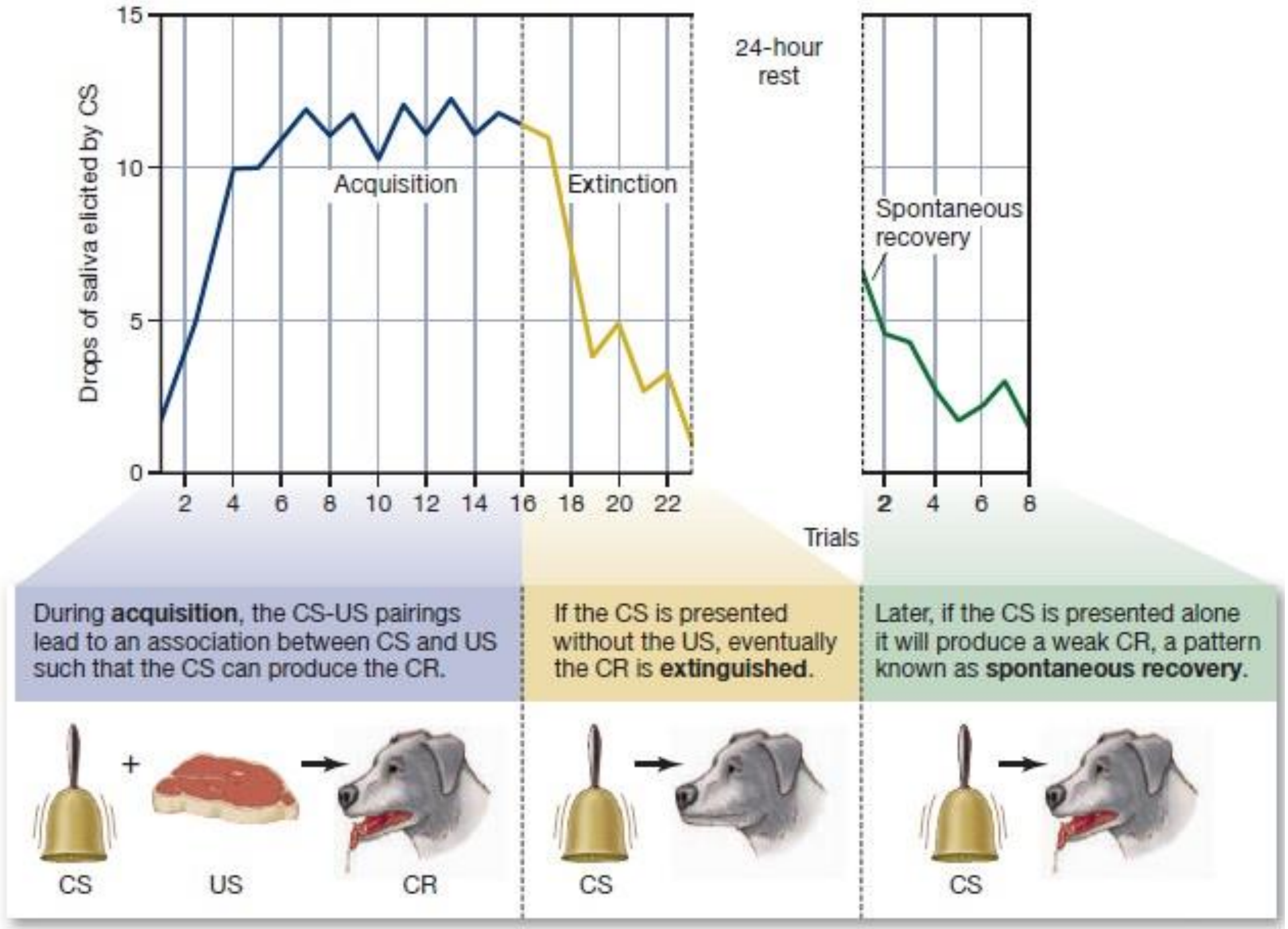
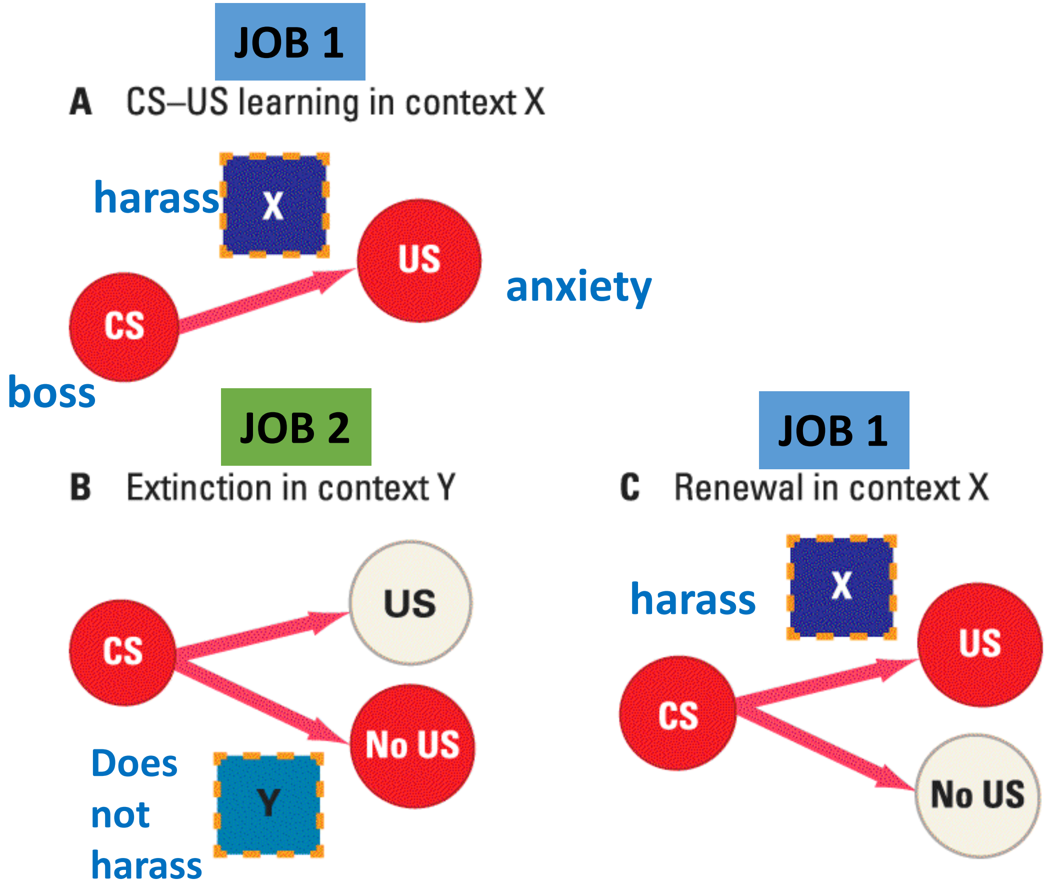


7.8 Extinction of a classically conditioned response The figure shows the decrease in the amount of saliva secreted (the CR) with increasing number of extinction trials—that is, trials on which the CS is presented without the US. However, if the animal then spends a little time away from the conditioning apparatus, the CR will reappear the next time the animal encounters the CS—a pattern known as spontaneous recovery.

Extinction

2. What if the employee changes the job?
    - Anxiety reduces/absent?

- Has the brain unlearned the association?
    - No, the original association is still there (memory trace)
    - The association (X) is suppressed (weakened)
    - Relearning occurs– makes another association (Y)
    - Employee visits old office or meets the ex-boss – anxiety behaviour reinstates – **spontaneous recovery** of the association



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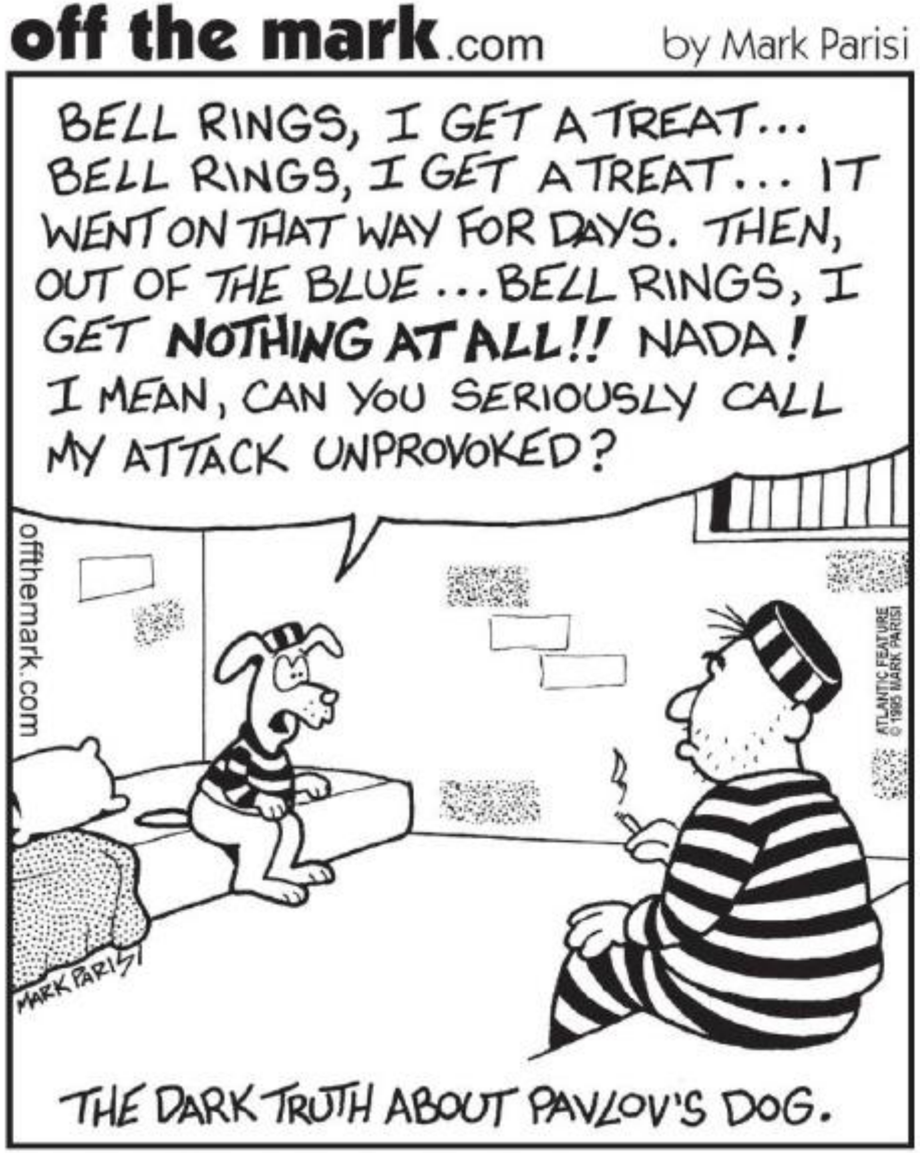
- Real life examples of extinction?



Mark Parisi/Atlantic Feature Syndicate

Rapid reacquisition

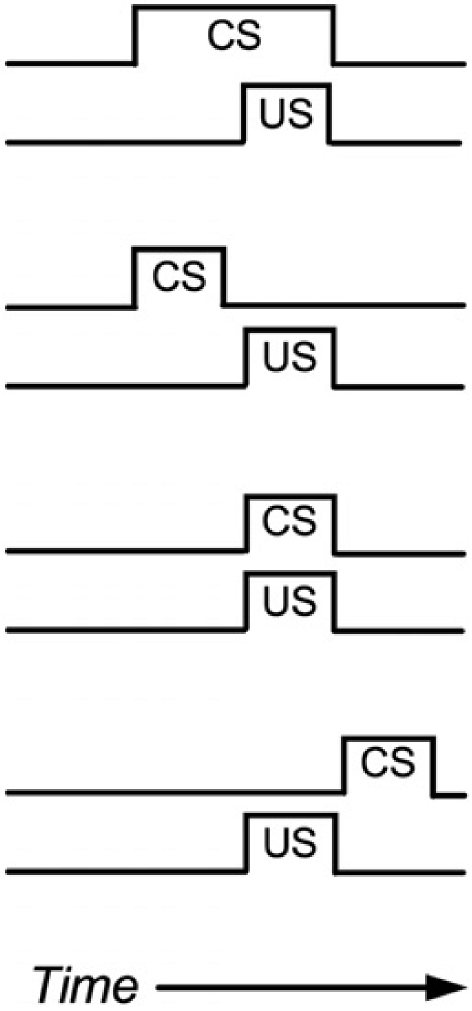
E.g. in the new office, if a colleague is uncooperative and prevents you from working efficiently

– anxiety returns very rapidly

The Informational Value of Cues

- Humans and animals are sensitive to the informational value of cues in determining which associations they do or do not learn

- Contiguity → closeness in time and space is necessary for learning a new association, such as that between a CS and a US



Delay

- Does not require the hippocampus to remember the CS
- Mid-brain+cerebellum needed
- Most effective
- CS predicts US

Trace

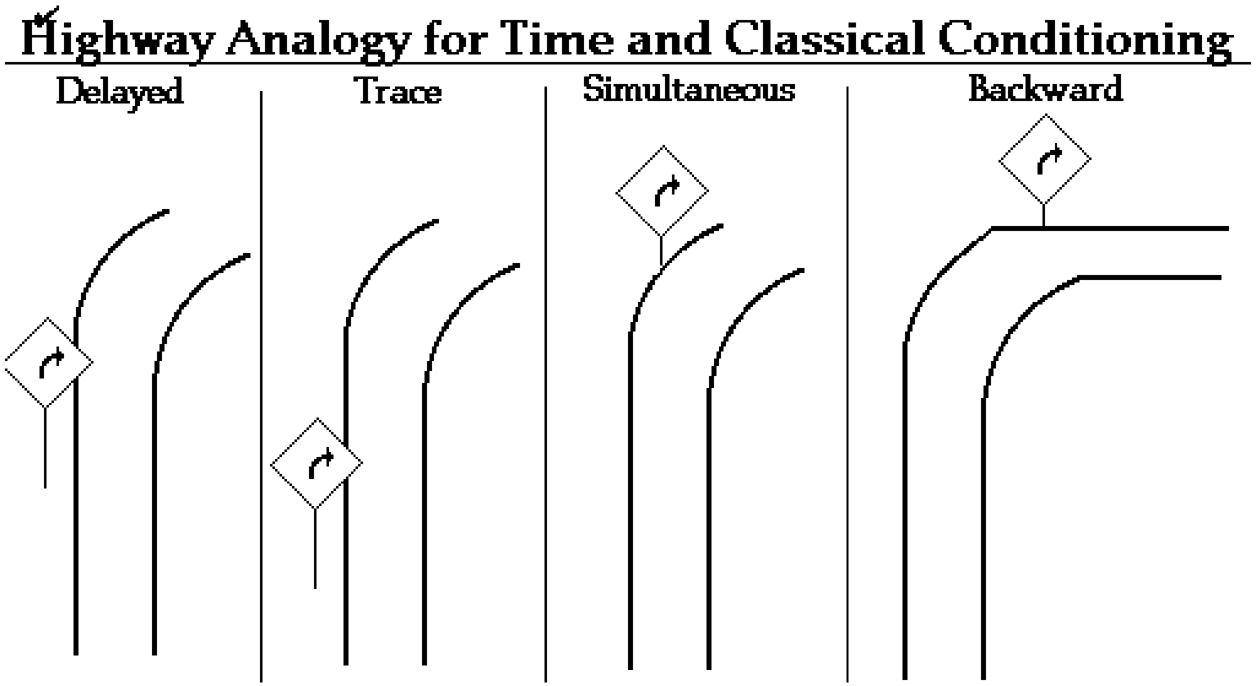
- Requires the hippocampus to remember the CS
- CS predicts US

Simultaneous

Not predictive
Weak association

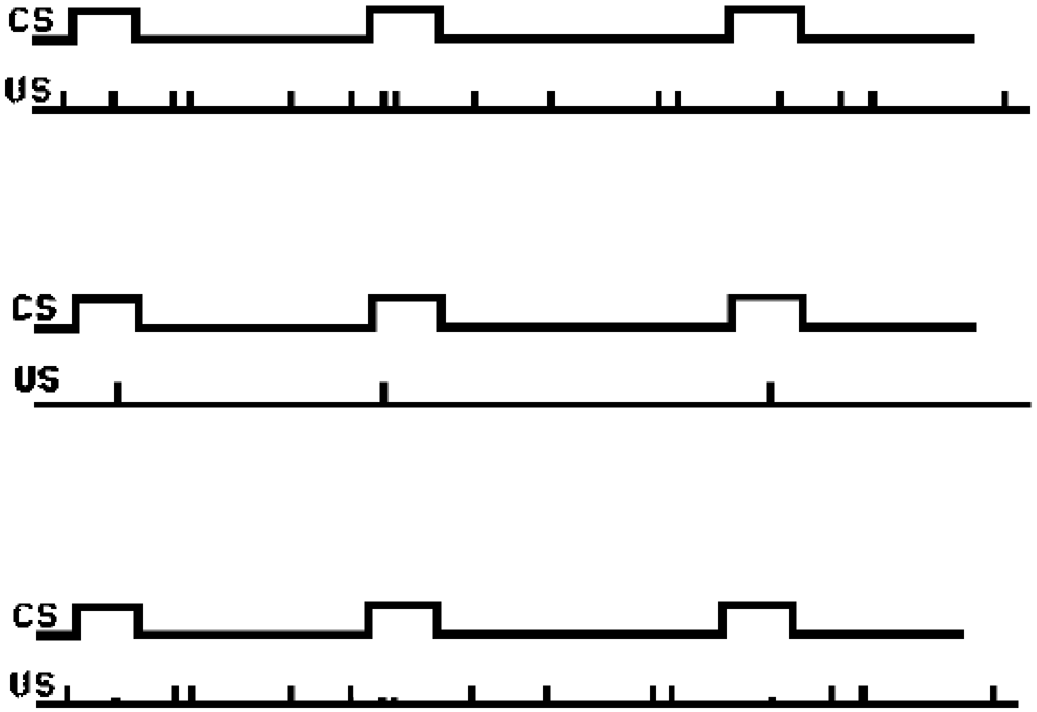
Backward

Not predictive
Weak association



http://peace.saumag.edu/faculty/kardas/courses/Learning/chapter2L.html

Schematic of Two Conditioned Stimulus/ Unconditioned Stimulus (CS/US) Relations That Share the Same Contiguity but Differ in the Information the CS Gives About the US



Conditioning occurs

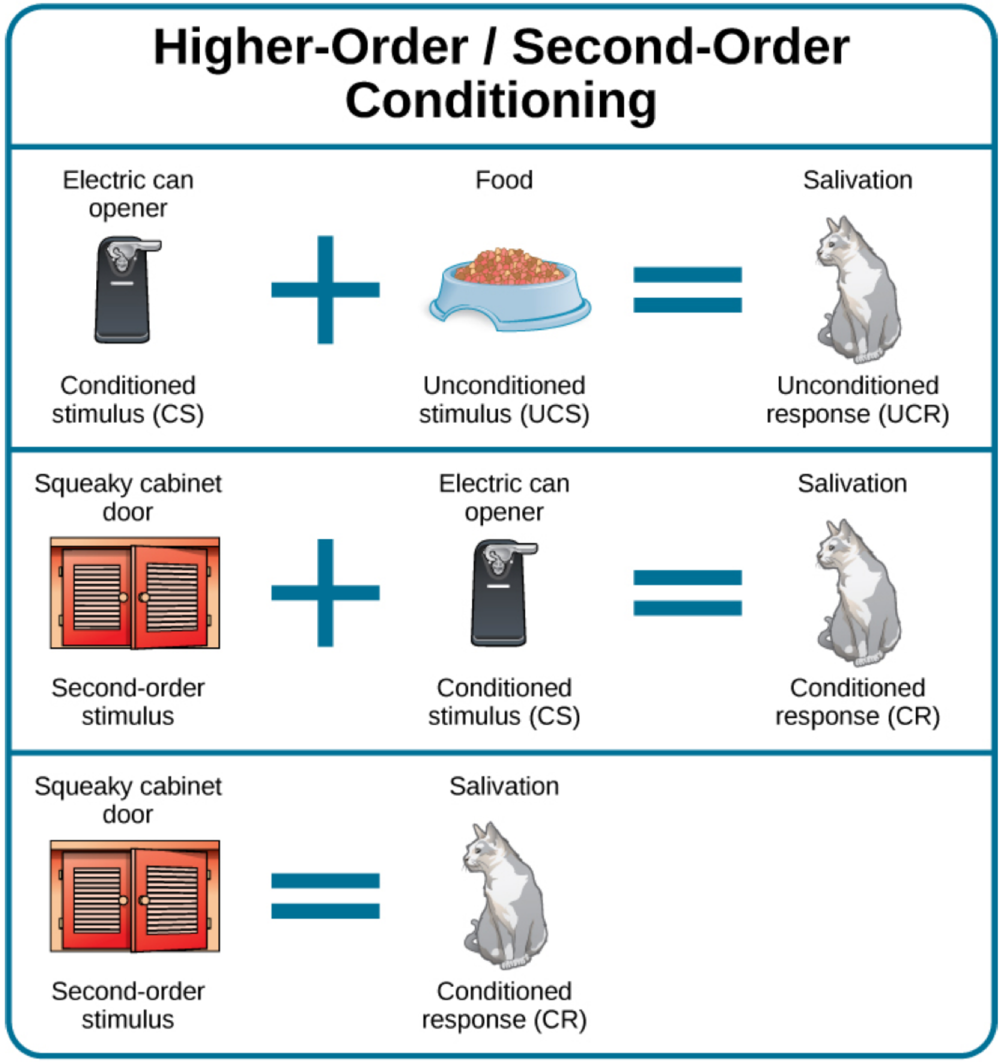
Conditioning may occur but may be weak

Conditioned inhibition

https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=02307d95d1ea9254c769b58051c06c3974f00eef

Conditioned inhibition

- Conditioned inhibition vs extinction?


Higher-Order / Second-Order Conditioning
Electric can opener
Food
Salvation
Conditioned stimulus (CS)
Unconditioned stimulus (UCS)
Unconditioned response (UCR)
Squeaky cabinet door
Electric can opener
Salivation
Second-order stimulus
Conditioned stimulus (CS)
Conditioned response (CR)
Squeaky cabinet door
Salivation
Second-order stimulus
Conditioned response (CR)

Learning to Predict..contd

Compound Conditioning and Overshadowing

- **Compound conditioning:** conditioning in which two or more cues are present together, usually simultaneously, forming a compound CS

Tone + light → eye-blink (CR)

Overshadowing: an effect seen in compound conditioning when a more salient cue within a compound acquires more association strength than does the less salient cue and is thus more strongly associated with the US

tone (loud) + light (dim)→ eye-blink

Tone (soft) + **light (bright)** → eye-blink

E.g. Packaging + Price → purchasing a product

Blocking effects

Group	Phase 1	Phase 2	Phase 3 (test)
Stock Prediction	Doris → stock market	Doris & Herman → stock market	*Hire Herman?* "No way; don't need him."
Medical Diagnosis	Janae eats chocolate → stomach ache	Janae eats chocolate & licorice → stomach ache	*Could the licorice be causing the stomach ache?* "Unlikely; Janae should enjoy licorice but avoid chocolate."

Kamin's Blocking Effect

Temporal Overshadowing:

Group	Phase 1	Phase 2	Phase 3 (test)
Control group	Rat sits in chamber; no training	Tone + light → eyeblink (CR)	Only light or only tone → medium CR
Experimental "pretrained" group	Tone → eyeblink	Tone + light → eyeblink (CR)	Only Tone → typical CR only light → little or no CR (learning is "blocked" for light's predictive value)

For a stimulus to become associated with a US, and become a CS, it must impart reliable, useful, and nonredundant information

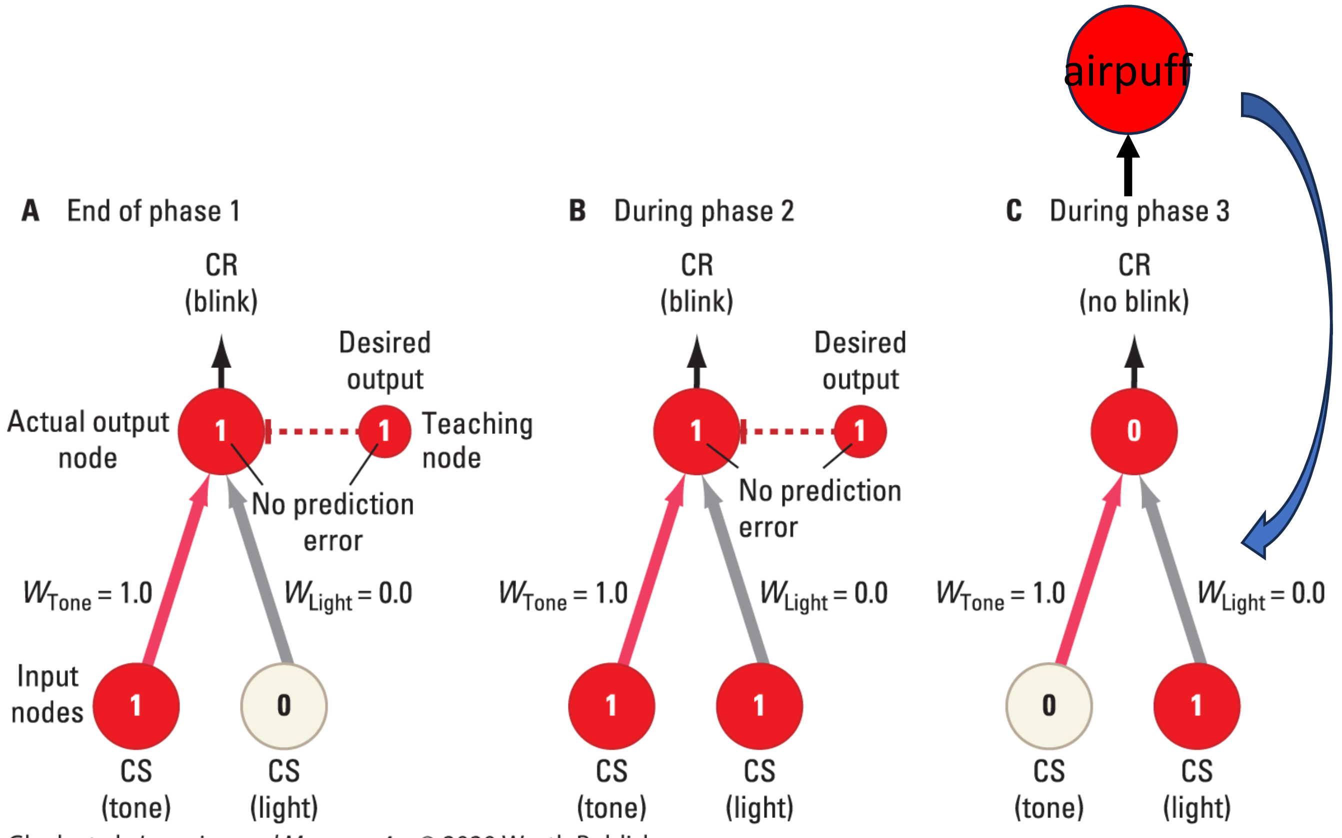
The ability of the light to predict eye-blink is lowered or lost

cues appear to compete with one another for associative strength.

The Rescorla–Wagner Model for Blocking

Group	Phase 1	Phase 2	Phase 3 (test)
Experimental "pretrained" group	Tone → eyeblink	Tone + light → eyeblink (CR)	Only Tone → typical CR only light → little or no CR (learning is "blocked" for light's predictive value)

- changes in CS–US associations on a trial are driven by the discrepancy (or error) between the animal's expectation (or prediction) of the US and whether the US actually occurred
- This error is sometimes referred to as the **prediction error**
- weights associated with one cue can indirectly influence the weights accruing to other, co-occurring cues
- Made surprising predictions about how animals would behave in *new* experimental procedures



Rescorla–Wagner model

Error correction and response

Conditioning error	R–W model response	Tennis error	Herman's response
Positive error: CS predicts nothing or too little, but US unexpectedly occurs or is unexpectedly strong	Increase association	Ball falls short	Increase strength of serve
No error: CS predicts US, and predicted US occurs	No new learning	Ball lands perfectly	Do same thing next time
Negative error: CS predicts US, but no US occurs	Decrease asso-ciation	Ball goes too far	Decrease strength of serve

Modify weight/strength of associations to reduce error

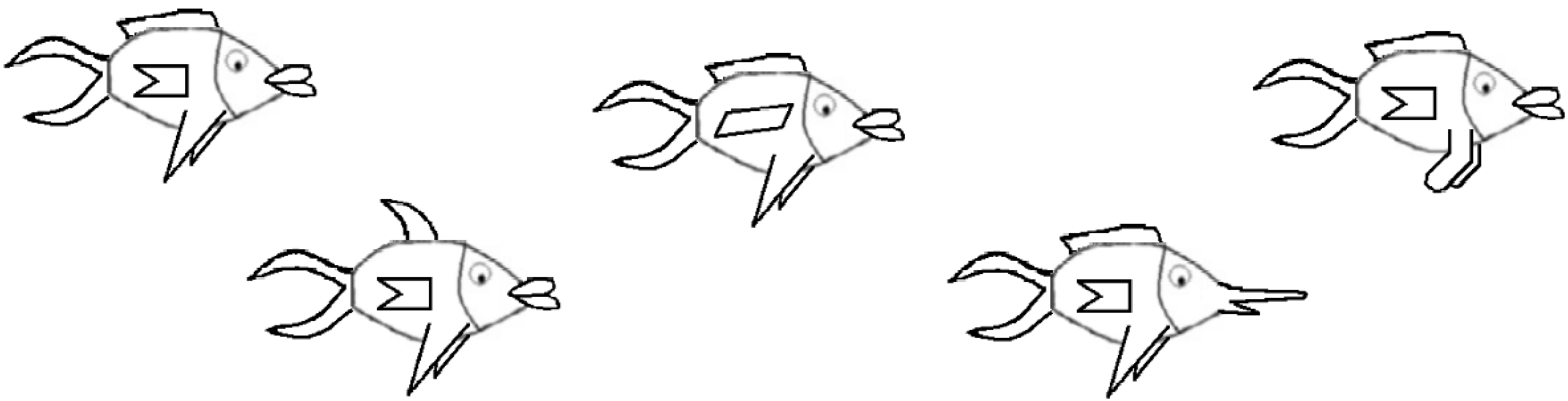
- Classical conditioning → event prediction → error prediction → ?

(lower order cognition)
Fewer cues to compete for CS

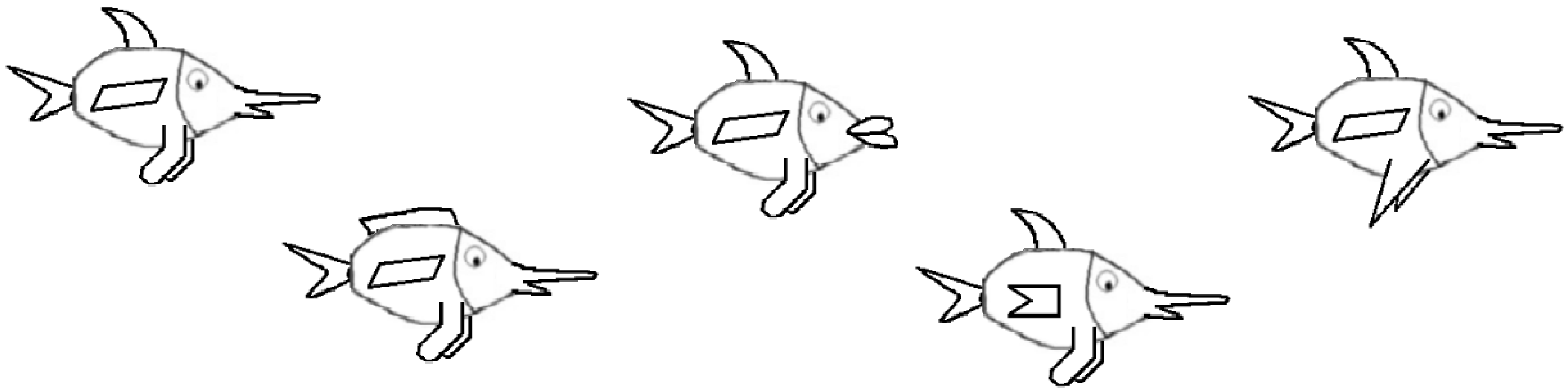
(multiple cues - higher order cognition)
Trial and error?

speech recognition,
category learning

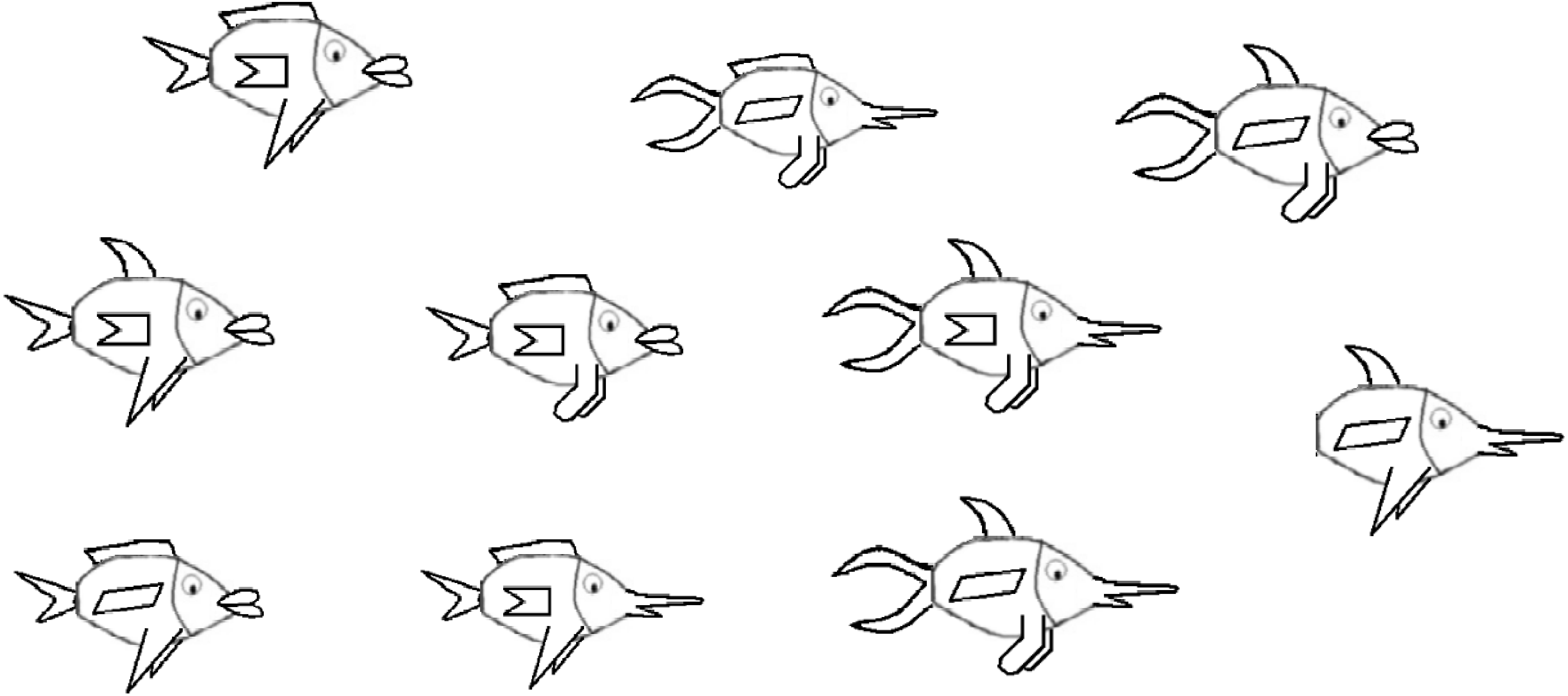
Category A



Category B



Which category?



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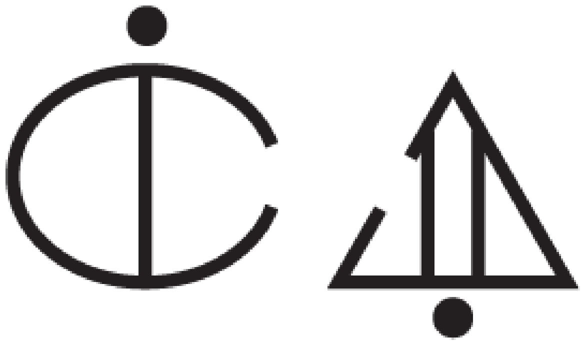
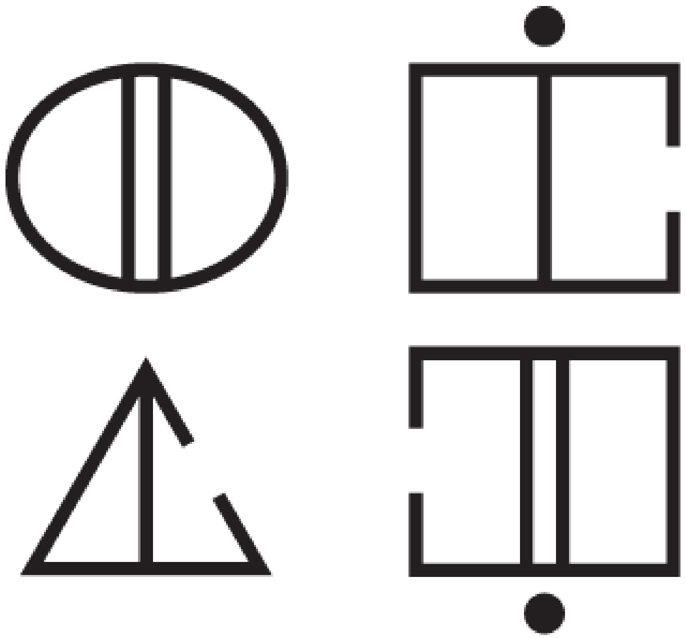
A Phase 1 training

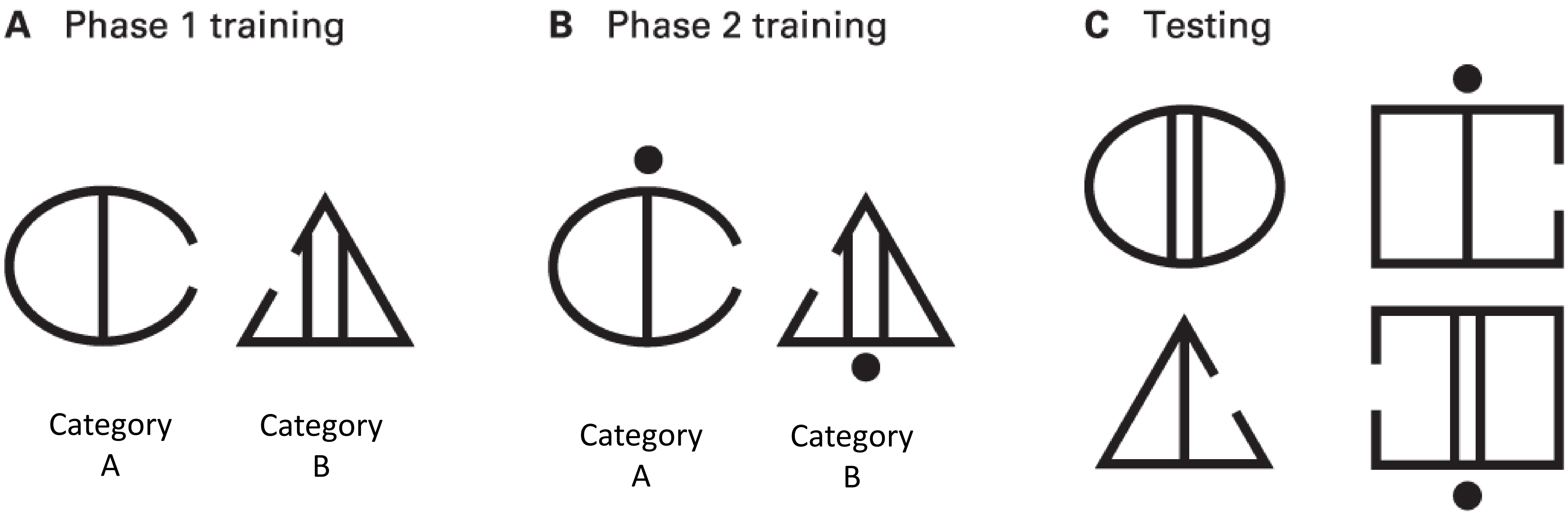
B Phase 2 training



C Testing

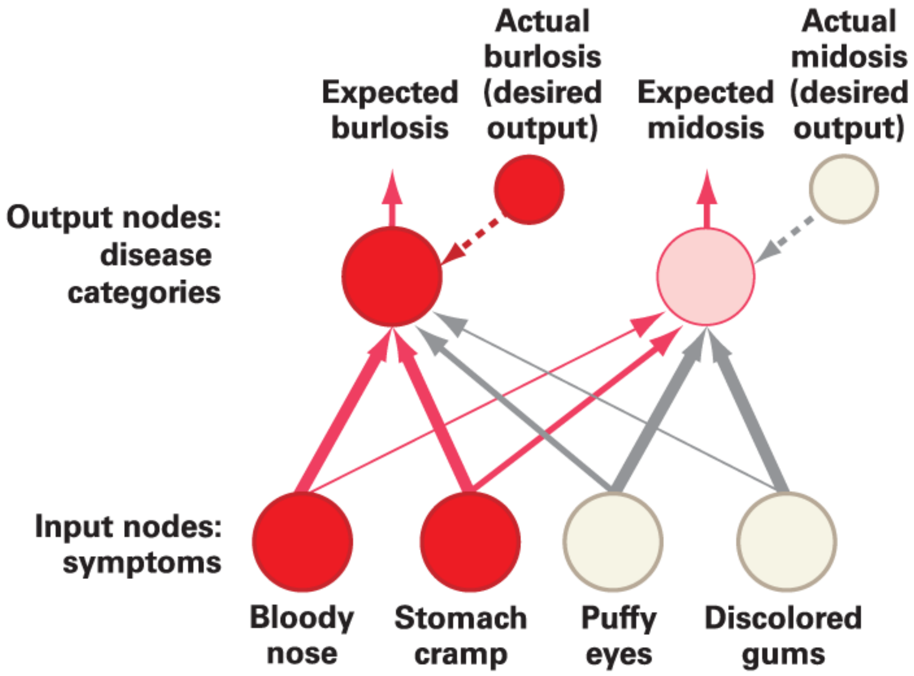


Category Learning Task – redundant cues – blocking effect?

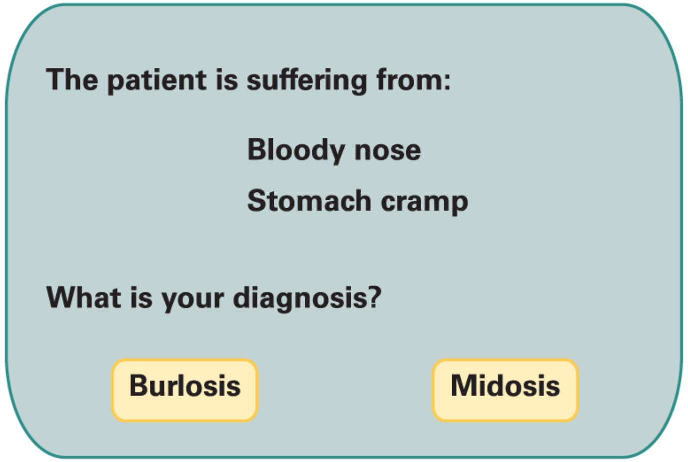


Gluck and Bower’s Probabilistic Categorization Task

Using error correction to understand predictive nature of cues



Gluck et al., *Learning and Memory*, 4e, © 2020 Worth Publishers



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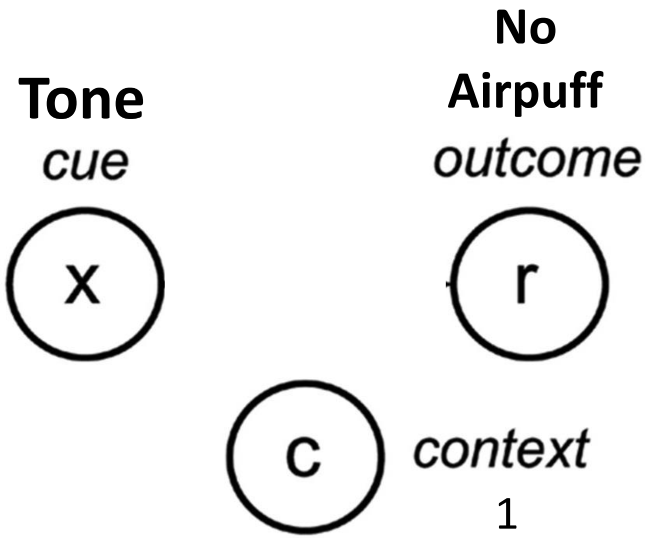
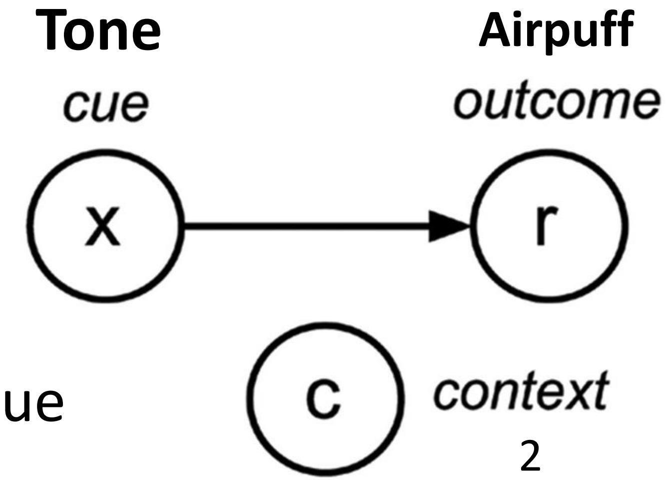
The same basic network model used by Rescorla and Wagner but the main difference is that the disease-category learning model has more possible outcome categories and more possible input cues.

On a particular learning trial, a research participant would see a listing of symptoms (e.g., bloody nose and stomach cramps), make a diagnosis, and then be given feedback about whether the diagnosis was correct

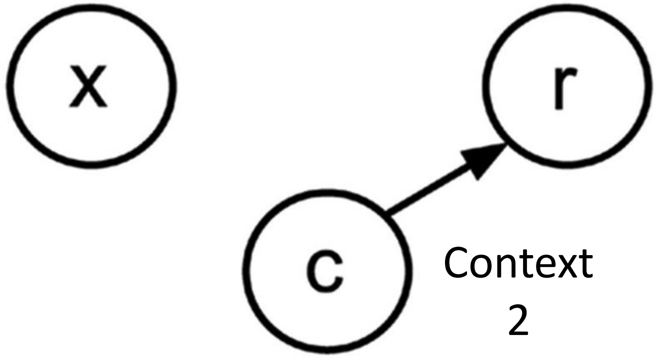
The model correctly predicted the percentage of participants who would classify each of the 14 possible symptom charts as being midosis versus burlosis; it also predicted how well the participants were later able to make judgments about the probabilities of the two diseases when they knew only one of the symptoms.

Cue–Outcome Contingency - causal inference





Tone is not a reliable cue



Risk of Lung Cancer Increases
But rate of smoking is the same

Smoking is not a reliable indicator of lung cancer.

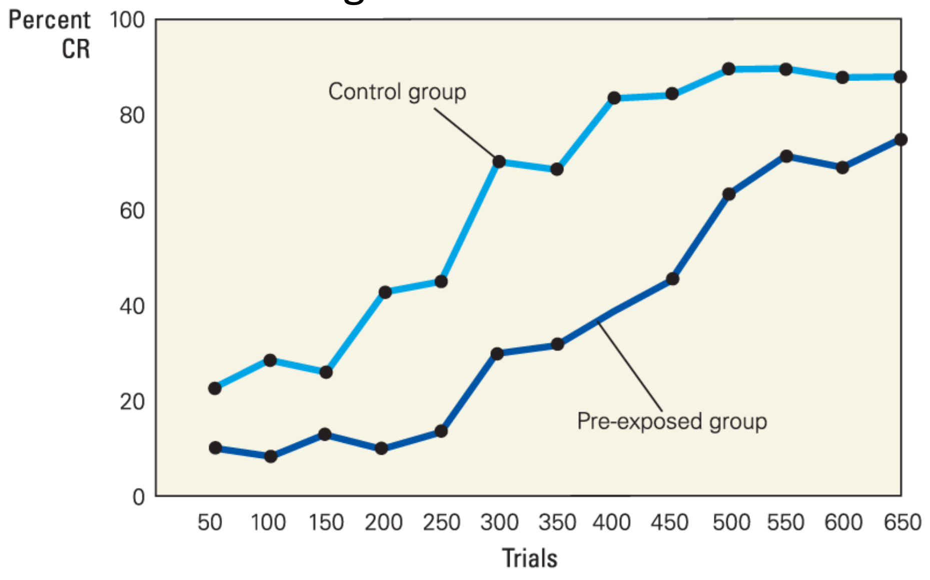
The Latent Inhibition

Group	Phase 1	Phase 2
Control group	No activity	Tone CS → airpuff US
Experimental "pretrained" group	Tone → but no airpuff	

Difference?

- **Error prediction (Rescorla Wagner) model failed to account for the latent inhibition**

prior exposure to a CS retards later learning of the CS–US association



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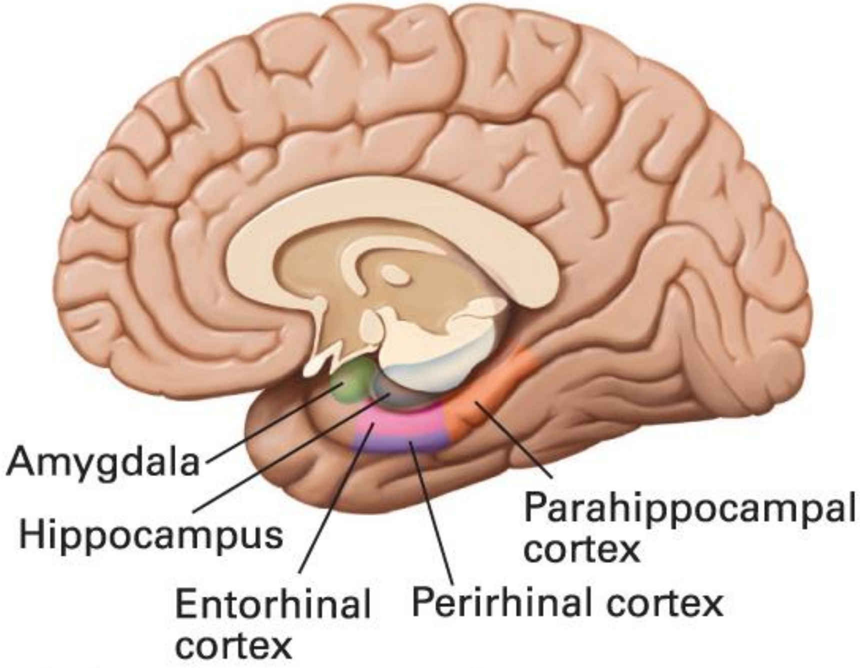
Latent Inhibition in Rabbit Eyeblink Conditioning



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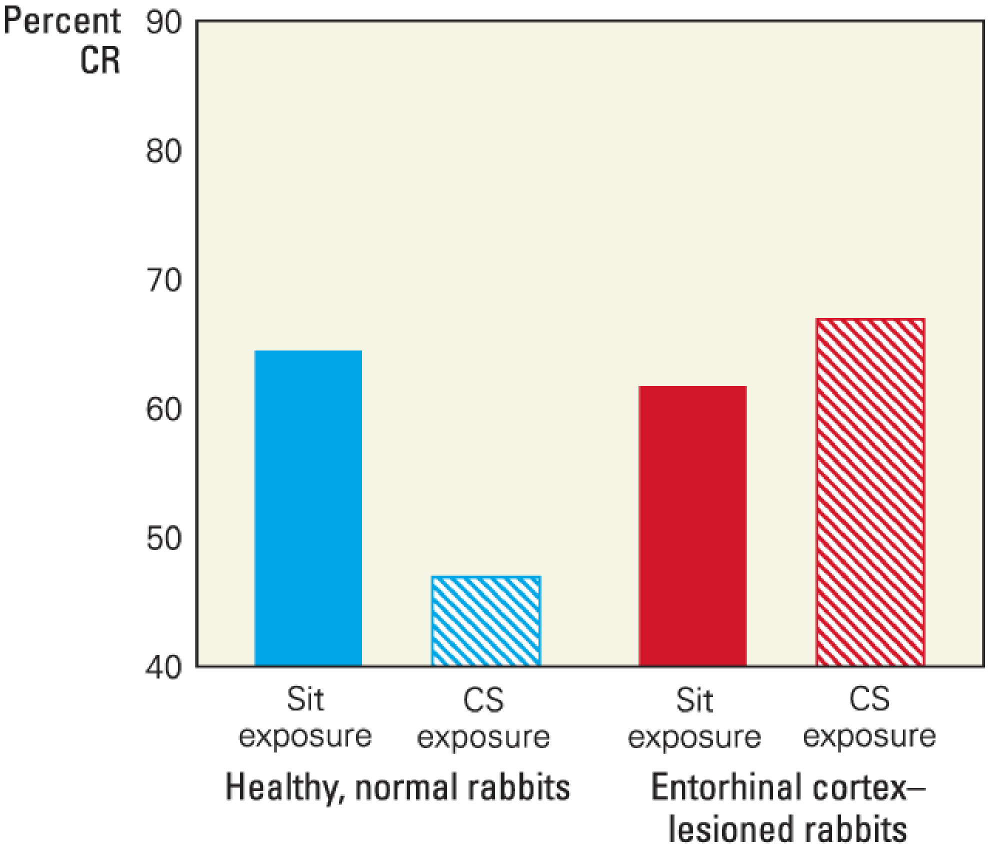


Gluck et al., *Learning and Memory*, 4e, © 2020 Worth Publishers

- People without a hippocampus do not show latent inhibition

Attentional Approach to Stimulus Selection

- **US modulation theory:** unexpected arrival of US (eyeblink) after a CS (tone)

(Example: Rescorla–Wagner model) – could not explain latent inhibition

- **CS modulation theory:** CS becomes associated to US because of the attention given to it and how it is processed

(Example: Mackintosh model)

- *people and animals have a limited capacity for processing incoming information (Mackintosh, 1975). This limited capacity means that paying attention to one stimulus diminishes (and hence modulates) our ability to attend to other stimuli.*

We all receive a constant stream of stimuli throughout the day — sights, sounds, smells, etc. A person with a normal level of latent inhibition is able to tune out the information that experience has shown to be irrelevant. Someone with *low* latent inhibition, however, doesn't do that as well. He or she pays attention to what can become a overwhelming amount of stimuli.

People with low latent inhibition tend to be easily distracted, which can lead to a diagnosis of ADHD. In more extreme cases, low latent inhibition manifests as psychosis (a mental disconnect from reality). In fact, during the early stages of schizophrenia, a chemical change occurs in which latent inhibition disappears.

But it turns out there's a good side to low latent inhibition, too. In people with high intelligence and good working memory (an ability to think about many things at once), it can lead to original ideas and creative achievement.

https://www.hopementalhealth.com/blog/latent-inhibition-filtering-out-the-madness

- A recovering drug addict attends therapy sessions in which cue-exposure therapy is used. The addict is exposed to drug-related stimuli (e.g., photos of common drug-taking environments, drug paraphernalia) in the therapy center several times a week for an extended period of time.
- Why might this treatment fail?

Extinguishing a Drug Habit

- Addiction can be partially reduced through Pavlovian extinction: rats that became addicted to alcohol showed significant extinction through repeated nonreinforced exposure to experimentally manipulated cues that had previously been paired with administration of alcohol

Extinguishing a Drug Habit

- Outside the laboratory it can be extremely difficult to extinguish a habit
- Boulton’s work suggests three principles that can help guide anyone trying to extinguish a habit or an association
  - The extinction training should be spread out over time, rather than conducted all at once
  - Whenever possible, the cue-exposure therapy should take place in the same contexts in which the original drug habits were acquired

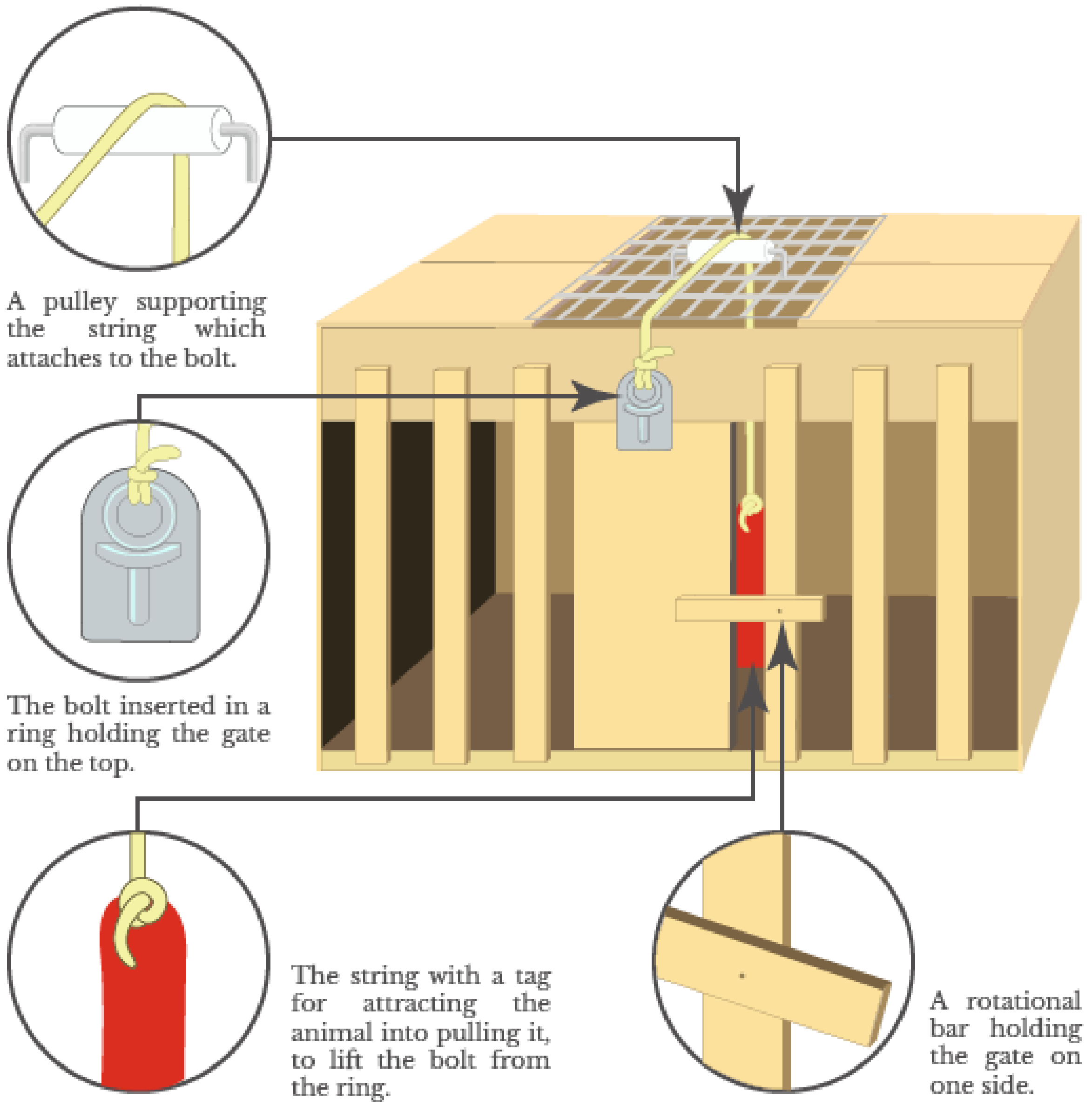
Learning the outcome of behaviour

- Military dogs sniffing bombs
- Washing hands before a meal
- Submitting projects within deadline

- How do we learn new behaviours?

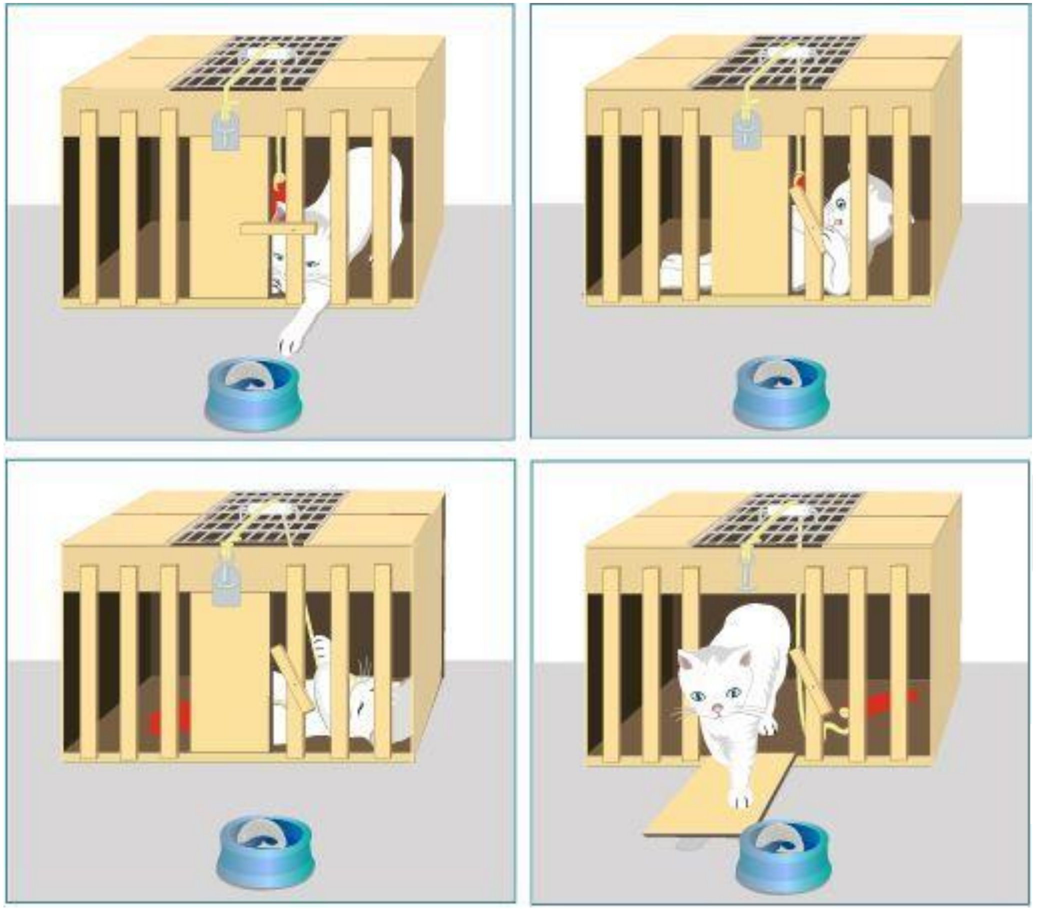
operant conditioning
The process whereby organisms learn to make or to refrain from making certain responses in order to obtain or avoid certain outcomes.

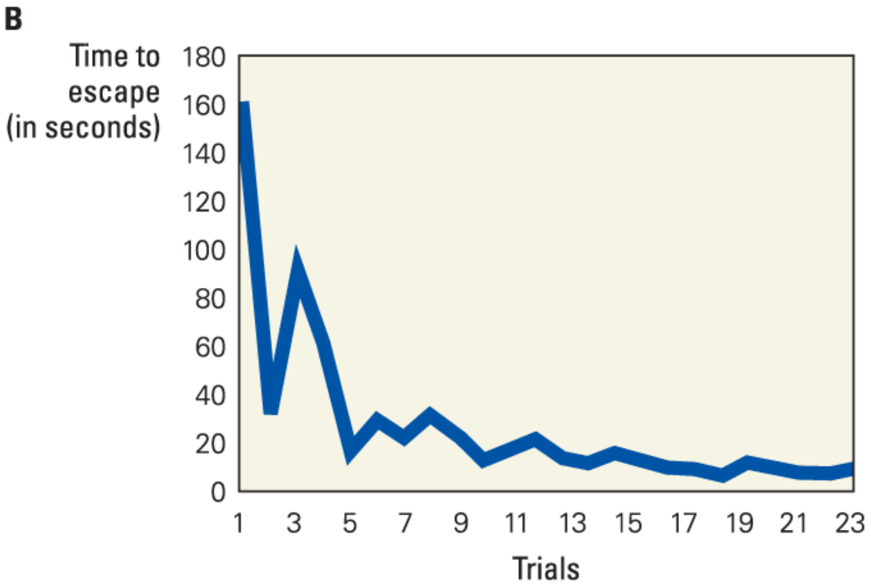
Operant conditioning box used in early experiments by Edward Thorndike



Operant or Instrumental conditioning

- The learning is called "operant" because the organism "operates" or is "instrumental" in taking an action for an outcome to occur.

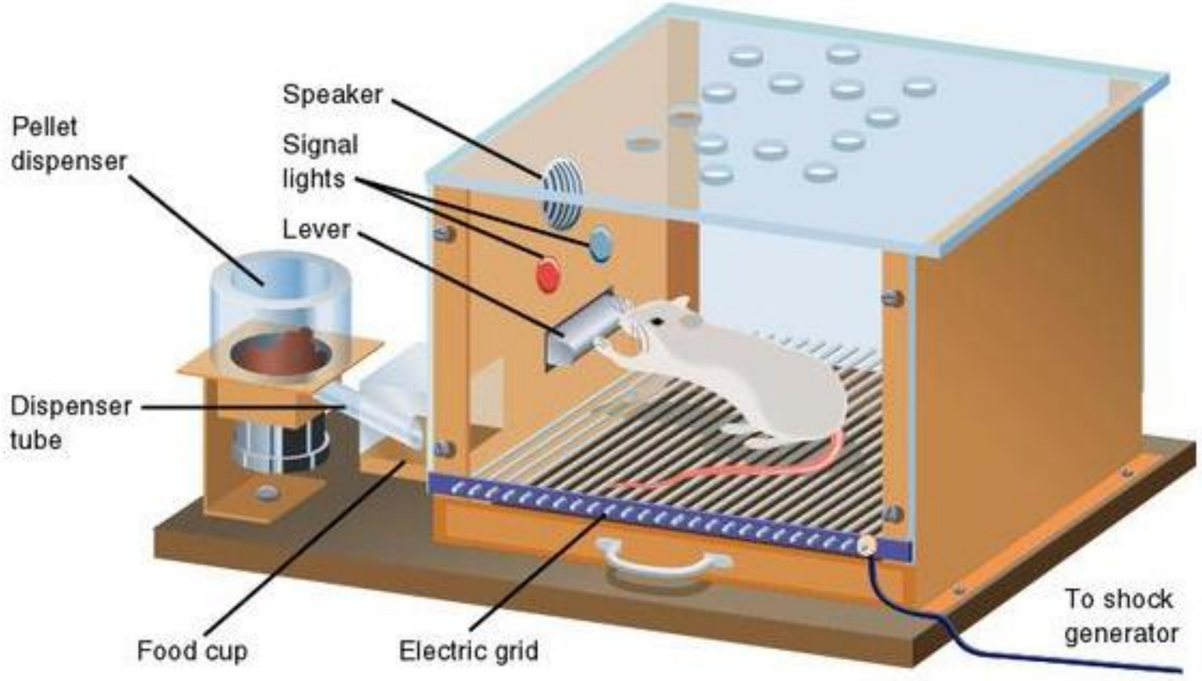




Edward Thorndike's cat puzzle box experiment

Skinner’s box

free-operant paradigm
An operant conditioning paradigm in which the animal can operate the apparatus as it chooses in order to obtain reinforcement (or avoid punishment).



lever presses (R) → food (O)

Skinner's box

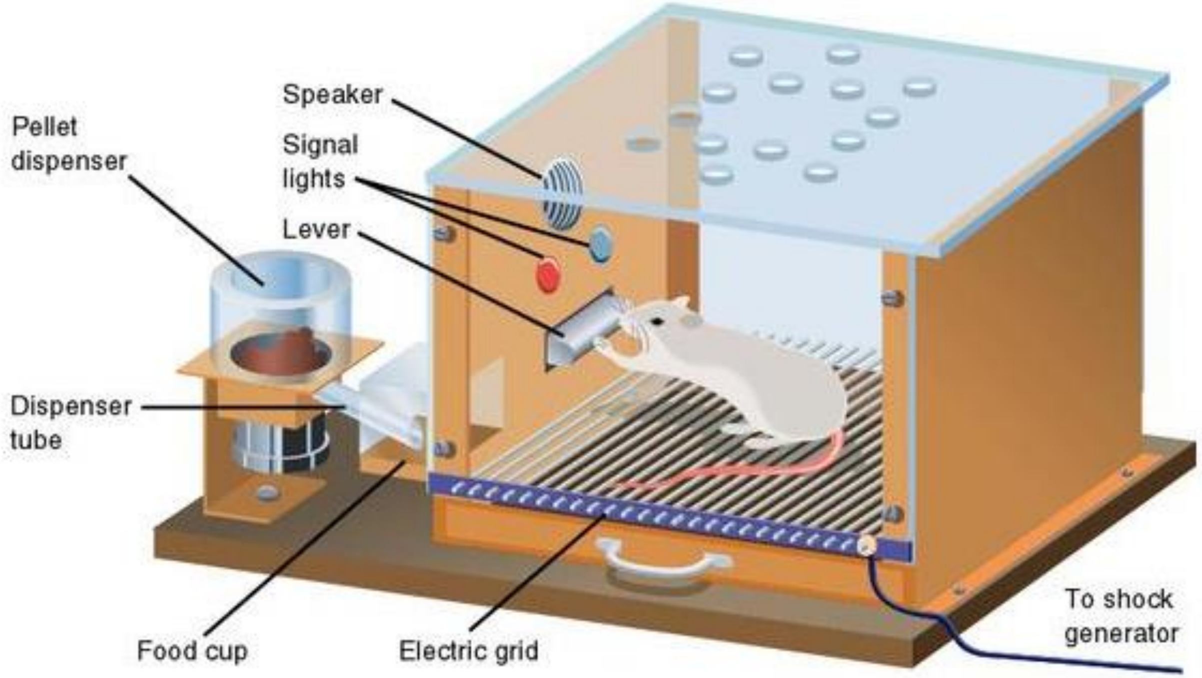
free-operant paradigm
An operant conditioning paradigm in which the animal can operate the apparatus as it chooses in order to obtain reinforcement (or avoid punishment).

lever presses (R) → food (O)

Discriminating stimulus → light

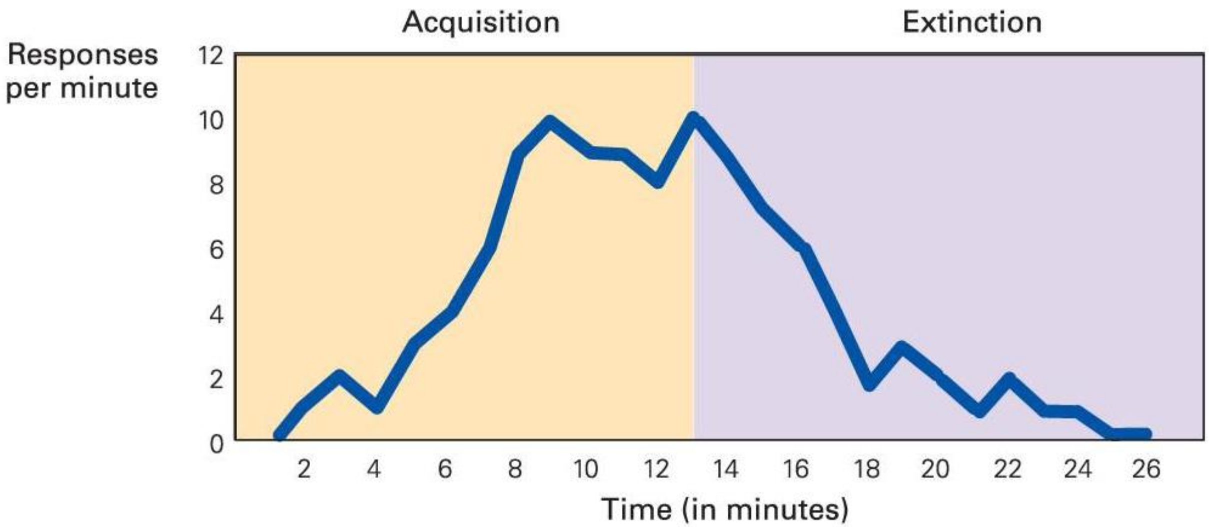
Light ON (SD) → lever presses (R) → food (O)

Light OFF (SD) → lever presses (R) → no food (O)



Light ON

Light OFF



Real life examples?

Exam hall

Breakdown of Behavioral Processes

- In the presence of a particular stimulus, called the **discriminative stimulus (S^D)**, a particular response (R) may lead to a particular outcome (O)

- Operant conditioning can be formulated as a three-part association
  - **Discriminative stimulus S^D → Response R → Outcome O**

- S^D is the puzzle box
- R is the sequence of movements needed to open the door,
- O is the escape

- The S^D → R association is strengthened when R is followed by a desirable outcome O

- How is operant conditioning different from classical conditioning?

Let’s look a few examples….

- In old apartment buildings of Mumbai, whenever someone flushes the toilet, the shower water becomes scalding hot. The hot water made Raghu flinch the last time in was in the shower. Now he flinches whenever he’s in the shower and hears the noise of flushing.

classical conditioning
CS – toilet flushing sound
US – hot water
CR - flinching

Context dependent classical conditioning
CS – toilet flushing sound while taking a shower
US – hot water
CR - flinching

Since retiring, Col. Singh spends a lot of time sitting on his back porch, watching the birds and whistling everyday. One day, after whistling he throws crumbs, and birds come and eat them. The next day, he sits and whistles and throws crumbs, and the birds return. After a few days, as soon as Col. Singh sits outside and starts whistling, the birds arrive.

Whistling is the discriminative stimulus (SD),
birds arriving is the learned response (R),
and birds eating the crumbs is the outcome (O).

The birds do not get the crumbs (O) unless SD is present and they make response R, so this is operant conditioning.

- Kabir’s dog Snoopy is afraid of thunder. Snoopy has learned that lightning always precedes thunder, so whenever Snoopy sees lightning, he runs and hides under the bed

- Ashwin has accepted a new job close to home, and now he can walk to work. On the first morning, there are clouds in the sky. It starts to rain and Ashwin gets wet while walking to work. The next morning, there are again clouds in the sky. Ashwin brings his umbrella along, just in case, and does not get wet. Ashwin carries his umbrella to work on days the sky looks cloudy.

Presence of clouds is the discriminative stimulus (SD),
bringing the umbrella is the learned response (R),
and staying dry is the outcome (O).

The outcome (O) does not occur unless SD was present and Ashwin brought his umbrella (R), so this is operant conditioning.

- In all examples discussed so far, there is an SD (discriminating stimulus)

- What happens in the absence of SD?

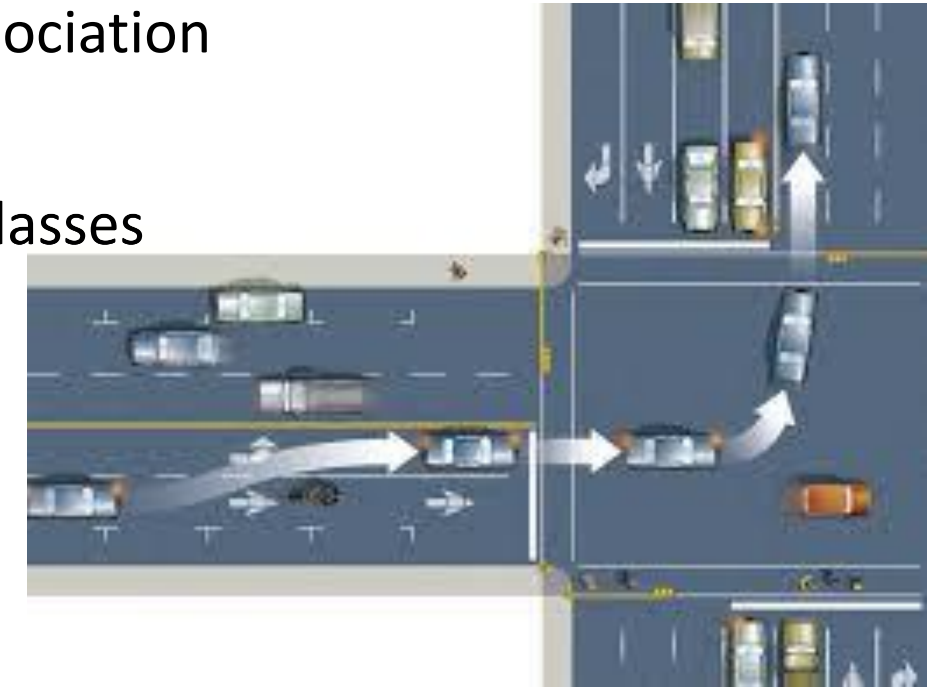
Swimming Race

S (starting whistle) ➔ R (dive) ➔ O (good start in the race)

R (dive) ➔ S (starting whistle) ➔ O (?)

Too Strong **Discriminative stimulus S^D → Response R** association

Habit



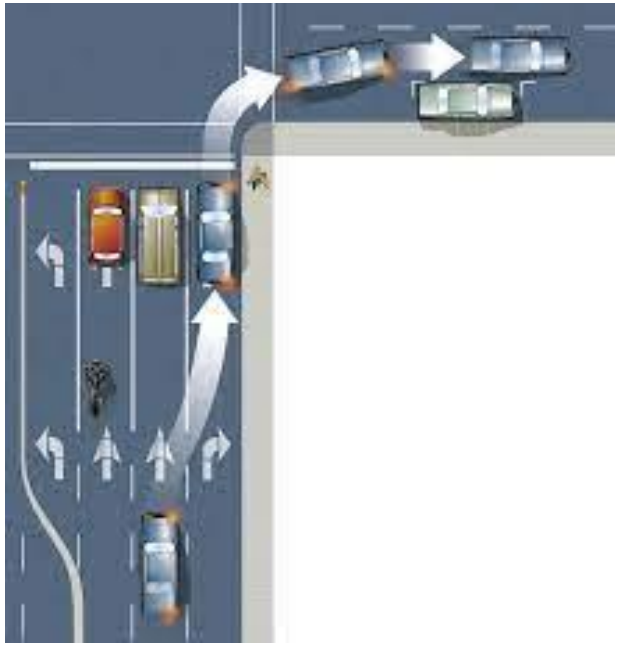
- Alarm rings on Sunday morning and you get ready for classes

Strong S ➔ R association

Automatic response (R) in the presence of SD

Strong operant conditioning can cause errors

Example?



Left side (India) vs right side (US) driving

Shaping Behaviour

Service dog helps a blind man cross a busy city street. How are these dogs trained?

Go to end of road → stop → wait for a green traffic light → check for oncoming cars → use zebra crossing to walk across

By reinforcing (rewarding) behaviour/every action that adds up

More examples?

Disciplining children at home – HW then play
Teaching autistic children to speak

What is a reinforcer?

- Possible reinforcers in real life?

- Reinforcement can be positive or negative
  - Positive reinforcement → increase outcome by encouraging a particular behaviour
  - Negative reinforcement → decrease outcome by encouraging a particular behaviour

Primary Reinforcers

- Food, water, sleep, comfortable temperatures, and sex
- Innate biological need to survive and thrive.
- Behaviours that provide access to these things or conditions are repeated
- Not all reinforcers are equal in value – only if you are hungry, food is a reinforcer.

If you are hungry but not thirty water loses its reinforcement power → conditional reinforcement

If you were expecting warm/hot food drink but were instead offered cold food,the value of reward decreases → negative contras

Secondary reinforcers

Money → food, water, shelter, etc.

Tokens (access to privileges) → prisons, grades/GPA, positions of power

Operant + classical conditioning

S (odor of bomb) ➔ R (sniff and hold) ➔ O (click sound) → food

S (no odor of bomb) ➔ R (sniff and hold) ➔ O (no clicker) → no food

O (clicker) → food

Some click sounds are rewarded with food while some are not?

Reward seeking behaviour lasts longer
Animals are kept partially hungry to perform the behaviour

Punishers?

- Social/parental disapproval
- Rejection
- Monetary fines
- Pain
- Serving jail time

- Does punishment produces the opposite effect of reinforcement ?

Punishment can lead to variable behavior

- Discriminative stimuli for punishment can encourage cheating…example?
  - Police absent → speeding → no punishment
  - Police present → speeding → punishment (fine)
  - Police present → speeding suppressed (avoid punishment)
  - Speeding behaviour is not altered

- Concurrent reinforcement can undermine the punishment
  - Thrill of breaking rules and driving fast near a policeman

- Initial intensity matters
  - Police present → speeding → punishment (very heavy fine)
  - Higher probability of reducing speeding behavior

Instead reinforce (desired behaviour) slow driving – give incentives for slow/careful riving

Other examples?

Reinforcing good behaviour in children instead of punishment

Appreciate doing homework or good behaviour in class

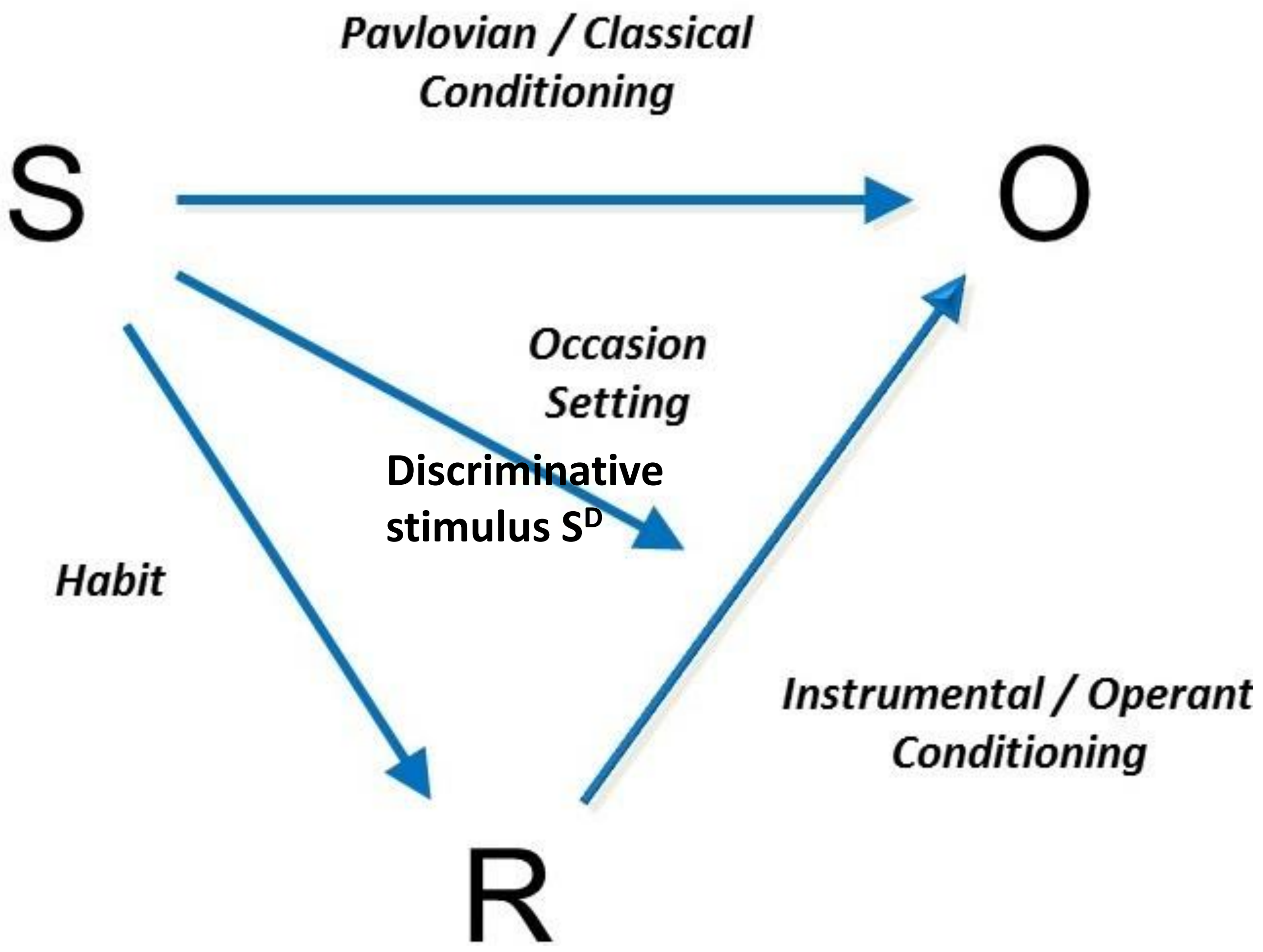
Anxiety -> Smoking
Fear -> Dog running under the bed

Coping mechanisms to overcome the body's natural response to CS

	Classical Conditioning	Operant Conditioning
Basic Idea	Organism associate events	Organisms associate behaviors and resulting events
Response	Involuntary, automatic	Voluntary, operates on environment
Acquisition	Associating events, NS is paired with US and becomes CS NS - Neutral stimulus	Associating response with a consequence (reinforcer or Punisher)
Extinction	CR decreases when CS is repeatedly presented alone	responding decreases when reinforcement stops
Spontaneous Recovery	The reappearance, after a resting period, of an extinguished CR	the reappearance, after a resting period, of an extinguished response
Generalization	the tendency to respond to stimuli rather than to the Cs	organism's response to similar stimuli is also reinforced
Discrimination	the Learned ability to distinguish between the Cs and other stimuli that do not signal a US	organism learns that certain responses,but not others, will be reinforced

Classical vs Operant conditioning

	Classical conditioning	Operant conditioning
Nature of response	Involuntary (reflexive)	Voluntary (usually) but can be both – Vol & Involuntary
Timing of Stimulus	Precedes the response	After the desired response
Timing of Response	After the stimulus	Before the stimulus
Role of learner	Passive	Active



https://nobaproject.com/modules/conditioning-and-learning#:~:text=Classical%20and%20operant%20conditioning%20are,occur%20at%20the%20same%20time.

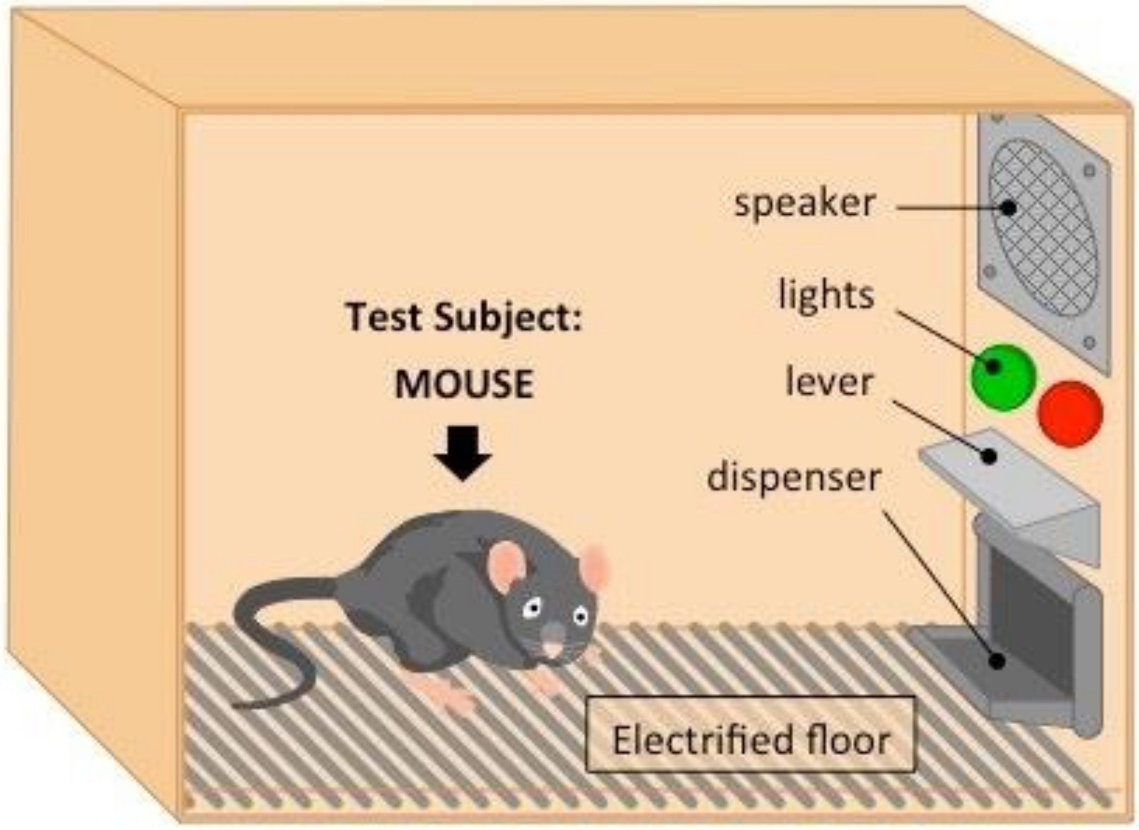
Predicting reward

- Getting a challan/ticket for speeding

vs

- License suspension for 1 year for DUI of alcohol.

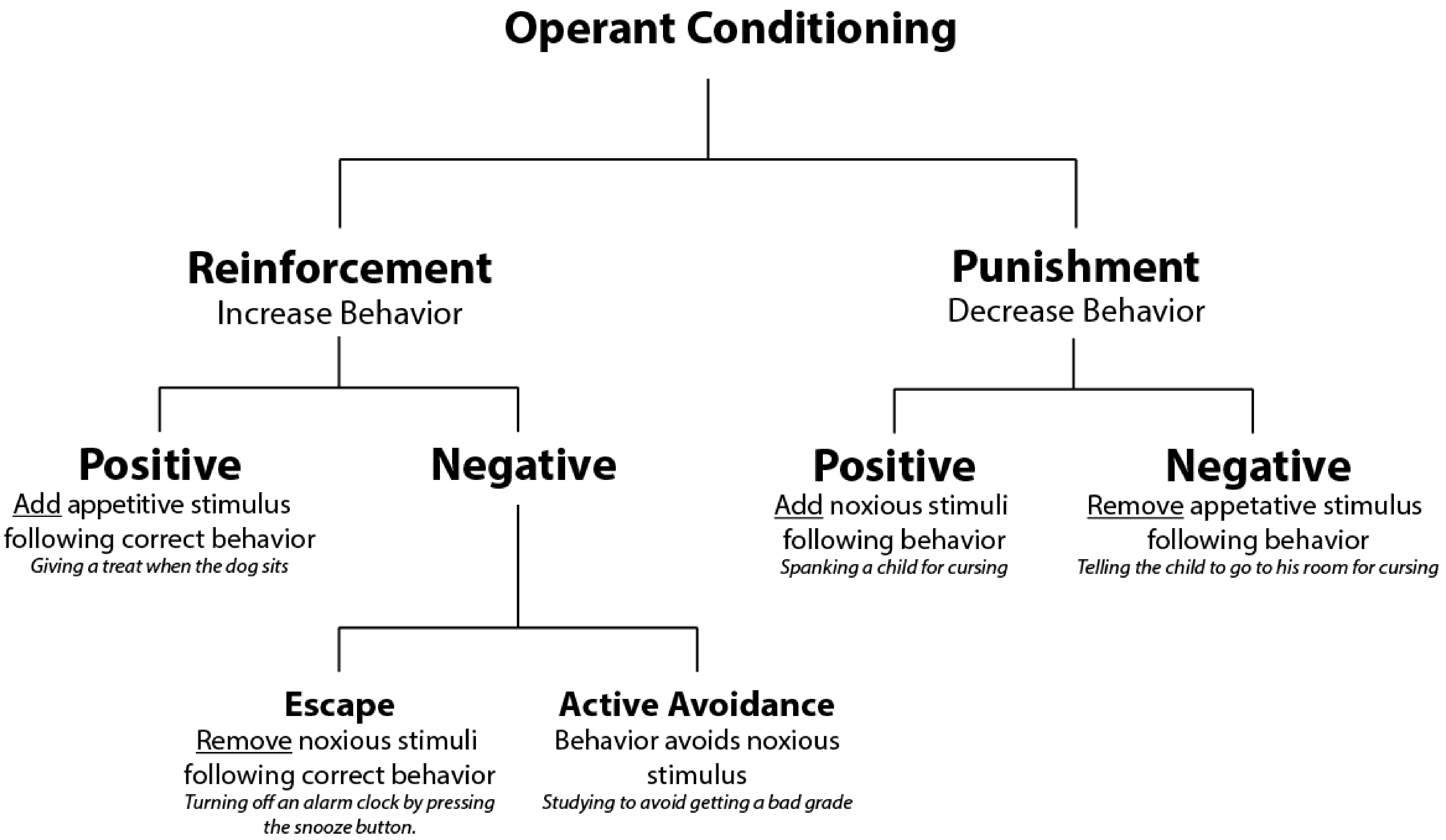
Skinner’s experiments



	Something **given** to the mouse	Something **taken** from the mouse
Increases likelihood of repeated behavior	**POSITIVE REINFORCEMENT** Mouse given food when lever pressed (after green light)	**NEGATIVE REINFORCEMENT** Loud noise stopped when lever pressed
Decreases likelihood of repeated behavior	**POSITIVE PUNISHMENT** Mouse is shocked when lever pressed (after red light)	**NEGATIVE PUNISHMENT** Not applicable in this scenario

Operant Conditioning Paradigms

	Something is given (positive)	**Something is taken away (negative)**
Increases response or behaviour (reinforcement)	Positive reinforcement Example: Clean room → get appreciation	Negative reinforcement (escape/avoidance training) Example (escape): Take aspirin → headache goes away Example (avoidance): Studying hard to avoid failing in exams
Decreases response or behaviour (punishment)	Positive punishment Example: (penalty/fine) → reduce driving speed	Negative punishment (omission training) Example: Fight with other children → time-out from play License suspension for 1 year for DUI of alcohol.


Operant Conditioning
Reinforcement
Increase Behavior
Punishment
Decrease Behavior
Positive
Add appetitive stimulus following correct behavior
Giving a treat when the dog sits
Negative
Positive
Add noxious stimuli following behavior
Spanking a child for cursing
Negative
Remove appetative stimulus following behavior
Telling the child to go to his room for cursing
Escape
Remove noxious stimuli following correct behavior
Turning off an alarm clock by pressing the snooze button.
Active Avoidance
Behavior avoids noxious stimulus
Studying to avoid getting a bad grade

At the grocery store, 2-year-old sees chocolates and wants it. Her mother says no, and the girl throws a tantrum. To calm her down, the mother relents and buys girl chocolates. The next time they go shopping, the girl sees chocolates and immediately throws another tantrum. This time, she gets the chocolates quickly.

Girl learns to throw tantrums to obtain chocolate. This is positive reinforcement.

- Scenario 1 is presented from the girl’s point of view. But consider the same story from the mother’s point of view:

Mother takes her daughter to a grocery store. The child sees chocolate, wants it, and throws a tantrum. Overtired and in a rush, the mother gives the child chocolate, and the tantrum stops. On the next trip, as soon as the child starts to cry, the mother quickly hands over some chocolate to stop the screaming.

Mother learns to give chocolate to stop the tantrums. This is negative reinforcement.

Kumar’s football team has a no-alcohol policy: players sign pledges not to drink alcohol during the football season. One night, Kumar goes out with some friends and has a few beers. The coach finds out and revokes Kumar’s playing privileges for a week. When allowed to rejoin the team, Kumar is careful to stay away from alcohol for the rest of the season.

Kumar learns not to drink alcohol during football season. This is negative punishment.

The coach is decreasing the drinking behavior (punishment) by taking away privileges/suspension (negative) .

Mrs. Qureshi installs an electric fence system around the perimeter of her yard and gives her dog a collar that makes a high-pitched noise whenever he gets too close to the boundary. The first time the dog strays out of bounds while wearing the collar, the noise plays and distresses him. Soon, the dog learns to avoid the noise by staying inside the yard.

Positive punishment transformed into Negative punishment

Raghav is a 10-year-old who hates PT class. One day, after eating the school lunch, he gets a stomachache. He tells his teacher that he is feeling sick, and the teacher allows him to skip PT class that afternoon. Now, on days when there is PT class, Raghav frequently feels sick after eating lunch at school.

Raghav learns to feel (or report) sickness in order to avoid PT class. This is negative reinforcement.

Reinforcement Need Not Follow Every Response

- An experimenter can also control the *frequency* with which outcomes are delivered

- **Continuous reinforcement schedule:** a reinforcement schedule in which every instance of the response is followed by the reinforcer
- **Partial reinforcement schedule:** a reinforcement schedule in which only some instances of the response are followed by the reinforcer

- The rules determining how and when outcomes are delivered in an experiment are called **reinforcement schedules**.

Reinforcement Schedules

Reinforcement is delivered after a predictable number of responses

<u>Effect</u>: produces high rate of response

Reinforcement is delivered at predictable time intervals

<u>Effect:</u> responses increase close to the time for next reward

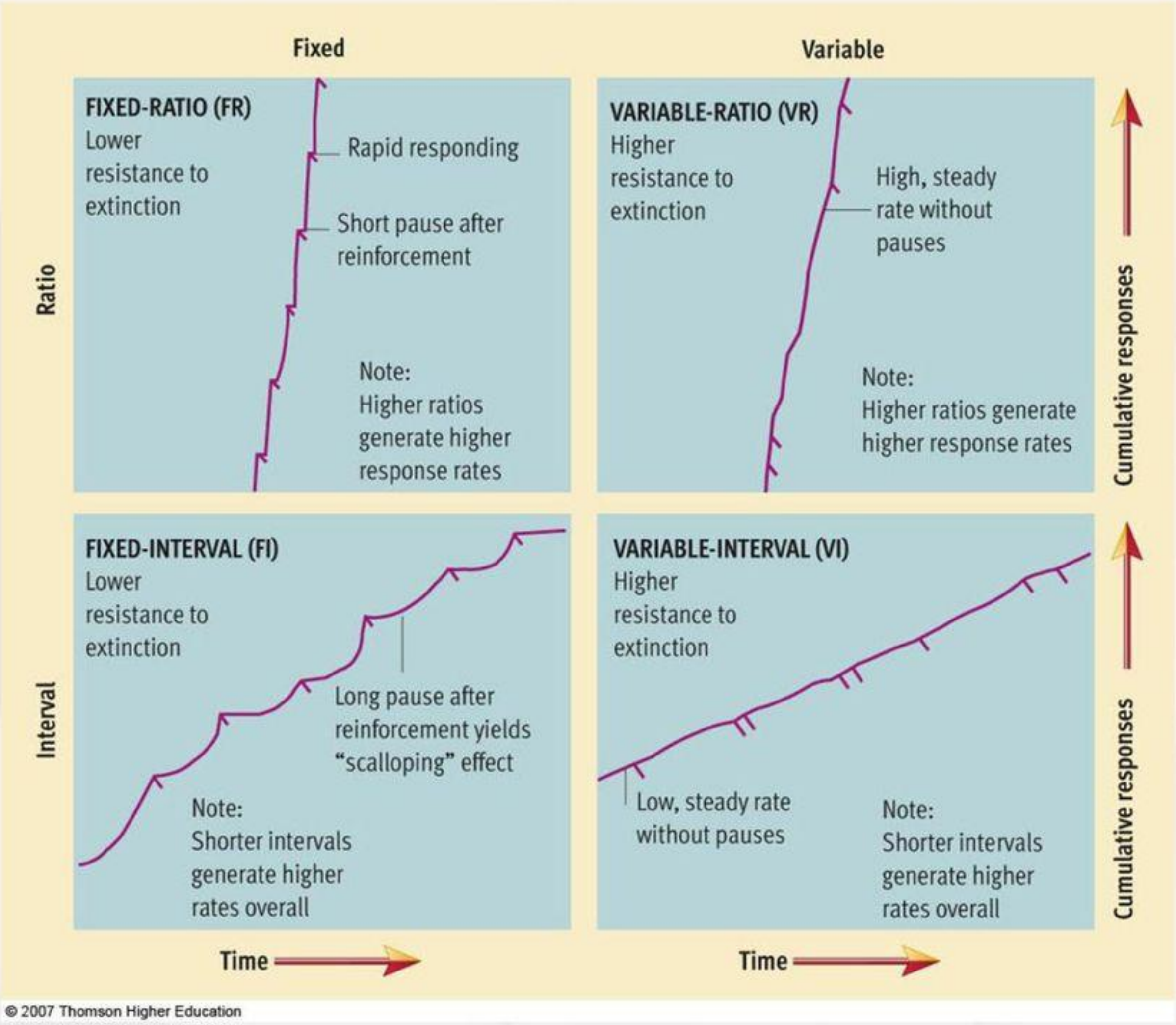


Figure 6.13 Schedules of reinforcement and patterns of response

Reinforcement is delivered after an unpredictable number of responses

<u>Effect:</u> produces a high steady rate of response

Reinforcement is delivered at unpredictable time intervals

<u>Effect:</u> produces a moderate, steady rate of response

Reinforcement Schedules

Gambling? VR

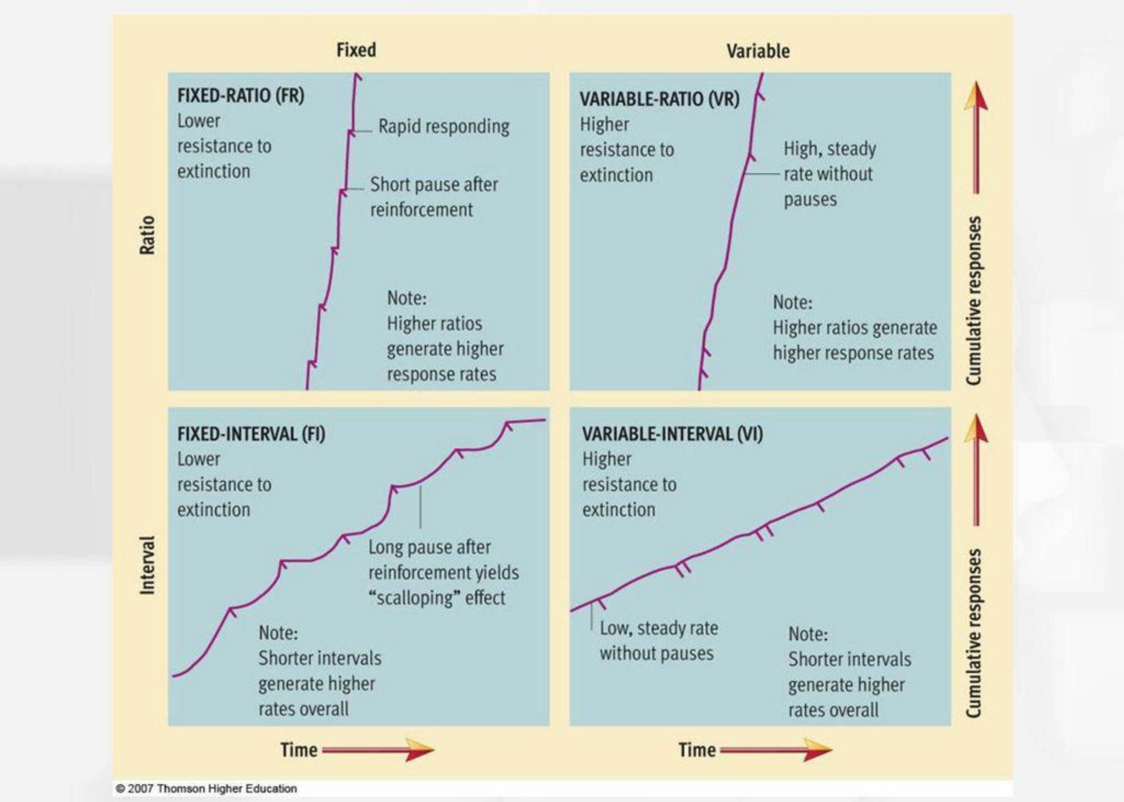


Figure 6.13 Schedules of reinforcement and patterns of response

Each first-grade student who completes the day's math worksheet receives a gold star from the teacher; at the end of the week, five gold stars can be exchanged for a toy. FR

A good telemarketer makes 20 calls and manages to sell his product to two customers, so he earns more profit if he makes a lot of calls. VR

Manish is a restaurant owner and has trained his employees to keep the restaurant clean with optimal service at all times. Every now and then the food inspector and quality control agents visit his restaurant. VI

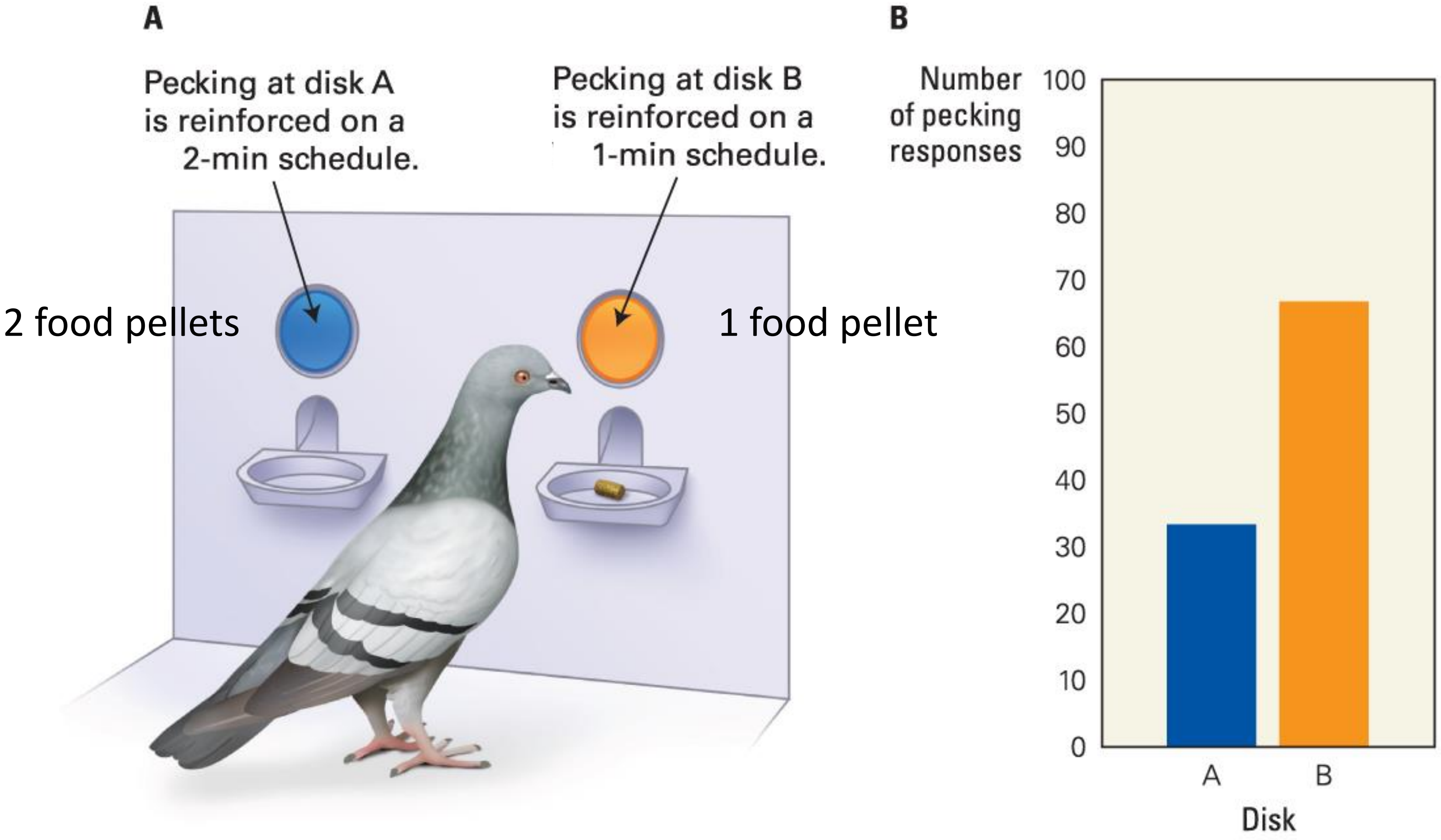
Maria donates blood regularly at the local hospital; they pay her for her donations, and it makes her feel good to know she's helping people in need. However, due to hospital policy, donors have to wait at least 2 weeks between donations. FI

A factory worker gets paid for every 10 clothes stitched FR

Getting random surprise quizzes in class. VI

Scheduled mid-term/end-term exams. FI

Choice behaviour



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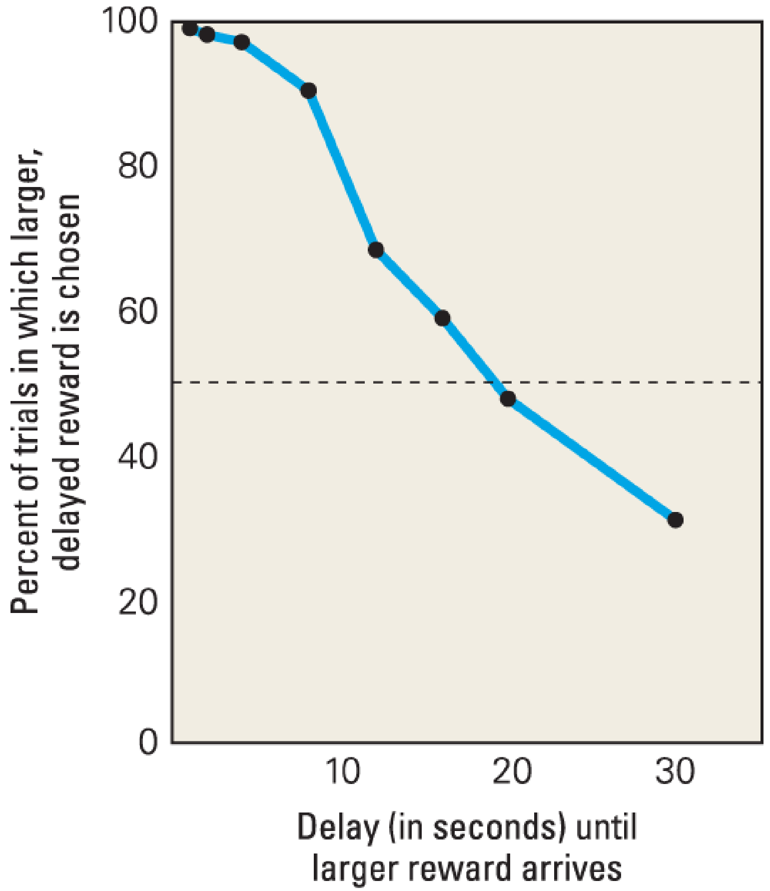
Delay Discounting

- **Delay discounting:** the progressive reduction (or discounting) of the subjective value of a reward the longer it is delayed
- For example, it is easy to put off having fun in order to study if the exam is coming up tomorrow; it is harder to wait if the exam is 5 weeks later, even though starting to study early will result in a better grade

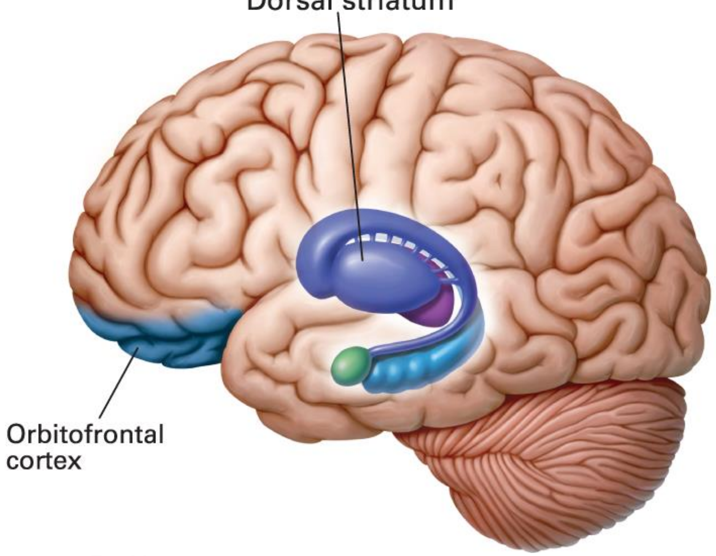


Gluck et al., *Learning and Memory*, 4e,

Rats were given a choice between two levers: one that delivers a small, immediate reward (1 food pellet) and one that delivers a larger reward (3 pellets) after some delay

If that delay was short (e.g., 0 to 5 seconds), rats would choose the larger reward on nearly 100% of choice trials; but as the delay grew longer (e.g., 20 to 30 seconds), they were increasingly less likely to wait, opting more often for the smaller, immediate reward

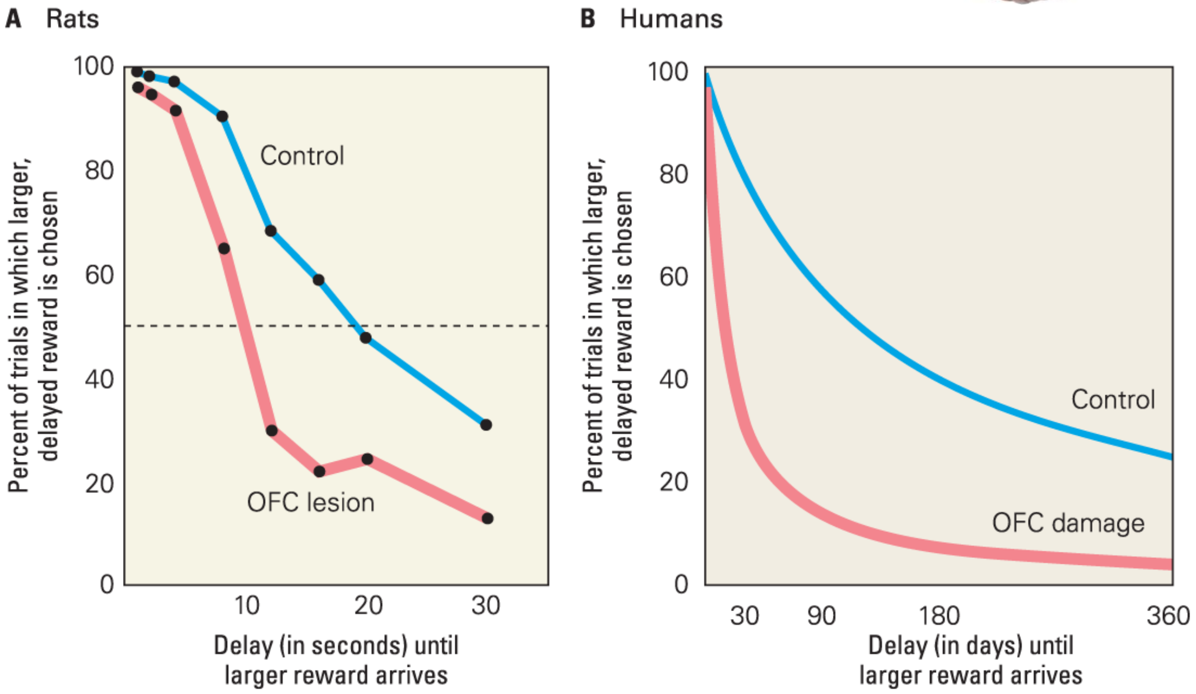
Delayed Reinforcement and the Orbitofrontal Cortex



Orbitofrontal cortex and self-control

(A) If control rats are given a choice between an immediate small reward and a larger, delayed reward, they will almost always prefer the larger reward if the delay is short (e.g., a few seconds), but as the delay increases, they will increasingly prefer the immediate reward. Rats with lesions of the orbitofrontal cortex (OFC) show much less self-control, indicated by a greatly decreased willingness to wait for the larger, delayed reward.

(B) Humans show a similar pattern: at short delays, both healthy (control) participants and people with OFC damage will usually opt for the larger reward; but as the delay increases, the people with OFC damage show much less self-control, indicated by decreased willingness to wait for the larger, delayed reward.



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orbitofrontal cortex evaluates → expected rewards + expected timing of those rewards

Delayed Reinforcement (gratification) and Self-Control

- **Self-control** refers to an organism's willingness to forgo a small immediate reward in favor of a larger future reward
- One way of improving an individual's ability to wait for a reward is to induce the person to make a *precommitment*—that is, to make a choice that is difficult to change later

Delayed gratification

Taken from Iddo Landau *Finding Meaning in an Imperfect World*

Problem of Delayed Reward

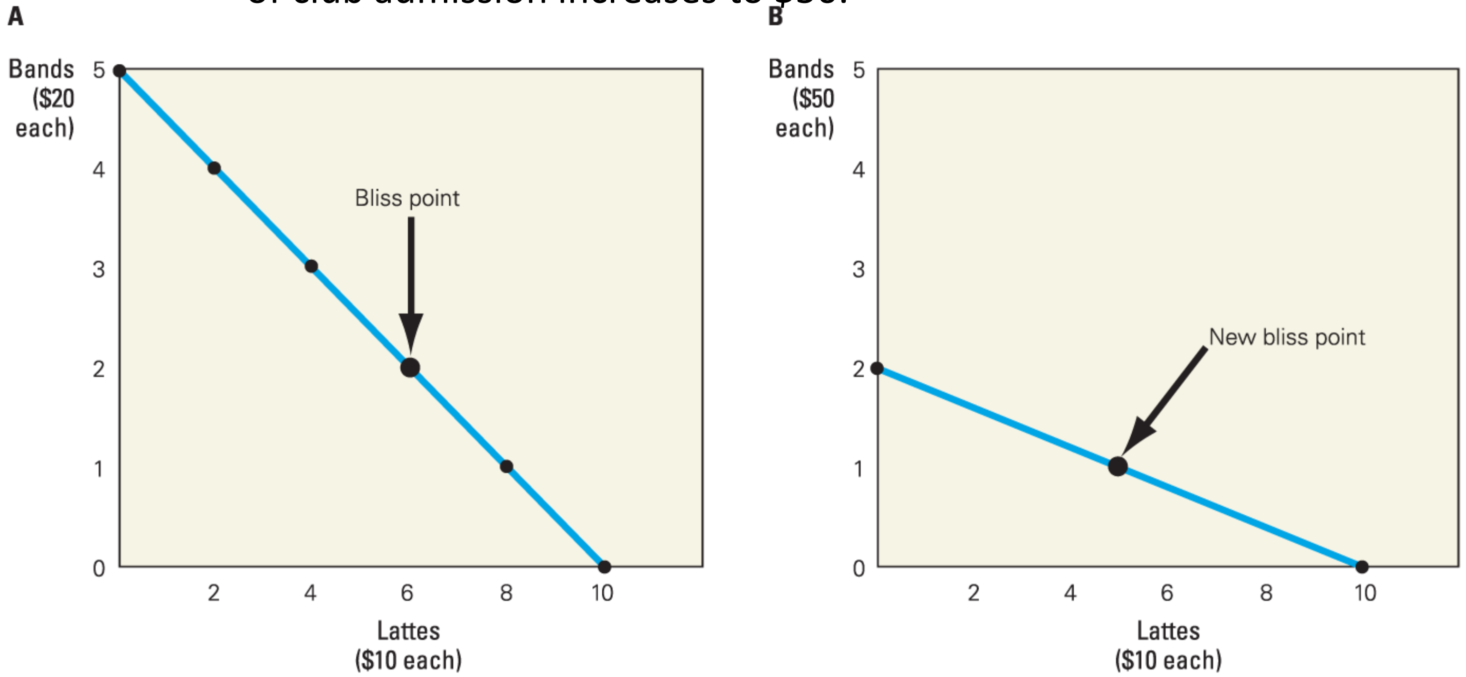
We are too successful in delaying gratification, which means we cannot stop to enjoy any of our achievements. We cannot rest on our laurels and appreciate what we have. We must always delay reward to the future.

1. **Workaholism**
   We always have to be busy, to be doing stuff, to be productive.
2. **Stinginess in Compliments**
   We must always find fault in what we do and what others do. We must always find the defect that needs to be fixed.
3. **Hyper-competitiveness**
   We must always compare our achievements to those of others; we must always find someone who is better than us in some respect.
4. **Overselling the future**
   We expect too much from future rewards, so much so that when they arrive we are inevitably disappointed.

Behavioral Economics

(A) A student with $100 income per week may choose to distribute it between buying expensive coffee ($10 per cup) and seeing live music bands ($20 club admission); any point on the line will satisfy the budgetary constraints. The bliss point is the point at which this particular individual gets maximum subjective value for his money. (B) The bliss point may shift as conditions change—for example, if the cost of club admission increases to $50.

- **Behavioral economics** is the study of how organisms allocate their time and resources among possible options
- Economic theory predicts that each consumer will allocate resources in a way that delivers the maximum "subjective value," or relative satisfaction, for that person
- The particular allocation of resources that provides maximal subjective value to an individual is called the **bliss point**



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Optimizing gain/loss – no direct operant conditioning

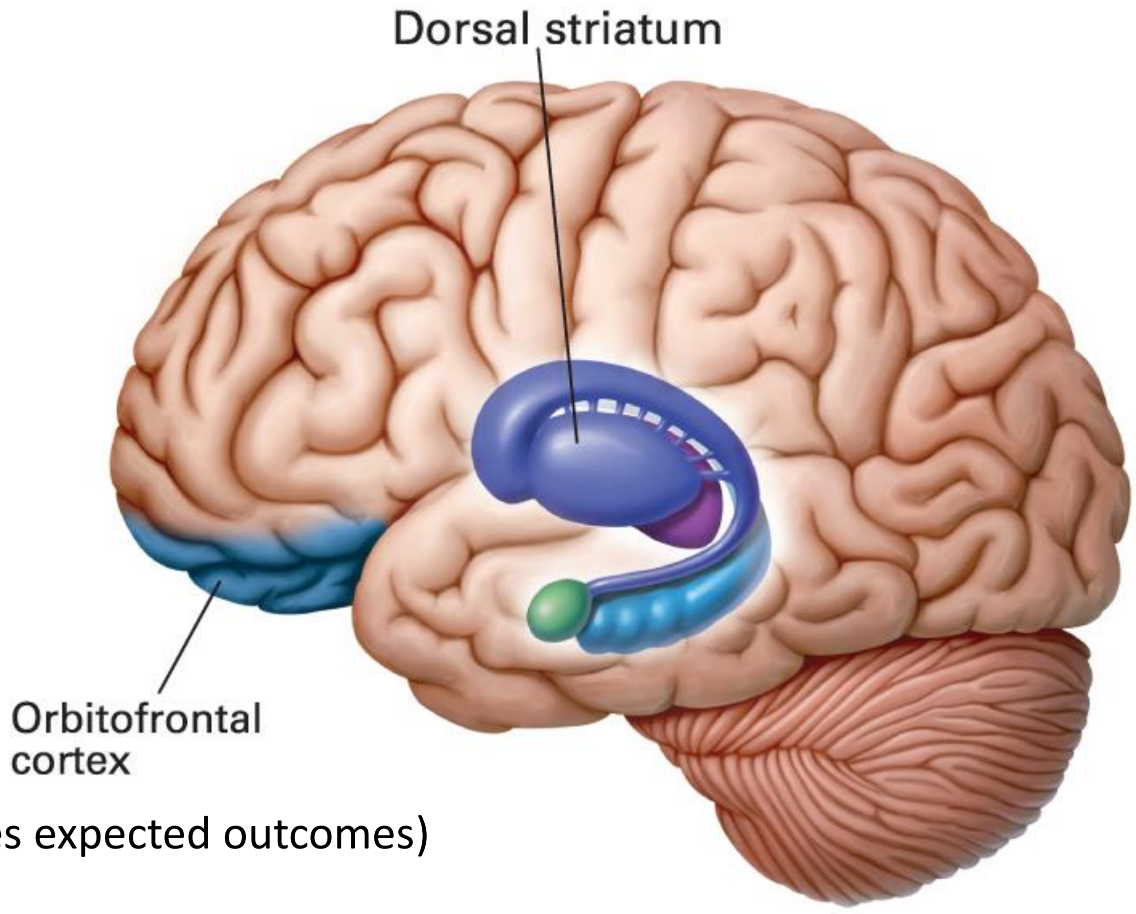
From a behavioral economics perspective, operant conditioning is not so much training an organism to execute a specific behavior as causing the organism to shift its allocation of time and energy among possible behaviors

Brain Substrates

- Two key areas
  - Dorsal striatum
  - Orbitofrontal cortex (expected outcomes)
    - Receives inputs that convey the full range of sensory info (visual, auditory, etc,) + visceral sensations (pain, nausea, etc)

(determines response and plans motor behaviour)

Part of the basal ganglia



(evaluates expected outcomes)

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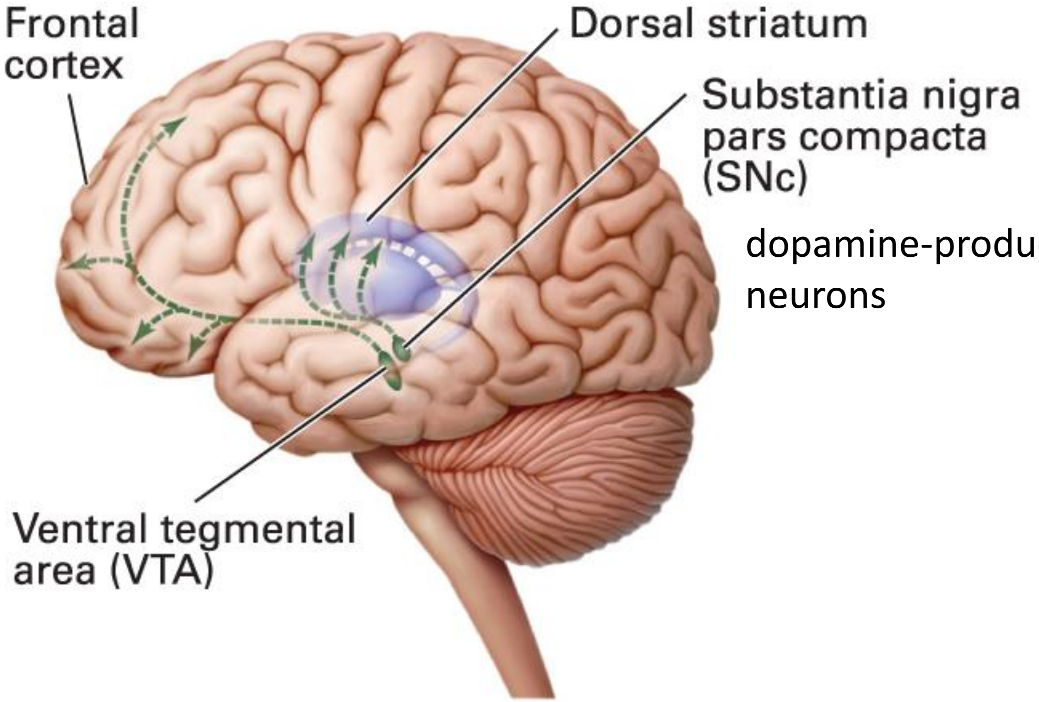
“Wanting” and “Liking” in the Brain



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dopamine-producing neurons

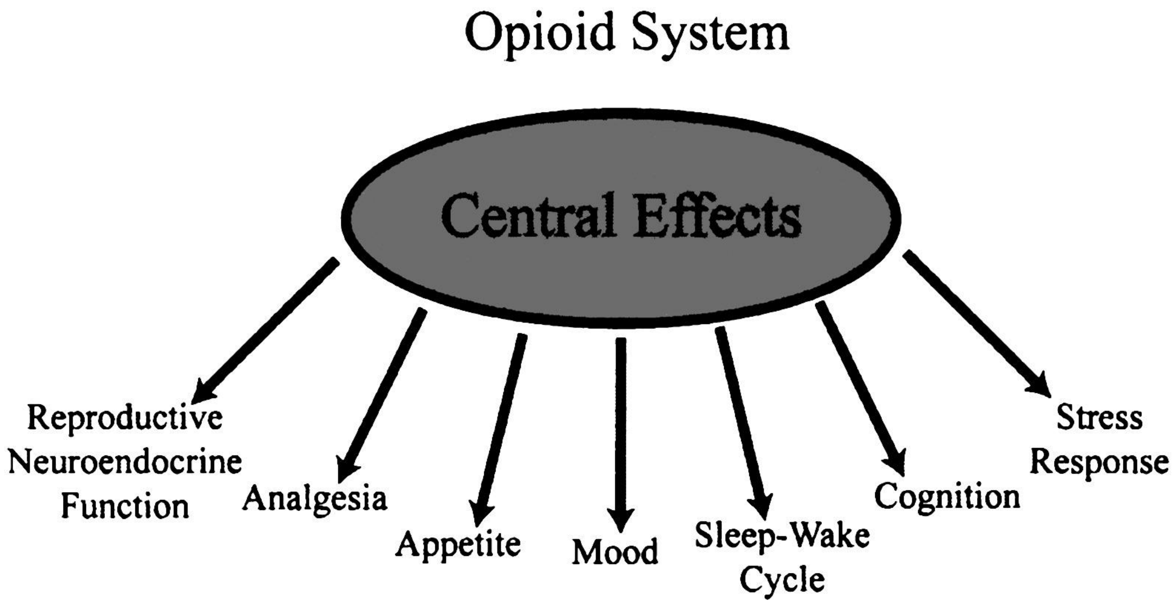
- Studies show that rats will work for electrical stimulation in several brain areas, in particular the **ventral tegmental area (VTA)**, a small region in the midbrain of rats, humans, and other mammals

- Many researchers believe that we have separate brain systems for signaling **hedonic value**—meaning the subjective “goodness” of a reinforcer, or how much we “like” it—that are distinct from those signaling **motivational value**—meaning how much we “want” a reinforcer and how hard we are willing to work to obtain it.

- **incentive salience hypothesis** of dopamine function states that one role of dopamine in operant conditioning is to signal how much the animal “wants” a particular outcome—that is, how motivated the animal is to work for it

Endogenous Opioids Signal "Liking"

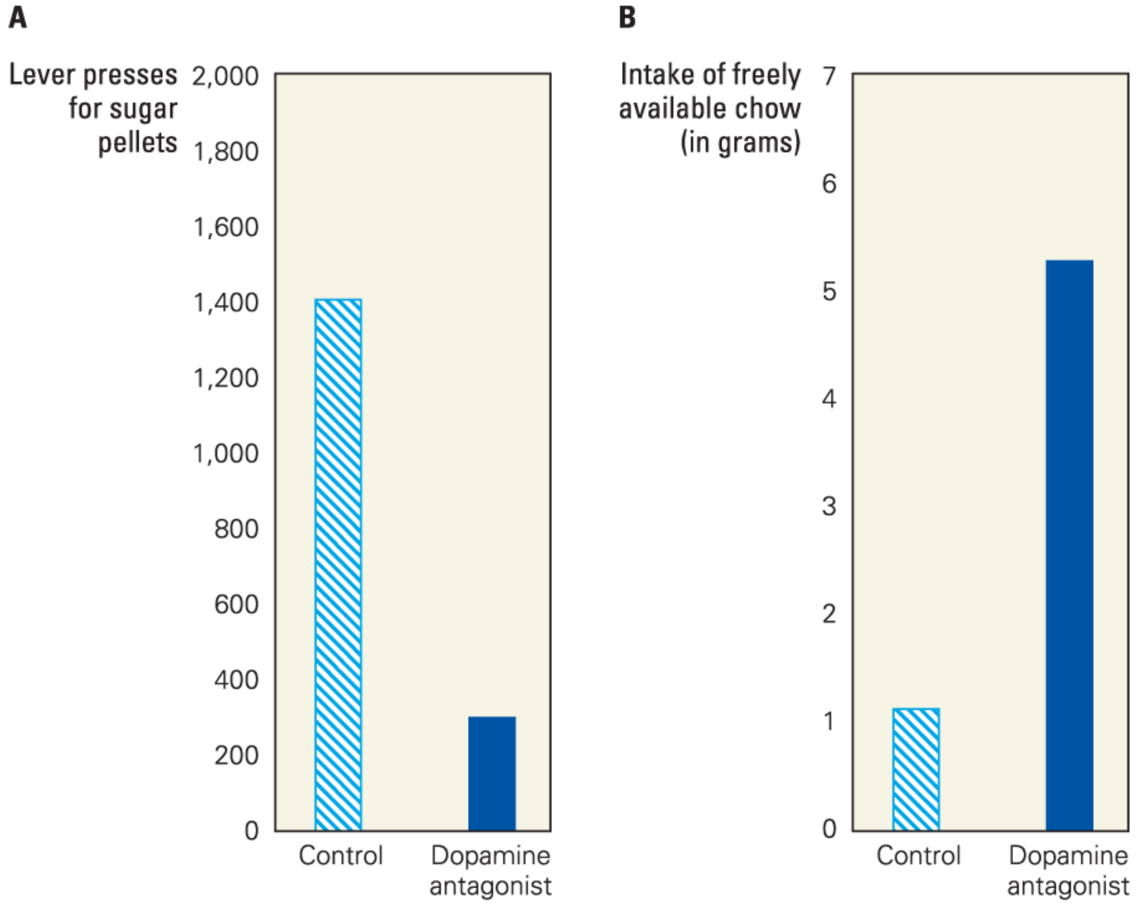
"liking" via the opioid system



- The **endogenous opioids (make you feel good, suppress pain)** are naturally occurring neurotransmitter-like substances that have many of the same effects as opiate drugs.

- Indirect dopamine signaling
- Opioids→ dopamine

Dopamine is important for motivation (wanting)



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Most rats prefer sugar pellets to rat food. If the food is freely available but sugar pellets have to be "earned" by pressing a lever, control rats (pale blue bars) will spend most of their time working for sugar pellets (A) and will eat relatively little free food (B). In contrast, rats given a dopamine antagonist (dark blue bars) are less willing to work for the sugar pellets and instead settle for eating more of the freely available food.

Dopamine Antagonist – dopamine blocker

Predicting Specific Outcomes

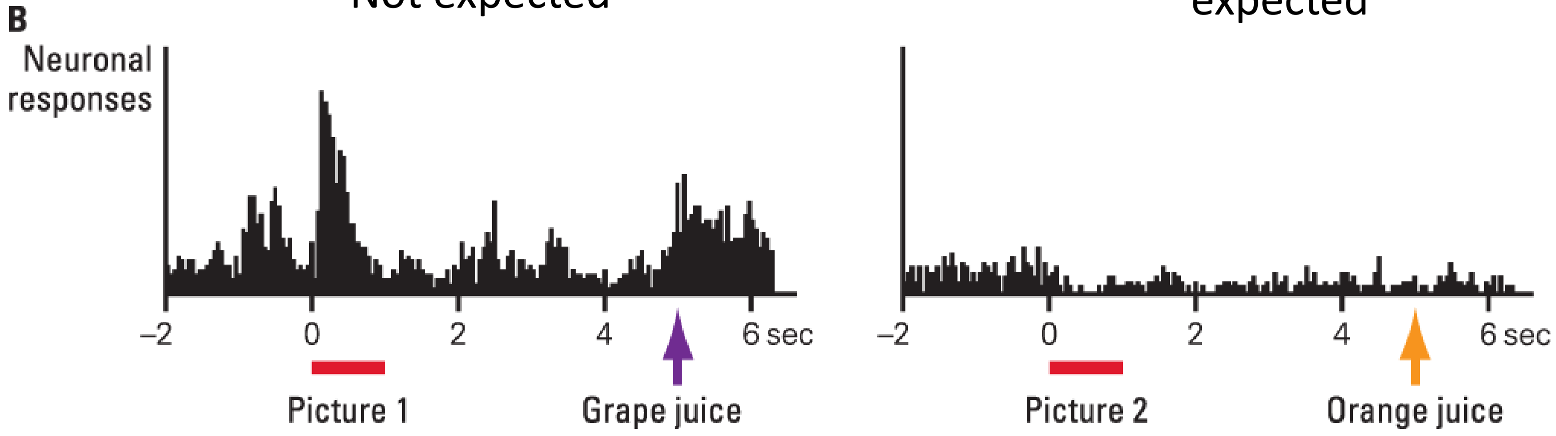
- Neuronal recordings provide strong evidence that the prefrontal cortex plays a role in predicting the outcomes of responses

- dopamine plays a key role in monitoring *reward prediction error*

- Reward prediction error information is critical when an organism is learning how to predict (and act to obtain) future reward

Not expected

expected



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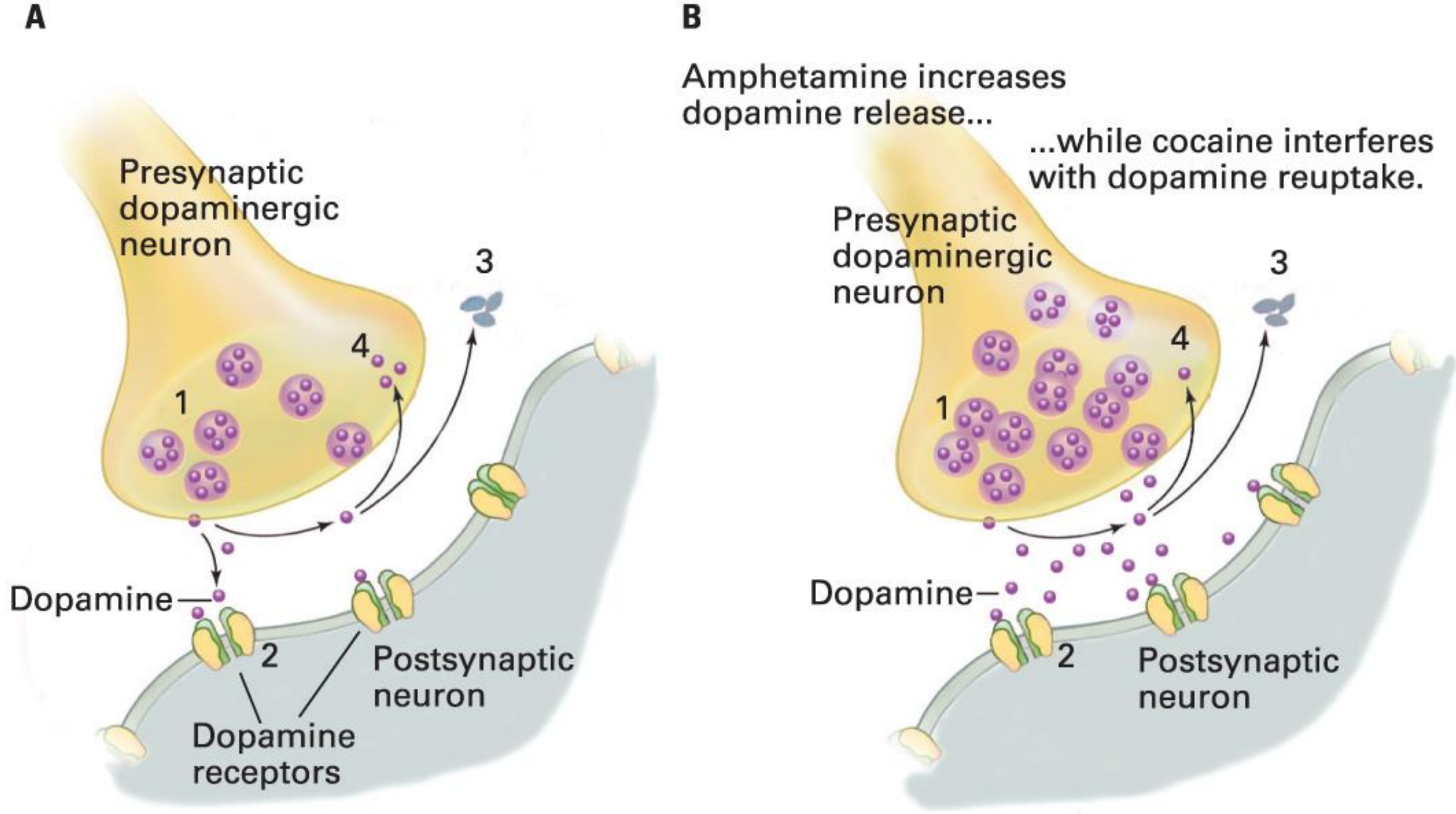
“wanting” or motivation via the dopamine system

Behavioral Addiction

- **Behavioral addictions** are addictions to behaviors that produce reinforcements or highs, as well as cravings and withdrawal symptoms when the behavior is prevented
- Examples: gambling, sex, social media, gaming
- Behavioral addictions seem to entail dysfunction in the same brain substrates that are affected by drug addictions.

The Effects of Amphetamine and Cocaine on Dopaminergic Neurons



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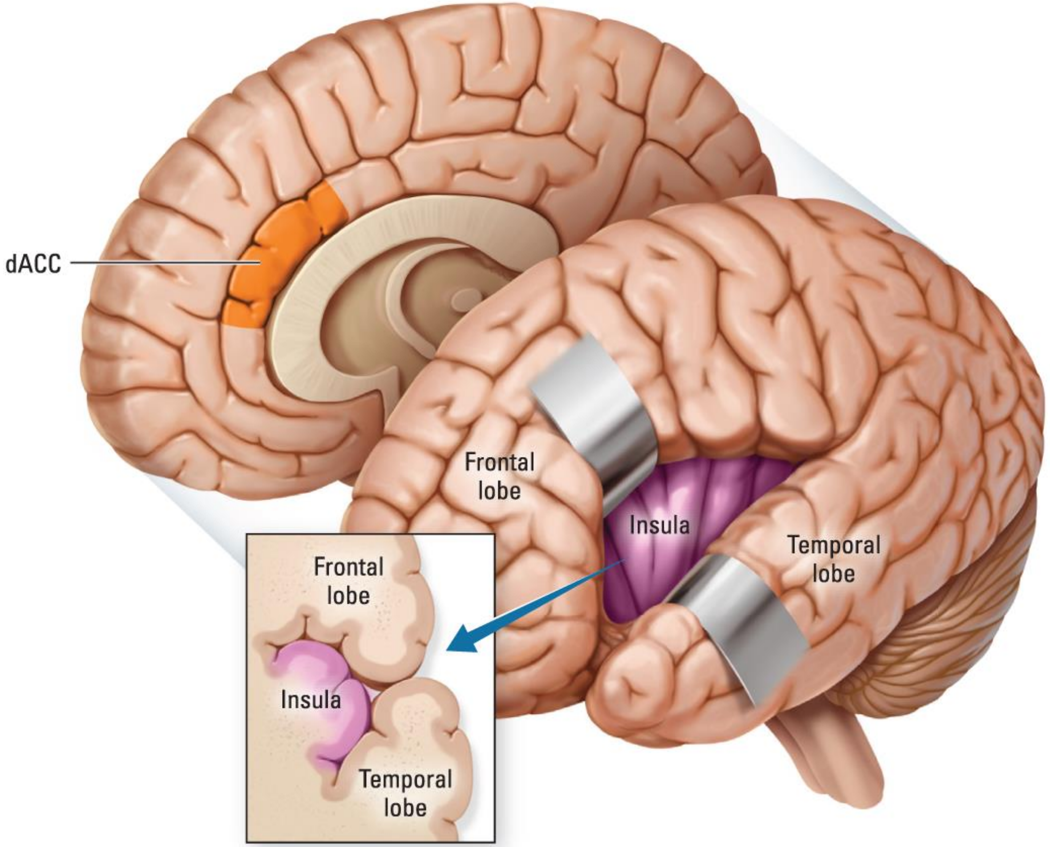
Insular Cortex (Insula) and Dorsal Anterior Cingulate Cortex (dACC)

Punishment Signaling in the Brain

- **dACC**
- evaluates motivational value of punishing stimuli
- Integrates emotion – reward – action
- links motivational outcomes to behavior
- The dACC shows increased activation when study participants unexpectedly receive a reduced reward



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- The **insular cortex (insula)** is a brain region that is involved in conscious awareness of bodily and emotional states and that may play a role in signaling the aversive value of stimuli

- Evaluates (pain, punishment)
- Relays signals to dACC

OCD and operant conditioning

- Rituals or compulsions
  - Excessive washing of hands
  - Checking repeatedly if doors are locked while leaving the house
  - Always arranging things in a particular order
  - Excessive cleaning of the house

- Rituals help to ease the anxiety and feel better
- Type of conditioning ?
- Solution? therapy?

https://www.sciencedirect.com/science/article/pii/S2949669123000106

https://www.betterhelp.com/advice/personality-disorders/examples-of-operant-conditioning-that-can-help-control-ocd/

Therapy using operant conditioning

- Rehabilitation of stroke patients using VR and operant conditioning

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6712808/

- After eating food in a branded restaurant, you fell ill, then you stopped visiting all other outlets of that brand

- Fire alarm in a movie vs fire alarm in your building

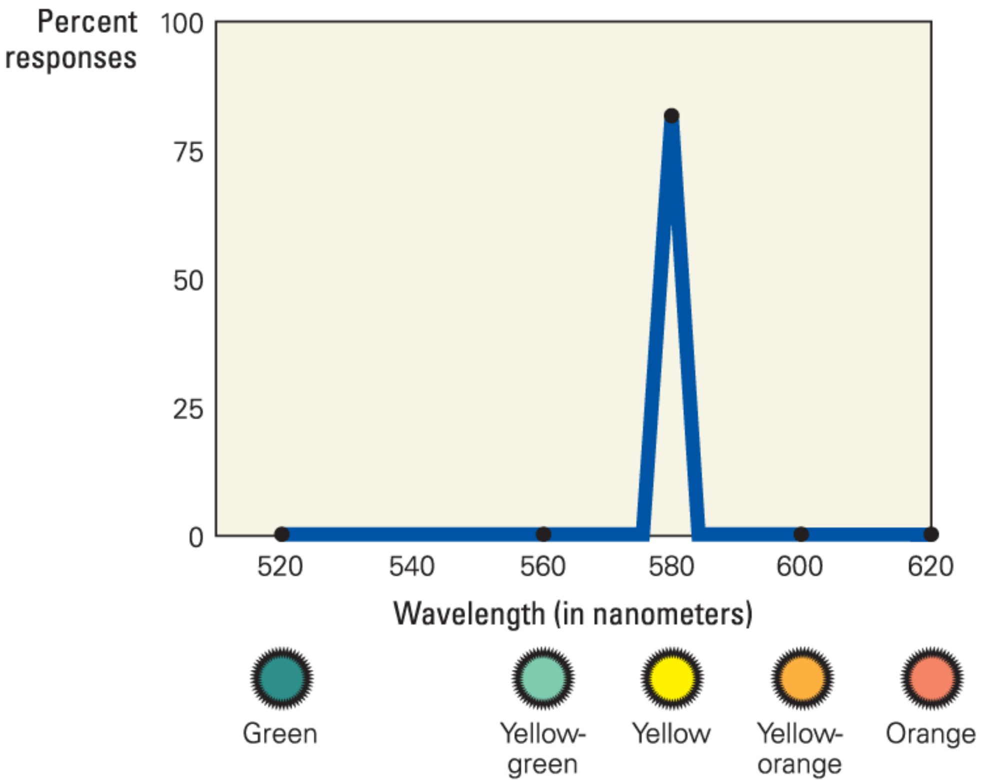
Can you compare?

Generalization & Discrimination

Why do we ?

Stimulus-Generalization Gradients in Pigeons

Ideal



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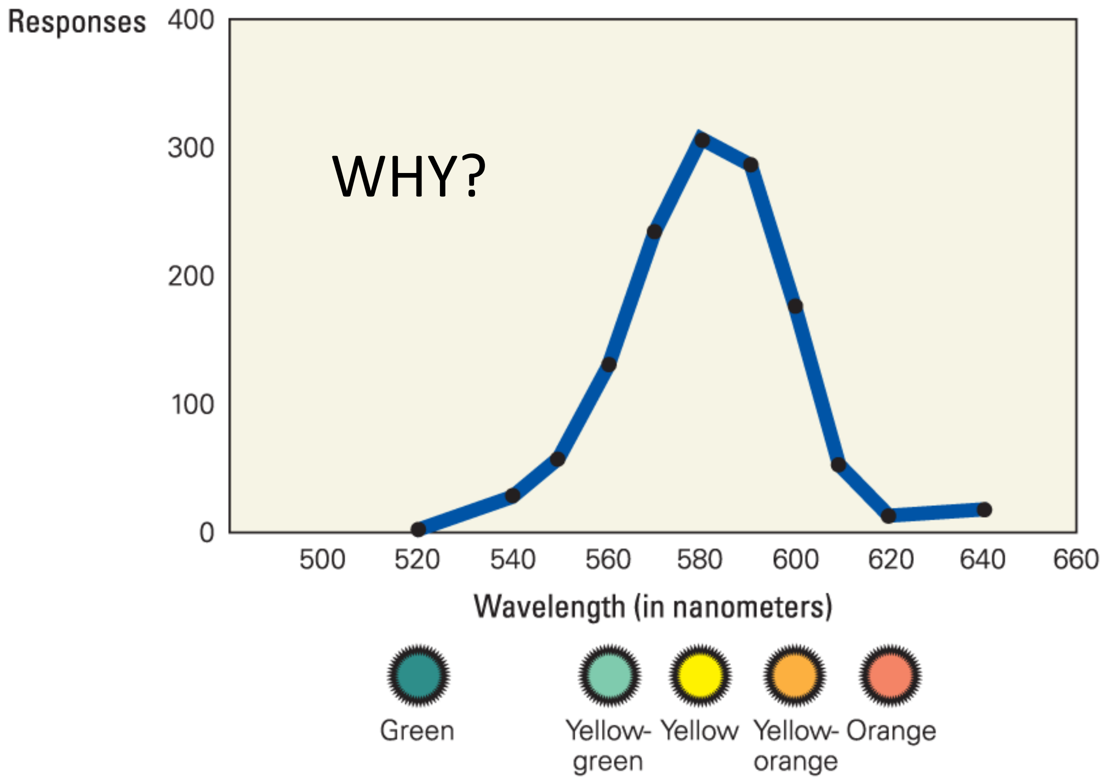
Realistic



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Similar stimuli might also be rewarding

Less error in prediction

Purpose of generalization - estimate probability of future events.

Behavioral Processes

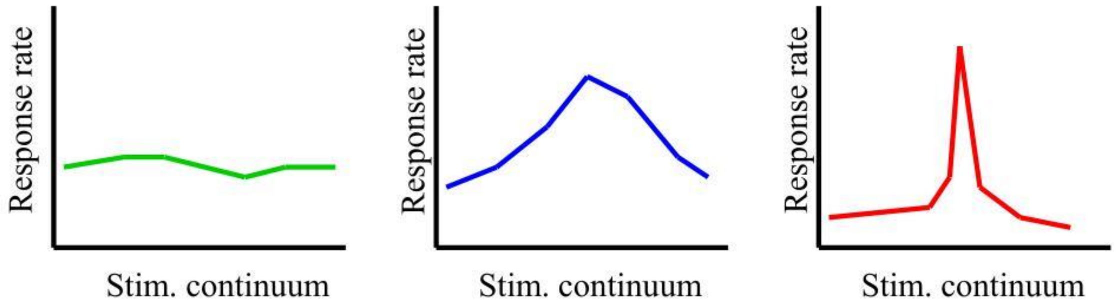
Generalization

transfer of past learning to novel events and problems

Discrimination

learn to respond differently to different stimuli

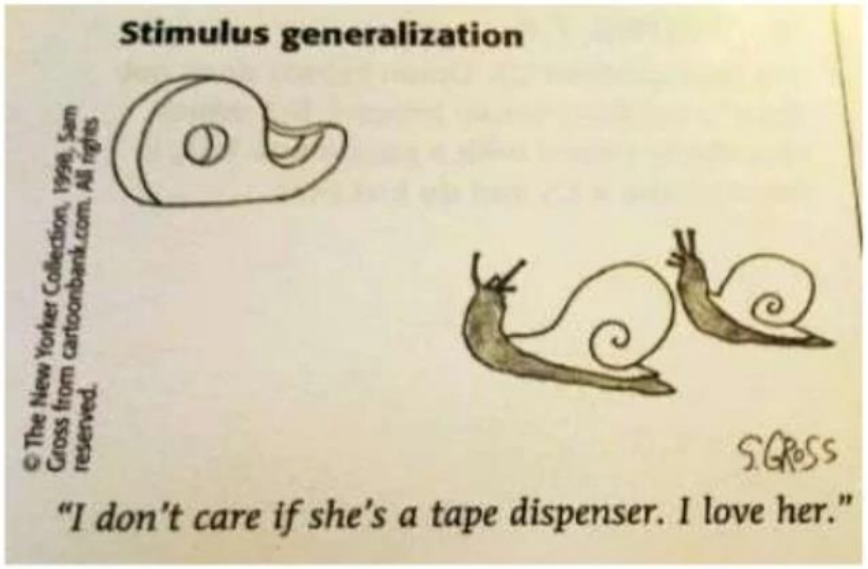
	Same outcome	**Different outcomes**
Similar stimuli	Similar stimuli → same outcome *Broccoli and cauliflower → nasty* **Moderate Generalization**	Similar stimuli → different outcomes *Broccoli → nasty* *Cauliflower → yummy* **High Discrimination**
Dissimilar stimuli	Dissimilar stimuli → same outcome *Broccoli and Brinjal → nasty* **High Generalization**	Dissimilar stimuli → different outcomes *Broccoli → nasty* *Brinjal →yummy*



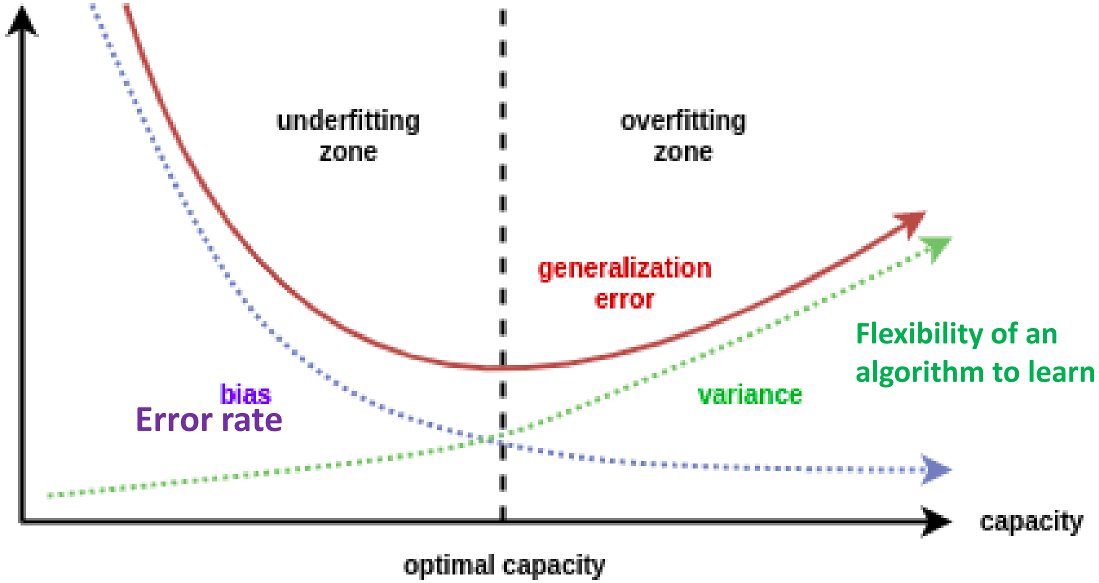
Flat: No discrimination/ high generalization

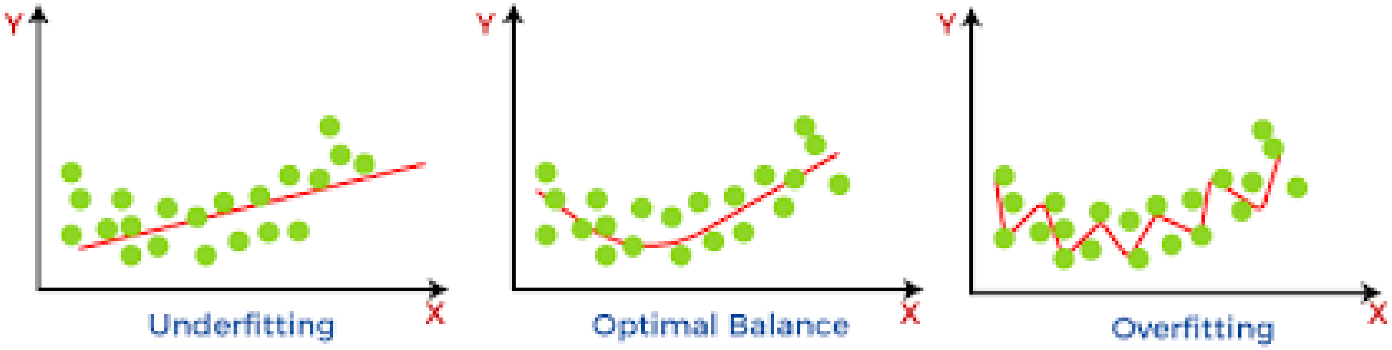
Broad: Some discrimination/ some generalization

Narrow: High discrimination/ low generalization



Generalization in machine learning



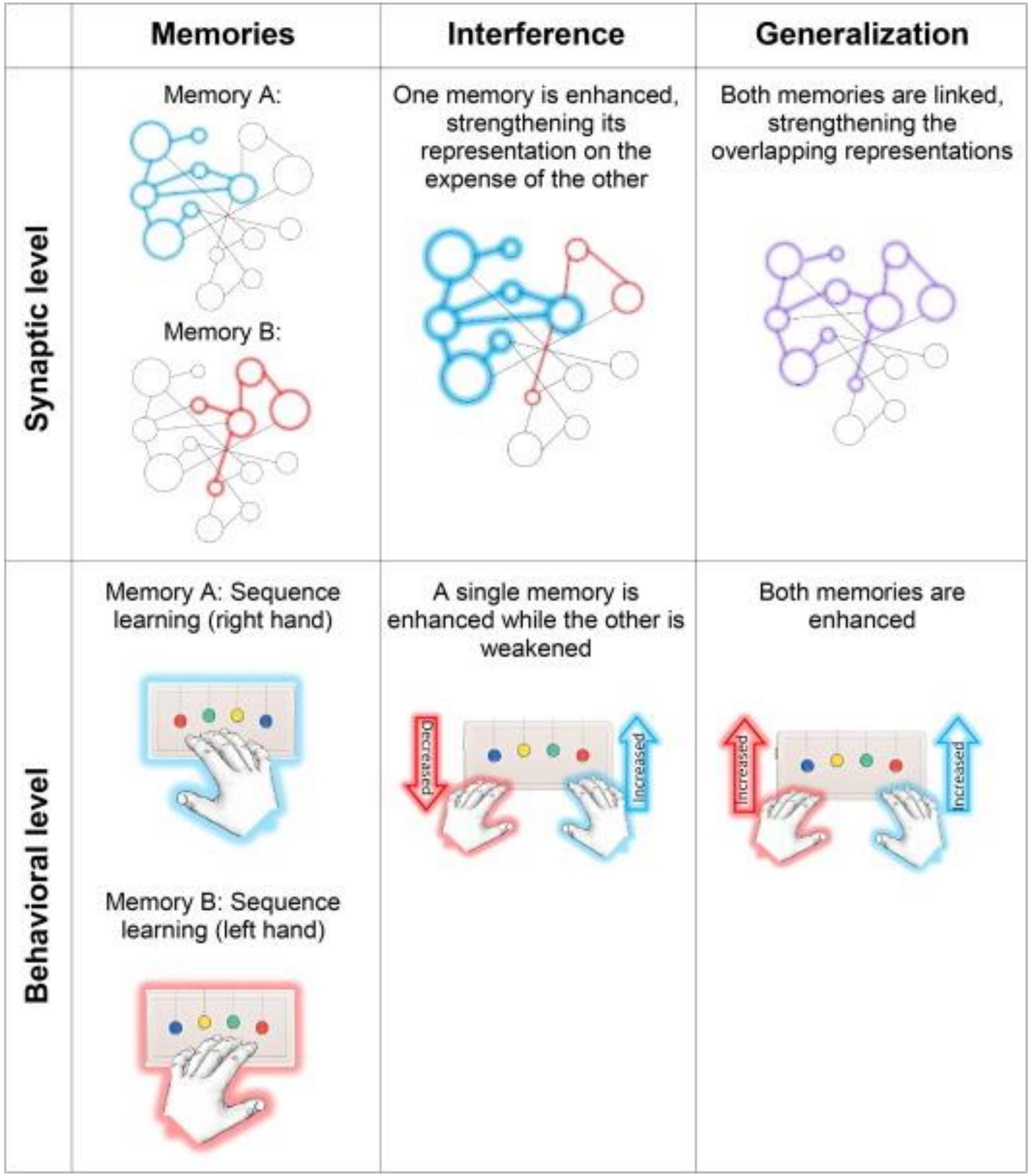


Training Data

Testing Data

how accurately an algorithm is able to predict outcome values for previously unseen data

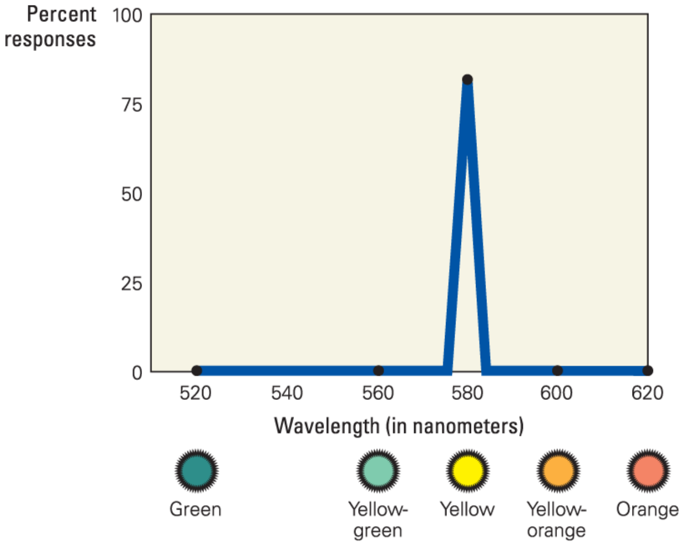
https://medium.com/@yixinsun_56102/understanding-generalization-error-in-machine-learning-e6c03b203036



Generalization at the neural and behavioural level

https://www.sciencedirect.com/science/article/abs/pii/S030645221830544X

Discrete Response model



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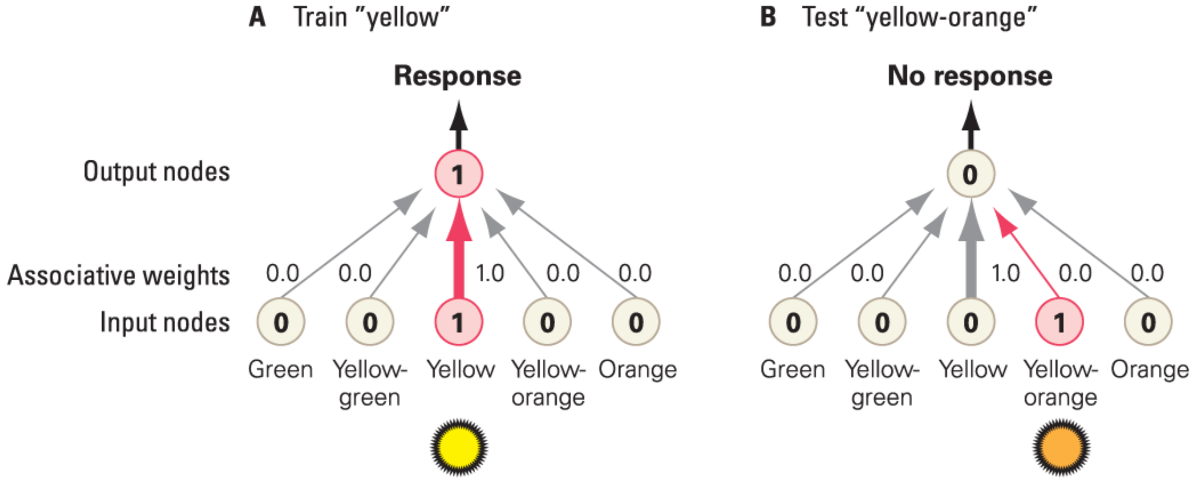

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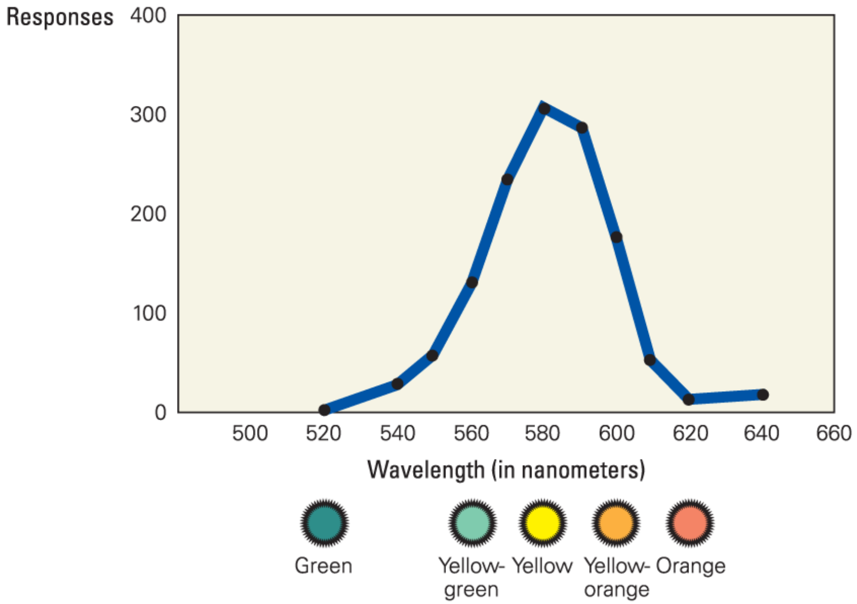
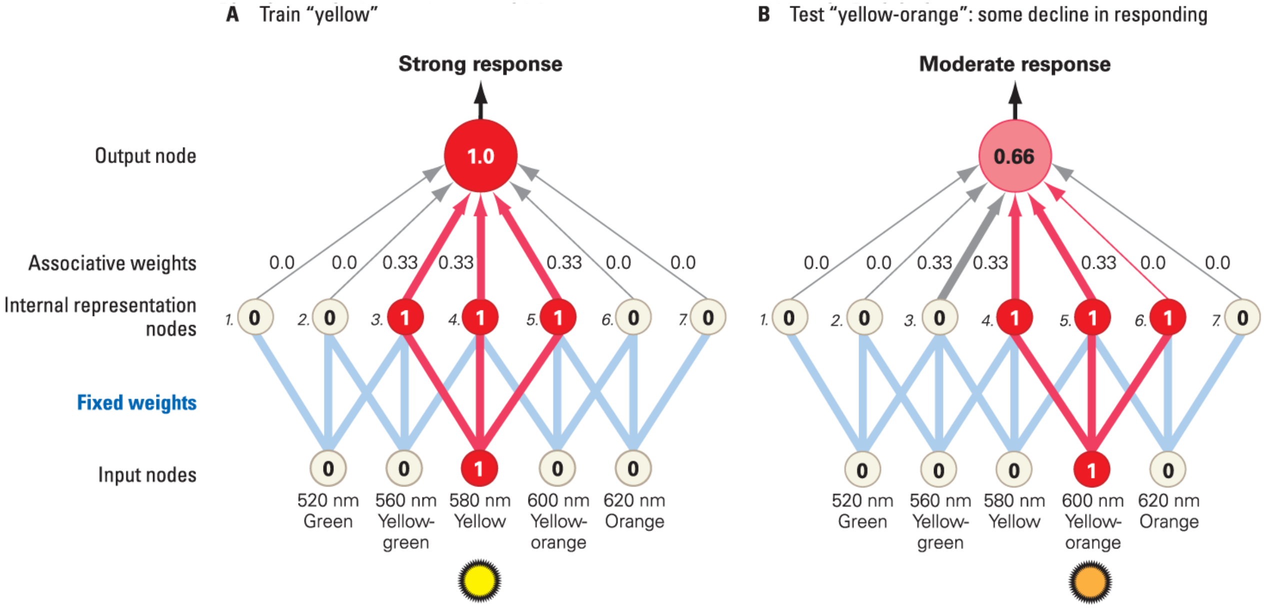
Distributed Response model





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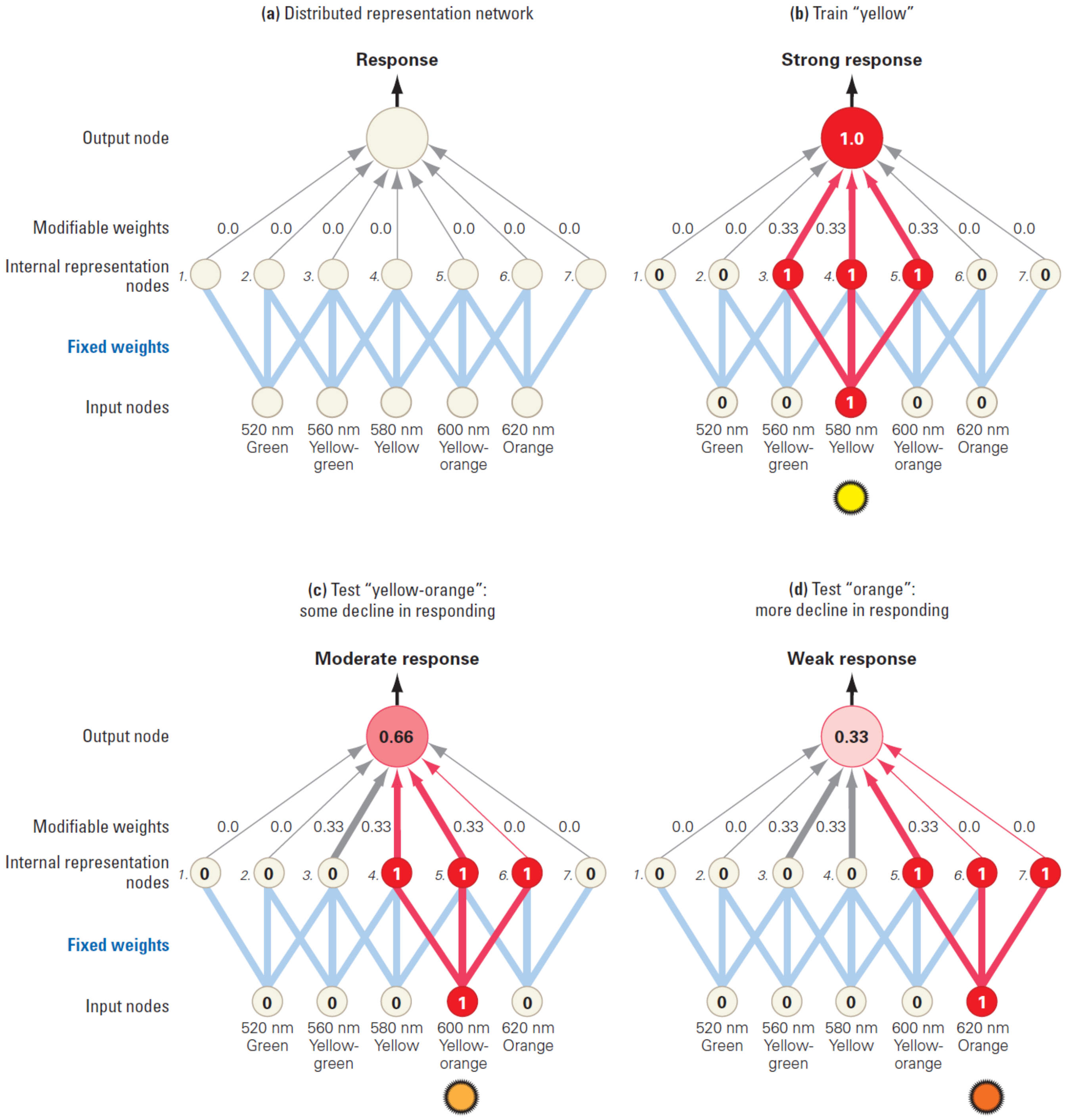


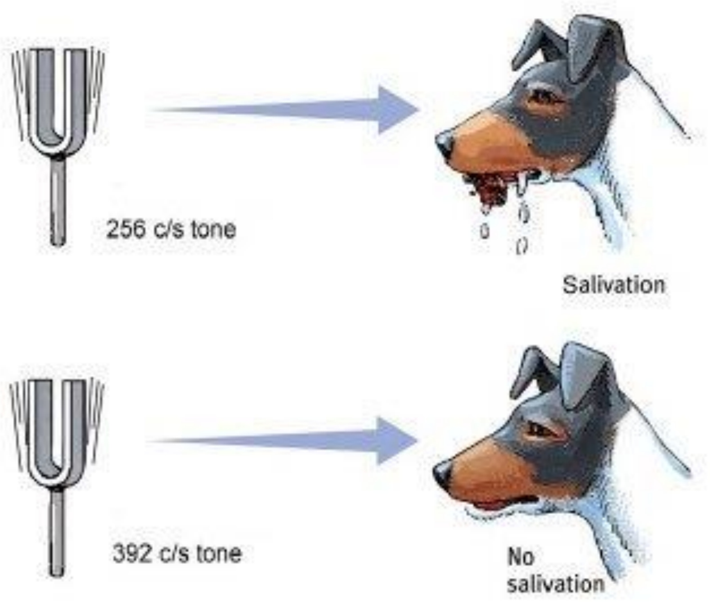
expect similar stimuli to have similar consequences

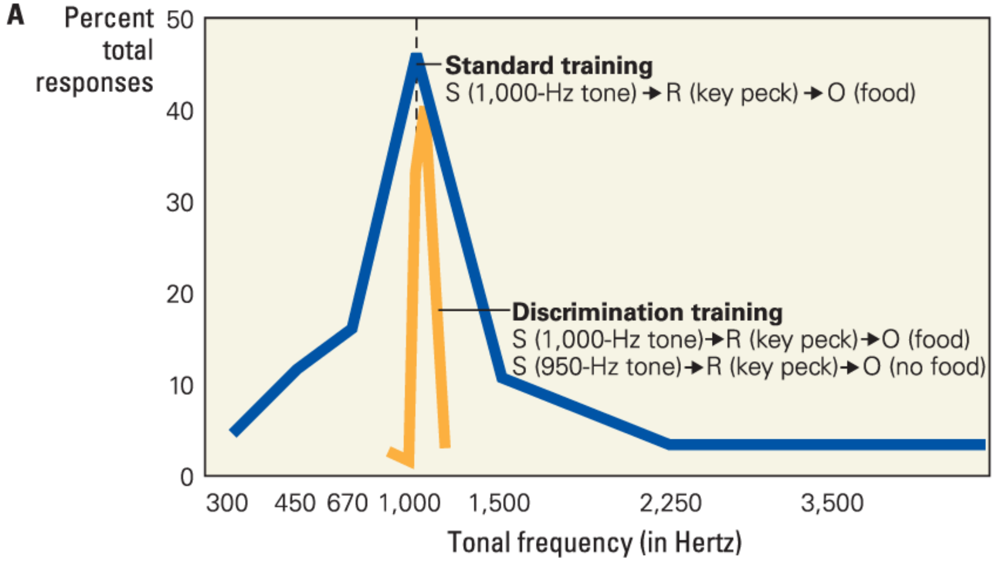
Distributed representation

Discrete representation

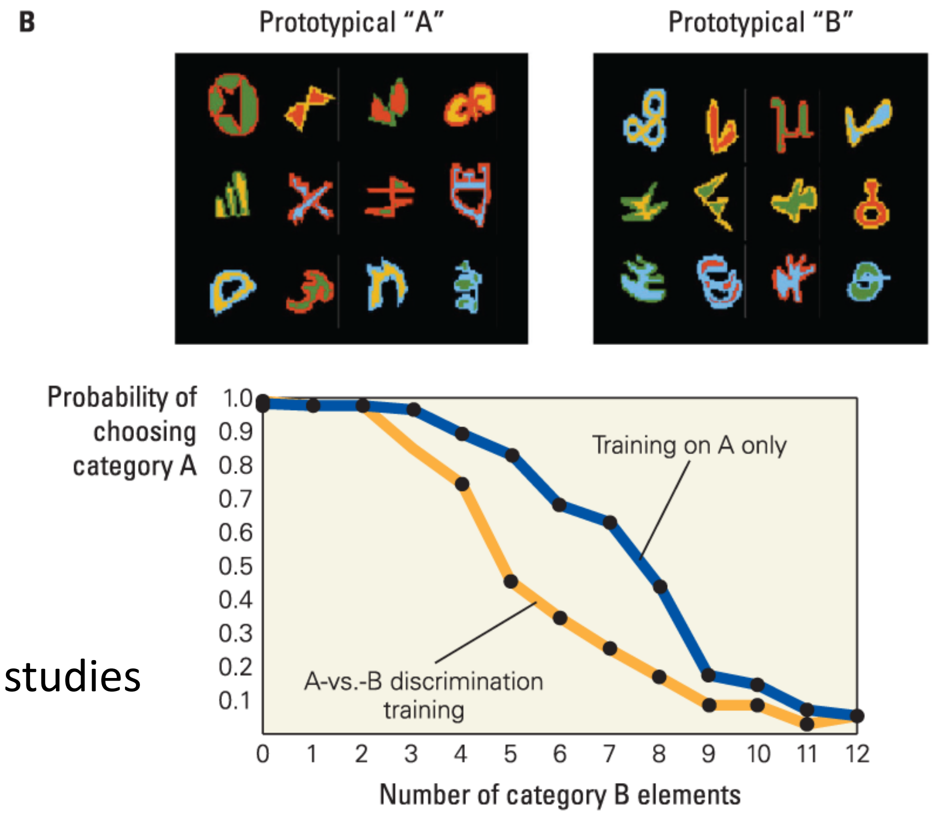
Generalization or Discrimination?

What determines whether two stimuli are to be treated as similar (generalization) or different (discrimination)?



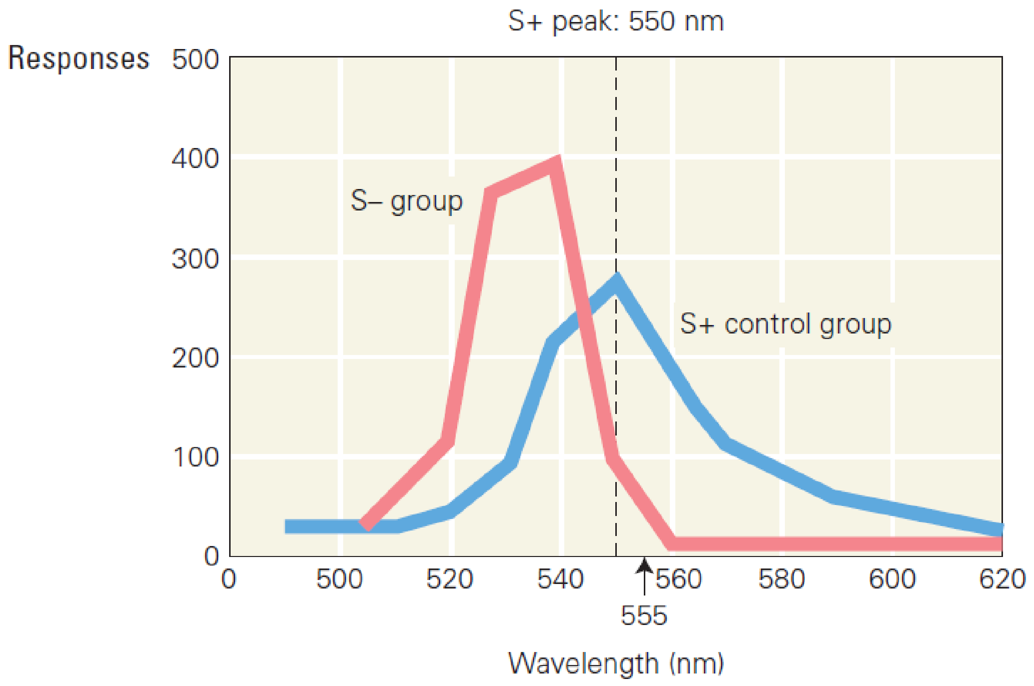


Human studies



Peak shift following discrimination training along a physical continuum

Pigeons were reinforced for pecking in the presence of a 550-nm light and then were divided into two groups. One group received only this training (the control group), while the other received discrimination training in which the 550-nm lights were rewards while a similar 555-nm light were paired with unpleasant/negative outcomes (the S- group).



Preconditioning:
Co-occurrence and Stimulus Generalization

meaning-based generalization

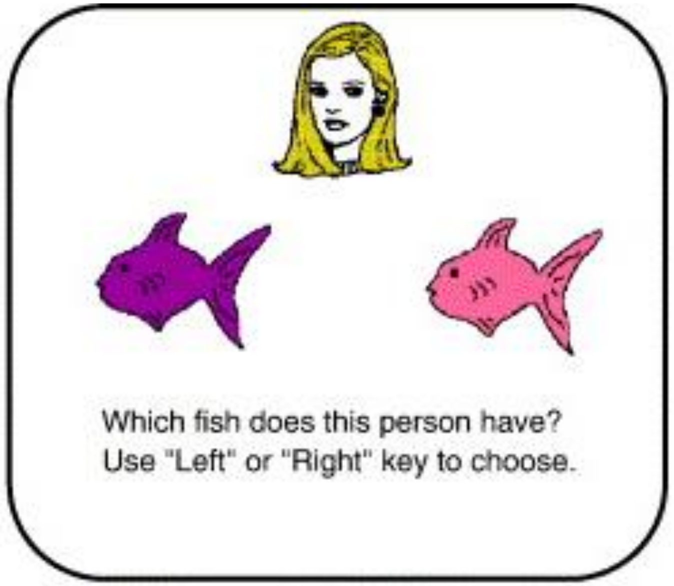
Generalization across two dissimilar stimuli → because of co-occurrence

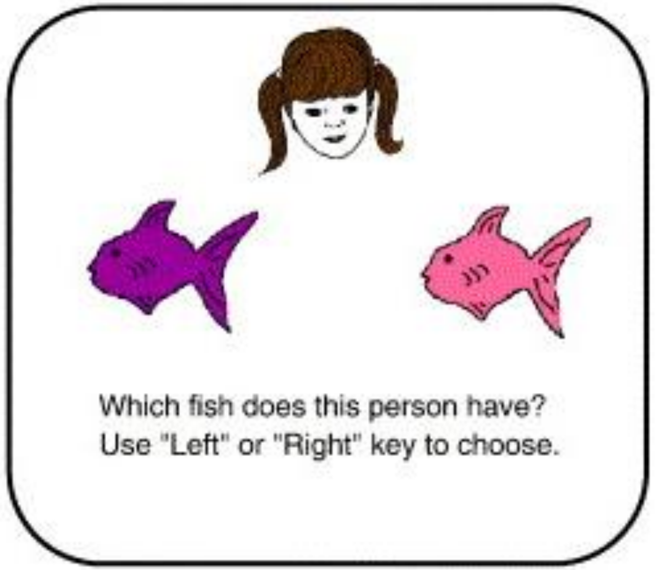
Group	Phase 1	Phase 2	Phase 3: test
Compound exposure	*Tone + light (together)*	Light → airpuff → blink!	Tone →
Separate exposure (control group)	*Tone, light (separately)*	Light → airpuff → blink!	Tone →

Reverse of blocking

In an unfamiliar area,
red light + other vehicles stop → reduce your speed
other vehicles stop → reduce your speed assuming a traffic light (when you can't see the red light)

Preconditioning can occur beyond the sensory level -


Which fish does this person have?
Use "Left" or "Right" key to choose.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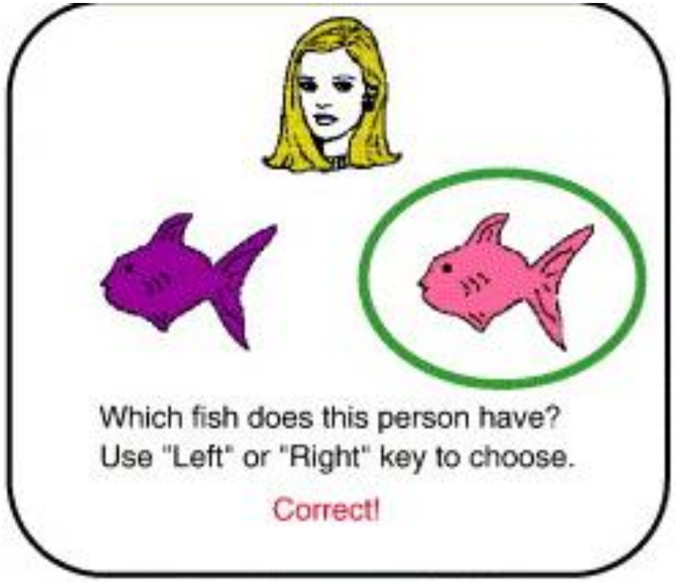
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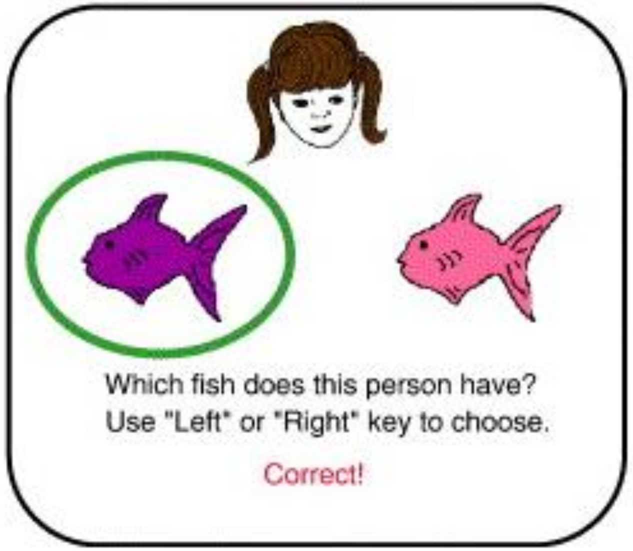
Correct!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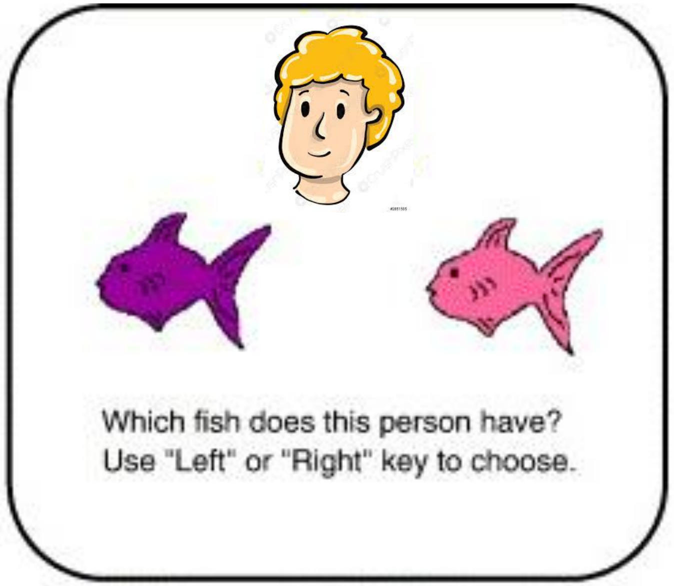
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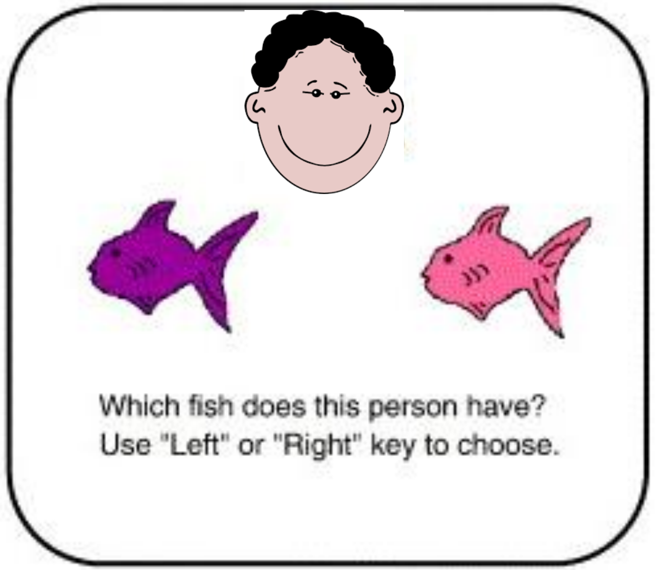
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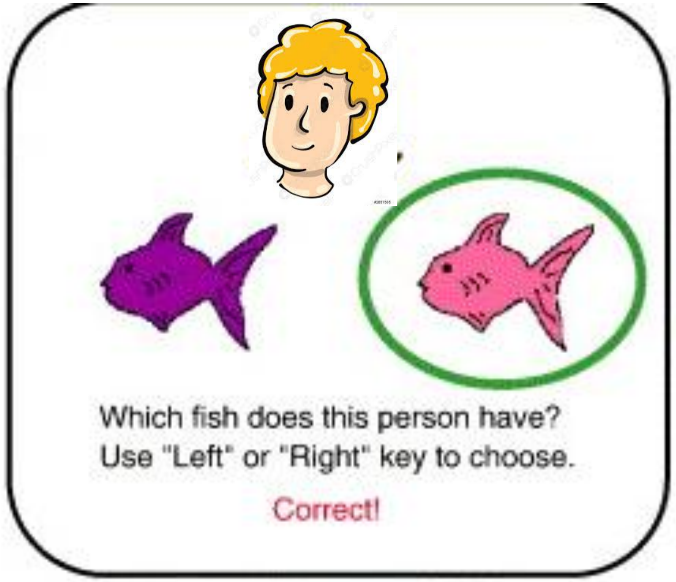
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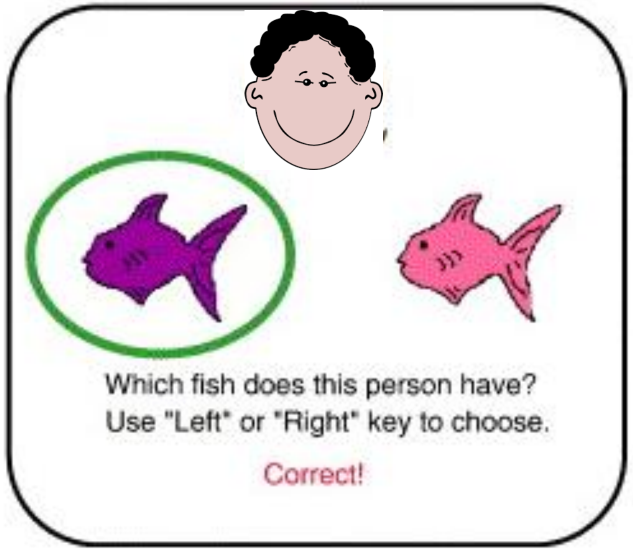
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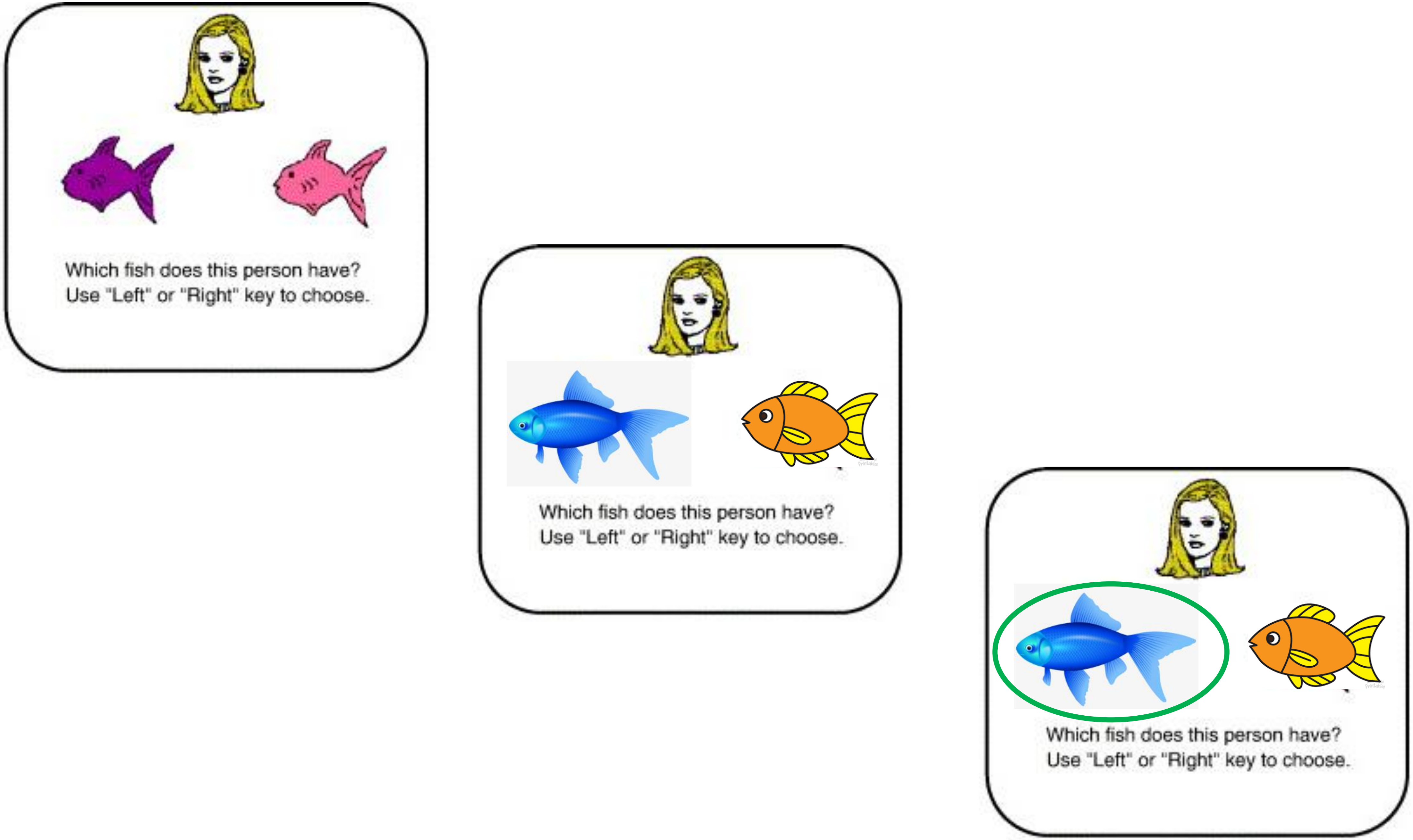
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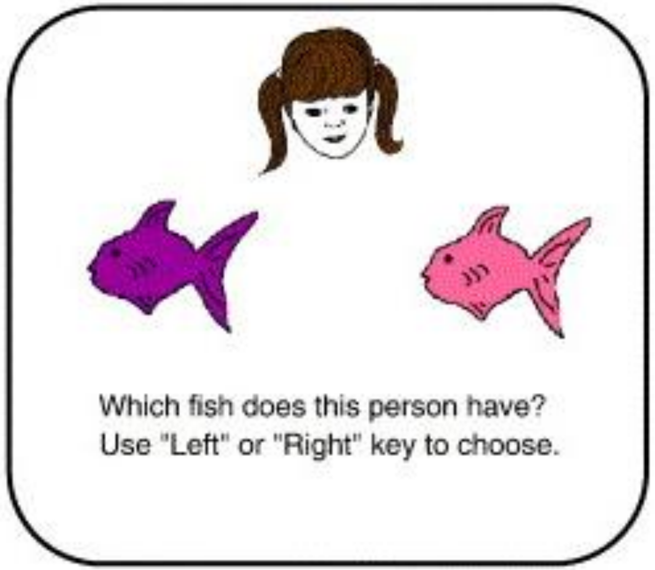
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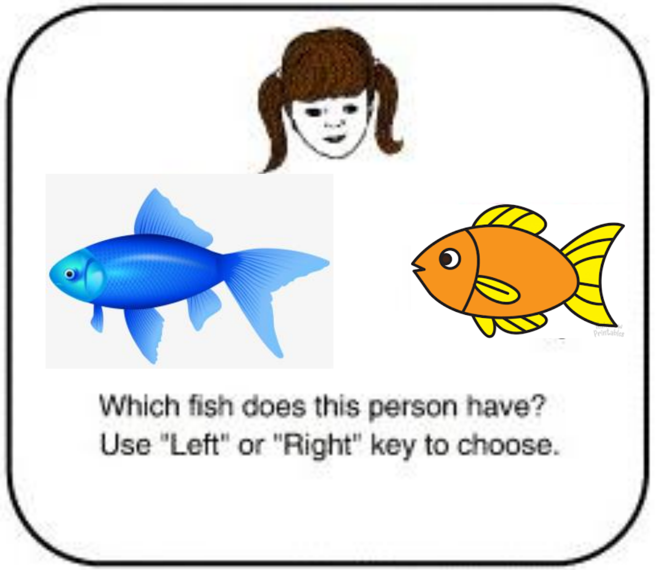
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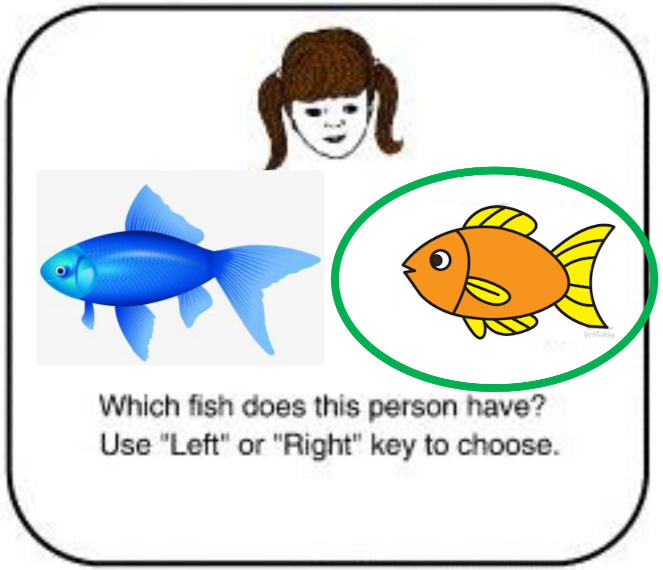
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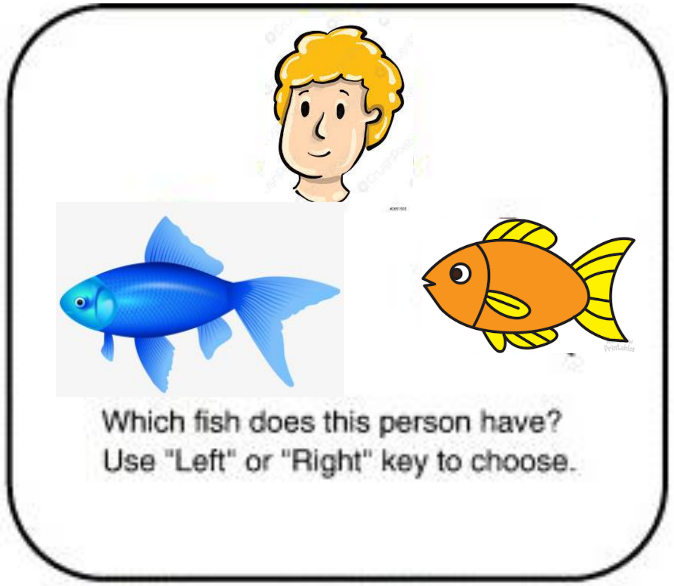
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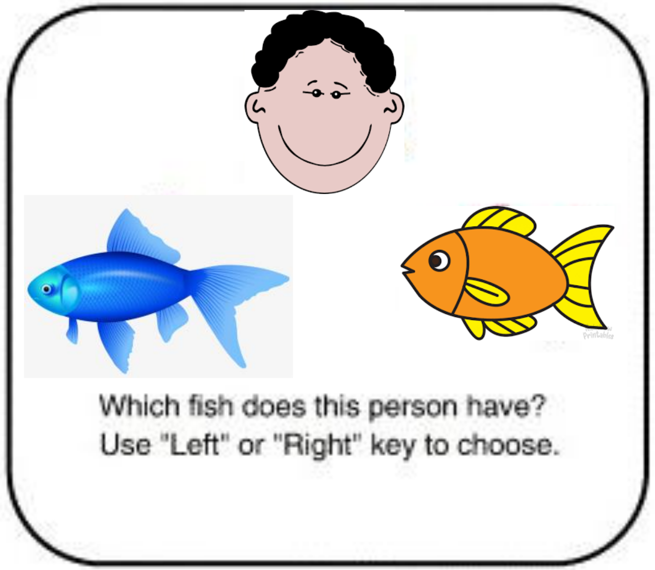

Which fish does this person have?
Use "Left" or "Right" key to choose.

Acquired Equivalence:
Novel Similar Predictions Based on Prior Similar Consequences

- **Acquired equivalence:** it is possible for generalization to occur between two very dissimilar stimuli even if they never co-occur

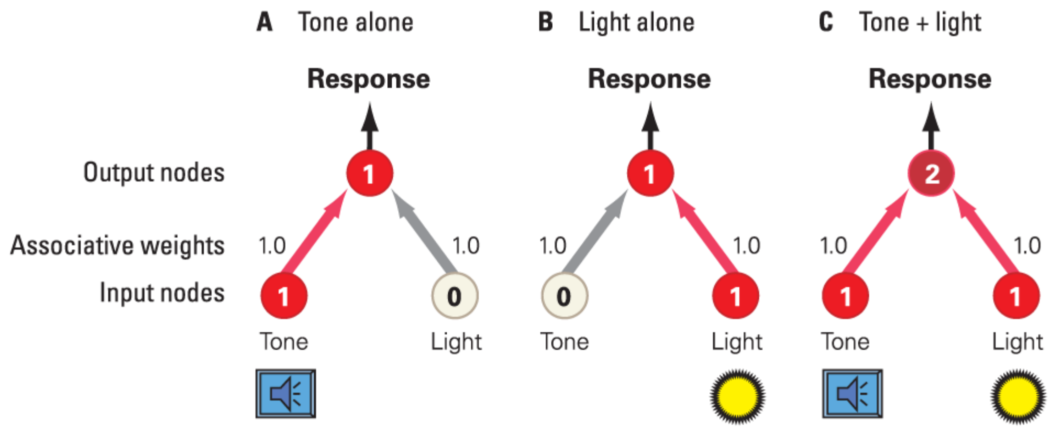
Phase 1 training	Phase 2 training	Phase 3: test
A1 →X1→ food A2 →X1→ food	A1→ food	A2: strong pecking response
B1→ Y1→ food B2 →Y1→ food	B1→ no food	B2: no strong response

Generalization of bad behaviour of black people by US police

Gender and Racial stereotyping

Negative Patterning: When the Whole Means Something Different Than the Parts

Tone ➔ airpuff
Light ➔ airpuff
Tone + light ➔ no airpuff



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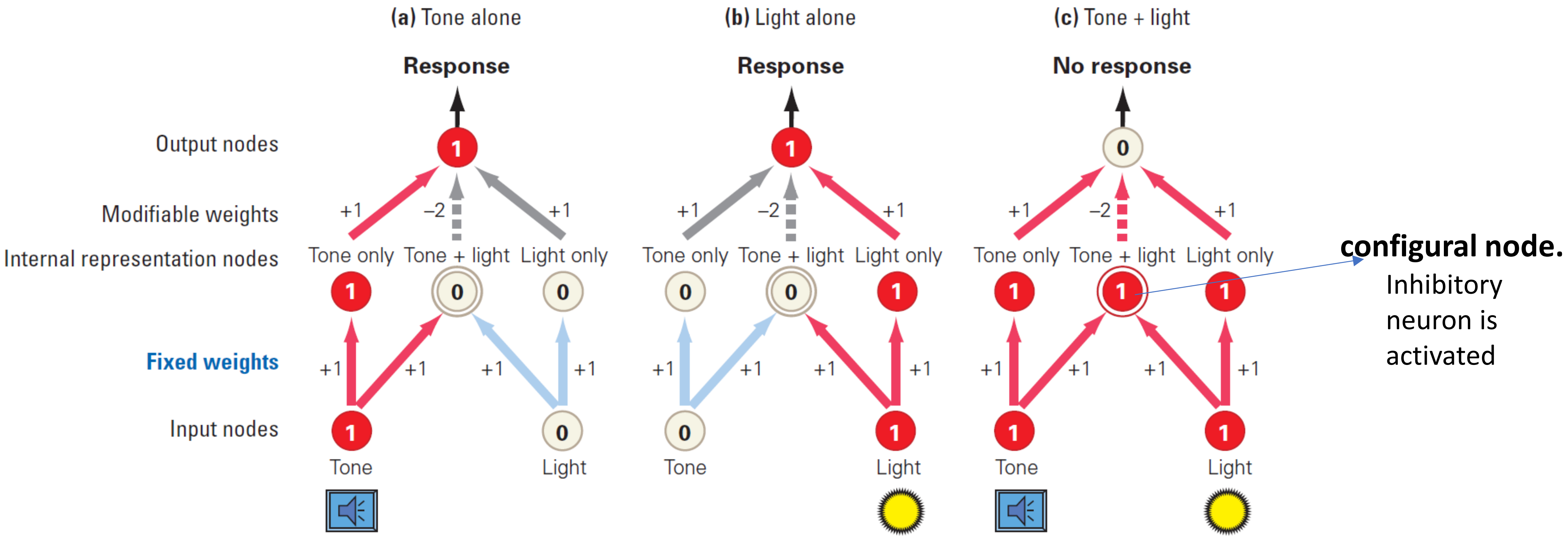
Generalization does not apply

Learned through experience or observation



(a) Tone alone
Response
(b) Light alone
Response
(c) Tone + light
No response
Output nodes
Modifiable weights
Internal representation nodes
Fixed weights
Input nodes
Tone only
Tone + light
Light only
+1
–2
1
0
Tone
Light
configural node.
Inhibitory
neuron is
activated

Various behavioral paradigms of generalization

a. discrimination training
b. preconditioning
c. acquired equivalence
d. negative patterning

1. Kareena is quite impressed by men who, on a first date, bring her either gifts or flowers. However, if a man shows up with both, she is turned off, feeling he is coming across too eager.
2. As a child, Karthik learned that people who have deep voices also tend to have beards. He later became convinced that men with beards are strong, and he inferred that a deep voice is also likely a sign of strength.
3. By playing snippets of music by Rahman, then Ilaiyaraja, and then Rahman again, a music teacher is able to teach his class how to recognize the style of each.
4. Two individuals launch a startup which takes off, makes huge profits. One of founders is hired by a competitor and expects the same growth.

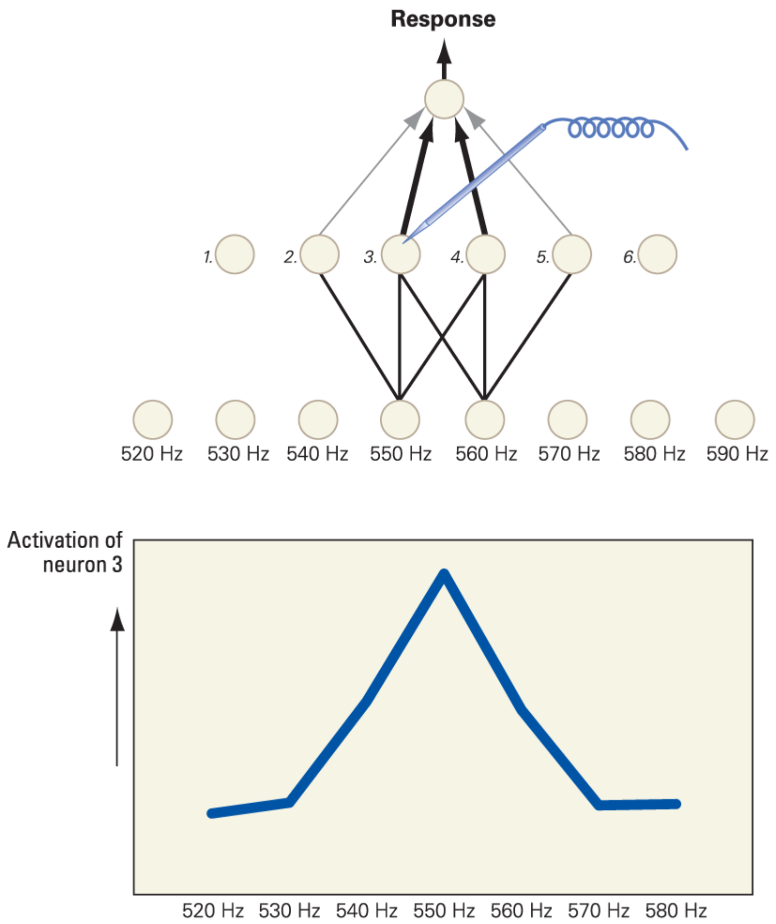
Generalization vs Discrimination

Various behavioral paradigms of generalization

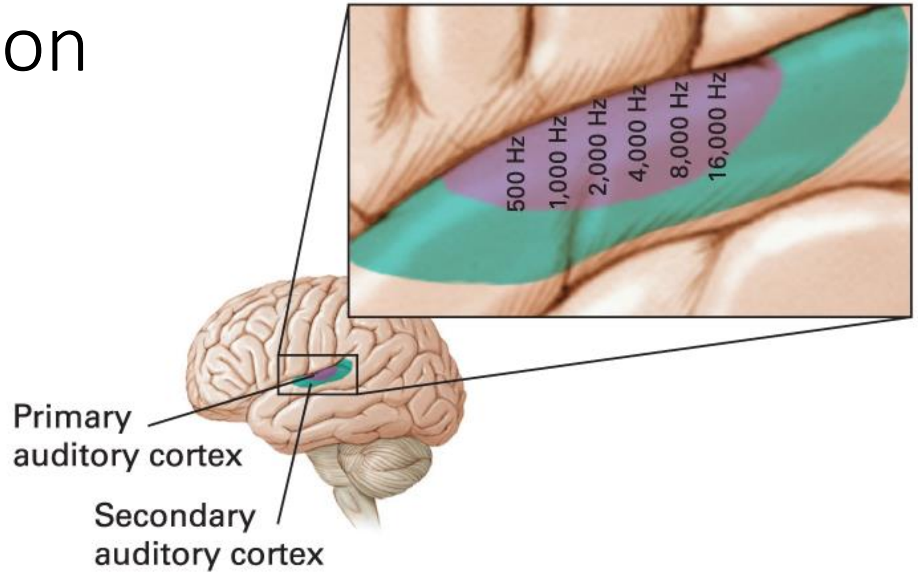
a. discrimination training
b. sensory preconditioning
c. acquired equivalence
d. negative patterning

Help us to form the basic knowledge systems that we develop

Brain mechanisms that lead to generalization



Gluck et al., *Learning and Memory*, 4e, © 2020 Worth Publishers



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- Overlapping representation
- Offers redundancy (One stimulus → ~3 neurons fire)
- Known as receptive field of neuron → same neuron fires to stimuli very similar to actual stimulus

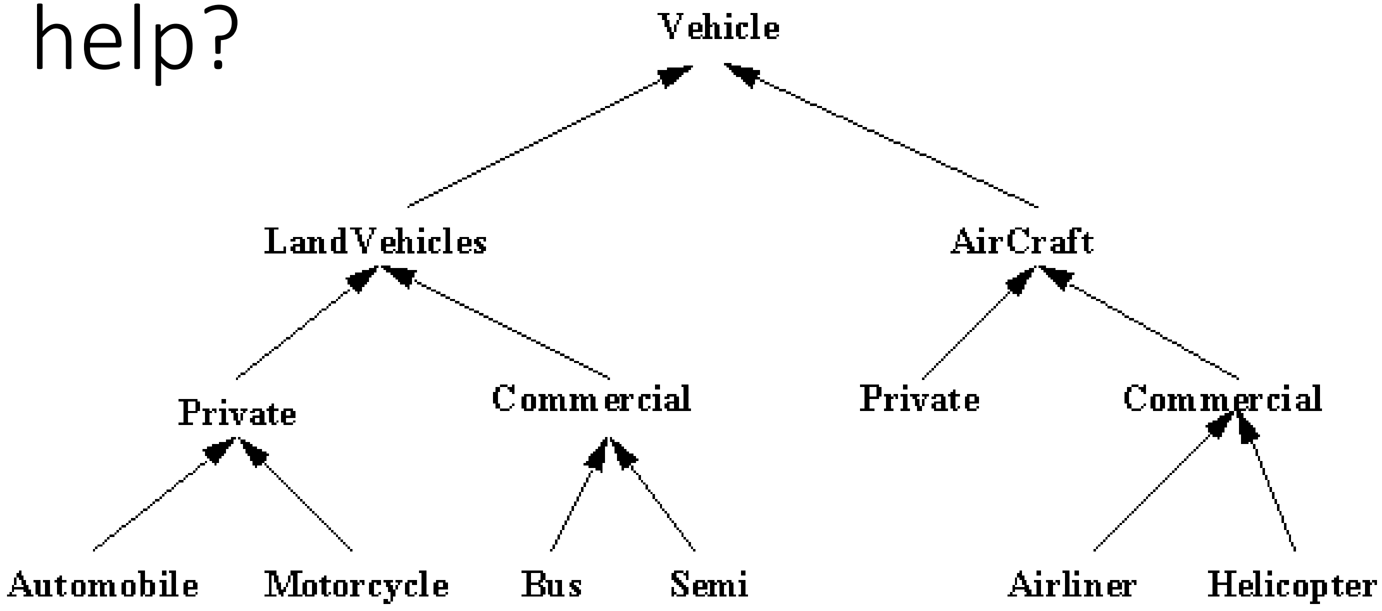
- Downside → stimulus detected by neighbouring neurons → loss of specificity → generalization

Receptive fields provide a balance between discrimination and generalization

How does generalization help?

Try to extract meaning from what you see

How does generalization help?



You try to extract commonalities from what you know and yet maintain distinction

Knowledge networks organize themselves to form concepts

Vehicle is a concept

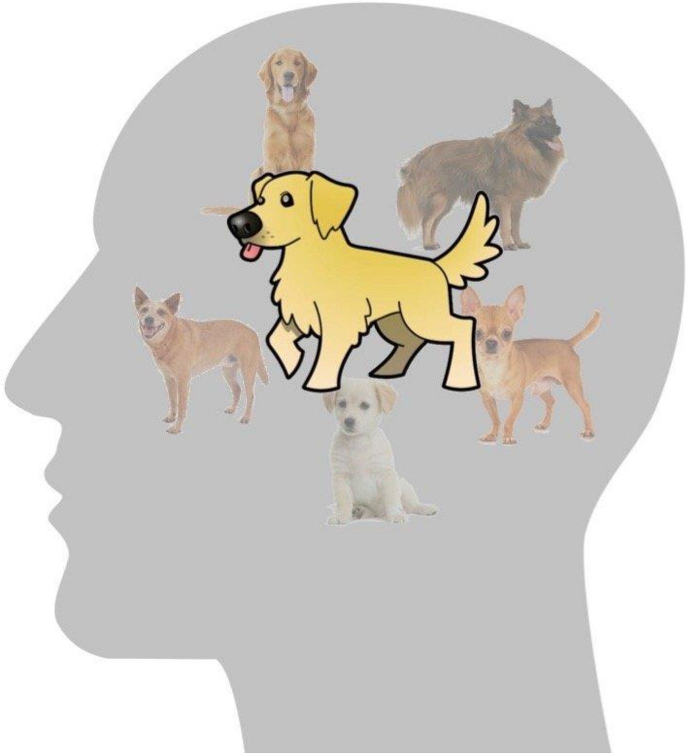
Concept Formation, Category Learning, and Prototypes

- **Concept:** an internal psychological representation of a real or abstract entity
- Forming concepts requires both generalization and discrimination. We generalize all dogs to have basic “dog feature” be but discriminate between its members to identify different breeds

E.g. dog → 4 legs, round nose, flappy ears, tapering jaw, etc.

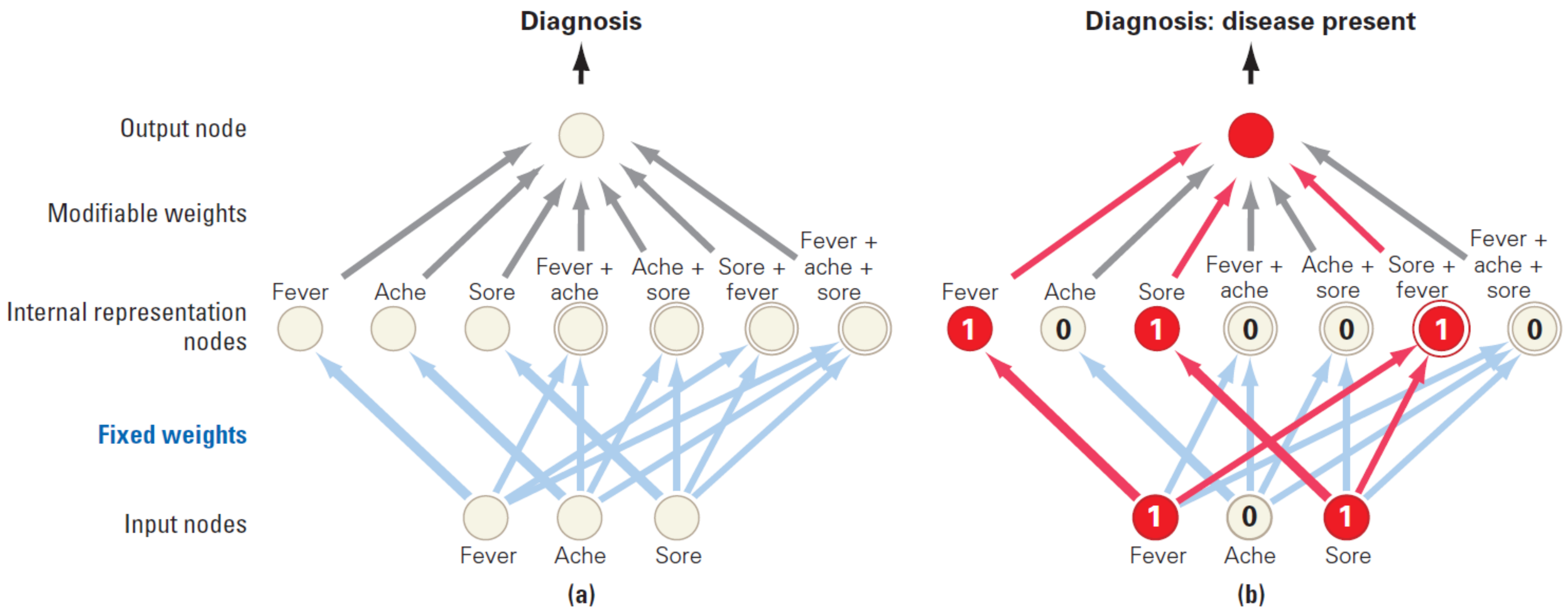
Concepts help to categorize information

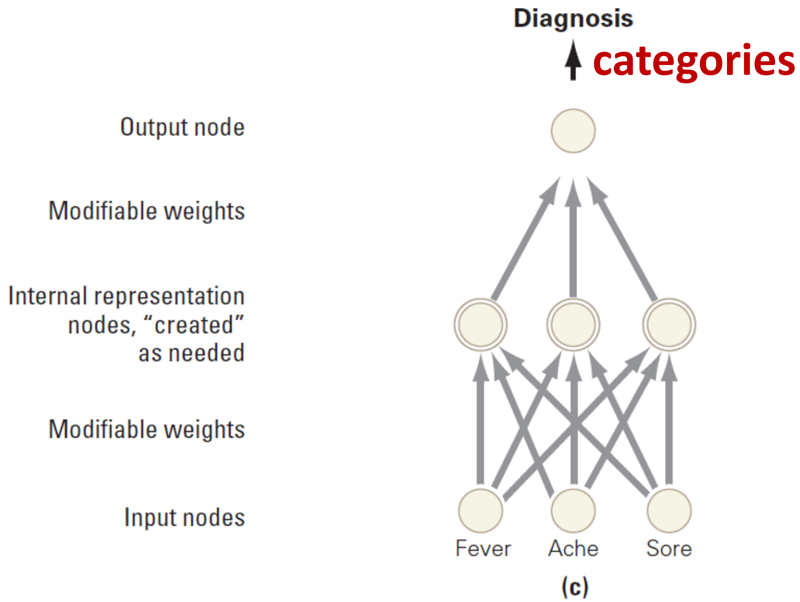
Prototype – Abstracted from examples

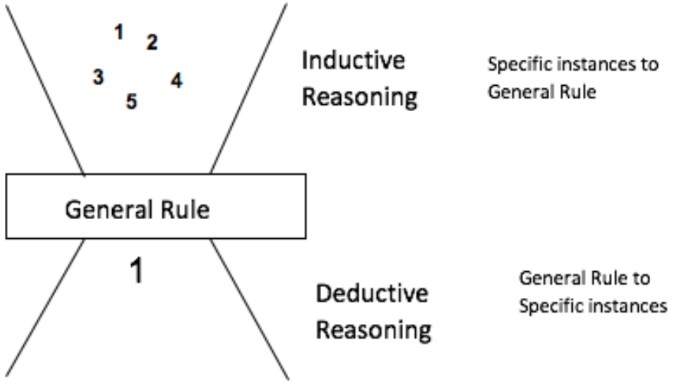


- **Category:** a division or class of entities in the world
- E.g. dogs, birds, cats, cars, fruits, vehicles
- categories help us make inferences about objects and events and guide us in predicting the future.

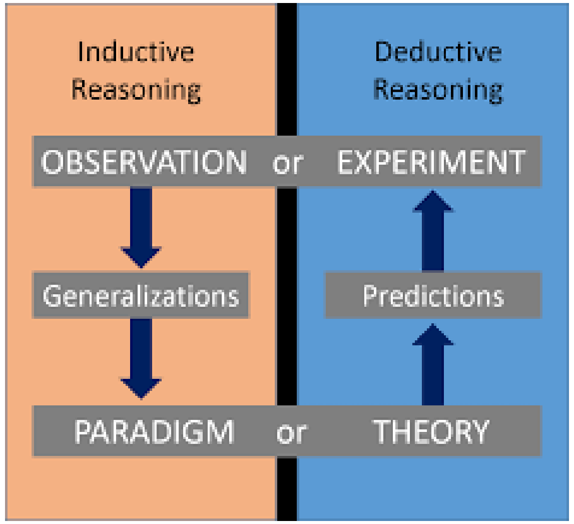
Classifying stimuli into categories







concepts derived from categories are tools for helping us induce meaningful relationships in the world, help us to make decisions or choices



Concept

inductive inference

A logical inference that is probably (but not necessarily) true and is usually based on attempts to draw a general rule from one or more specific instances or premises.

Prototypes and exceptions

All birds that fly have wings

All birds who have wings can fly
(but not penguins, ostrich, emu, kiwi, etc.)

Category

Quiz

What is categorizing people called?

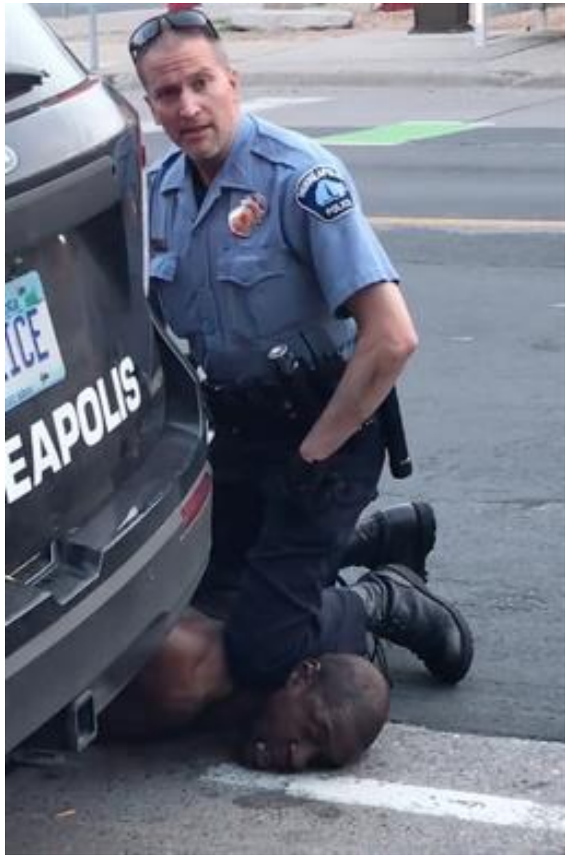
stereotype

Stereotypes & Generalizations about Other People

Religious stereotyping

- **Stereotype:** A set of beliefs about the attributes of the members of a group
- In everyday social contexts, *discrimination* is more often used to mean the unfair differential treatment of individuals on the basis of the group to which they are perceived to belong

Negative stereotype
vs
Positive stereotype



How do people learn stereotyping?

- Personal experiences
- through our parents,
- friends,
- Second-hand reports in books, movies, TV, and social media

- people filter what they attend to through the personal lens of their own needs and self-interest.

- We tend to believe good things about the groups we belong to and view groups that are different from ours with varying degrees of skepticism.

- Once we have formed a negative stereotype about members of another group, we are more likely to pay attention to examples that confirm this stereotype; this process is known as **confirmation bias**

Why do we stereotype?

the cost of finding out correct information is too high relative to the ease of making a choice informed by only an inductive inference based on category membership.

How do we evaluate accuracy of stereotyping?

(1) all bull dogs are dangerous,
(2) most bull dogs are dangerous, or
(3) bull dogs are more dangerous than most other breeds of dog?

finding a balance between
- Specificity/discrimination (does the stereotype apply only to members of a particular group?) and
- generality (does it apply to all members of that group?)

Appropriate vs Inappropriate -- generalization errors – overcoming stereotype

All zebras have 4 legs

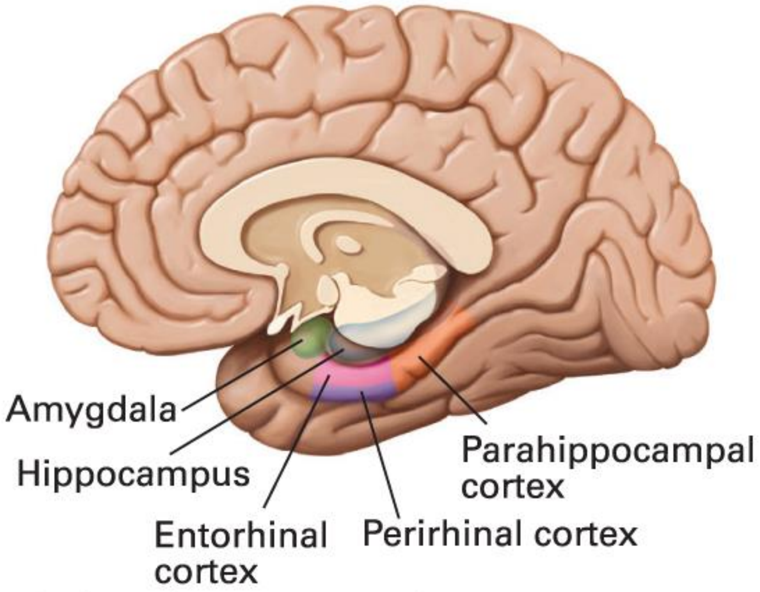
All 4-legged animals are zebras

People with malaria have high fever

People with high fever have malaria

Effect of Damage to the Hippocampal Region on Sensory preconditioning

- Rabbits with surgically created lesions in the fornix (a part of the hippocampal region) display no sensory preconditioning



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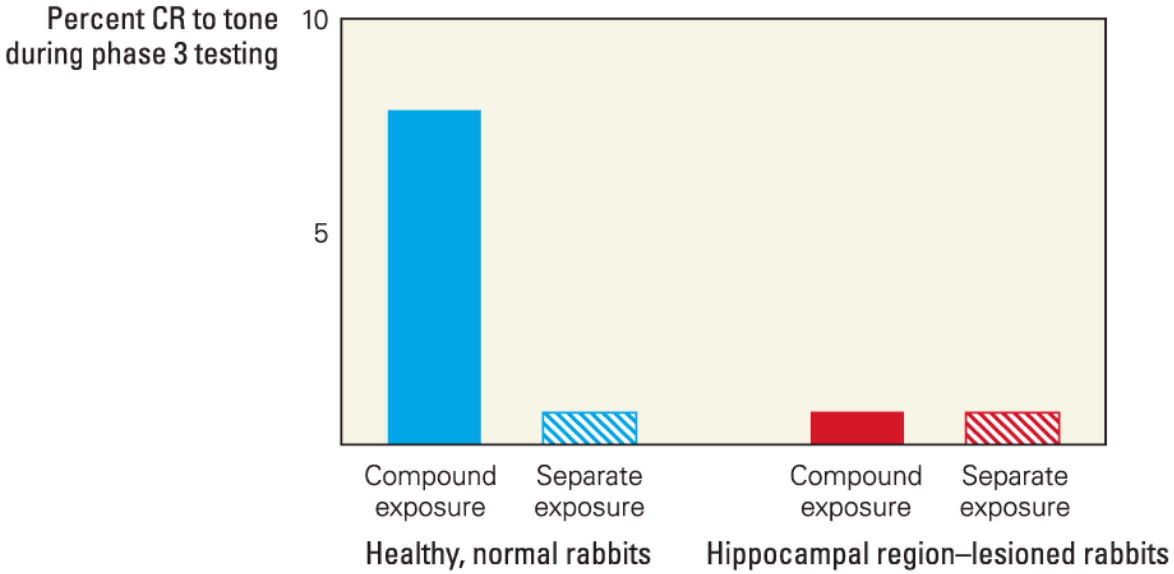

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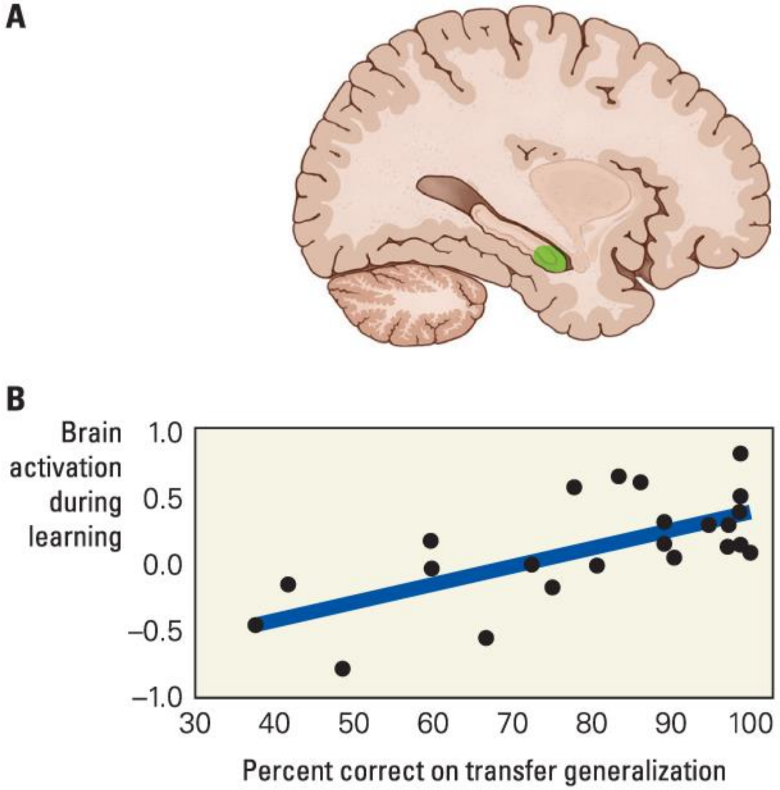
Group	Phase 1	Phase 2	Phase 3: test
Compound exposure	*Tone + light (together)*	Light → airpuff → blink!	Tone → blink!
Separate exposure (control group)	*Tone, light (separately)*	Light → airpuff → blink!	Tone → no blink

Individual Differences in Acquired-Equivalence Learning in Healthy Subjects



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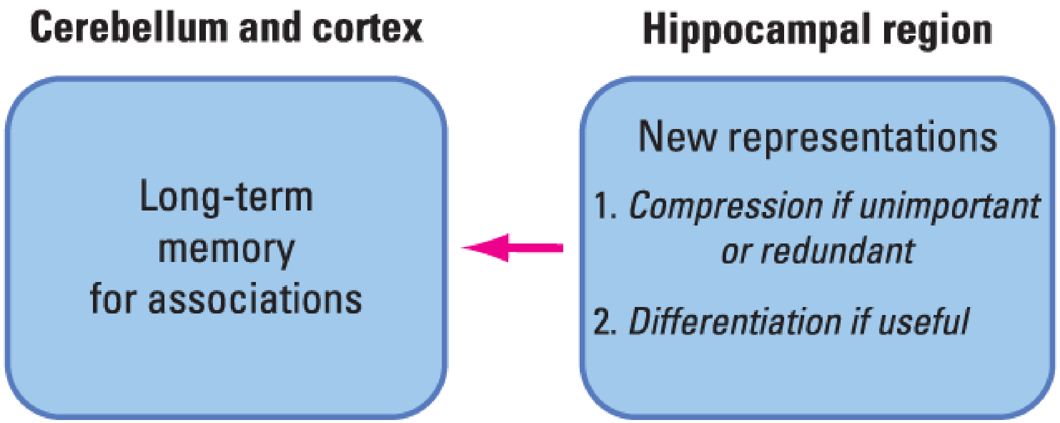
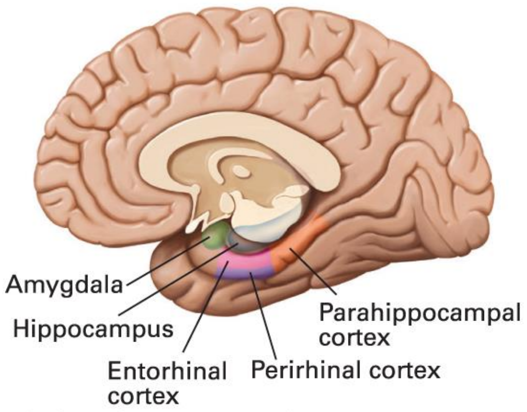
- (A) Brain images showed that hippocampus activation correlated with learning in an acquired-equivalence task

- (B) Brain activation signal during learning correlated with accuracy in tests of generalization across all subjects

Gluck and Myers's Model of Hippocampal-Region Function in Learning



Gluck et al., *Learning a*
Publishers

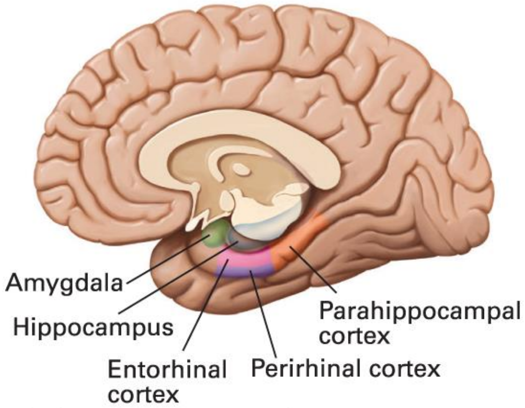


Gluck et al., *Learning and Memory*, 4e,

- hippocampal region operates as an "information gateway" during associative learning, processing new representations of events that are experienced
- hippocampal region selects what information is allowed to enter memory and how it is to be encoded by other brain regions
- hippocampal-region function imp for modification of stimulus representations in human learning and generalization

Schizophrenia

- Schizophrenia is a severe mental disorder with symptoms of hallucinations, delusions, flattened affect, and social impairment
- People diagnosed with schizophrenia show abnormalities in their hippocampal shape and reduced hippocampal activity



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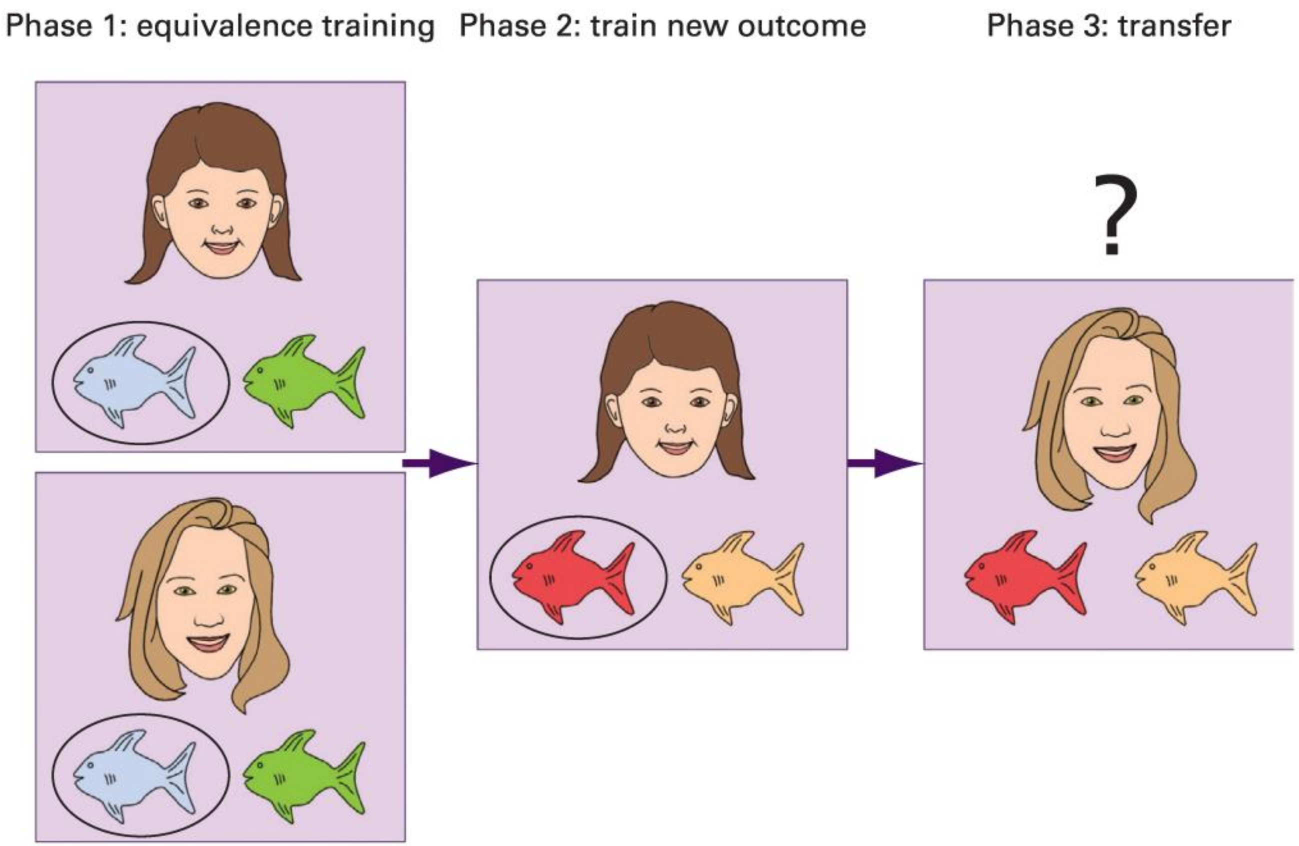
An Acquired-Equivalence Task for Humans



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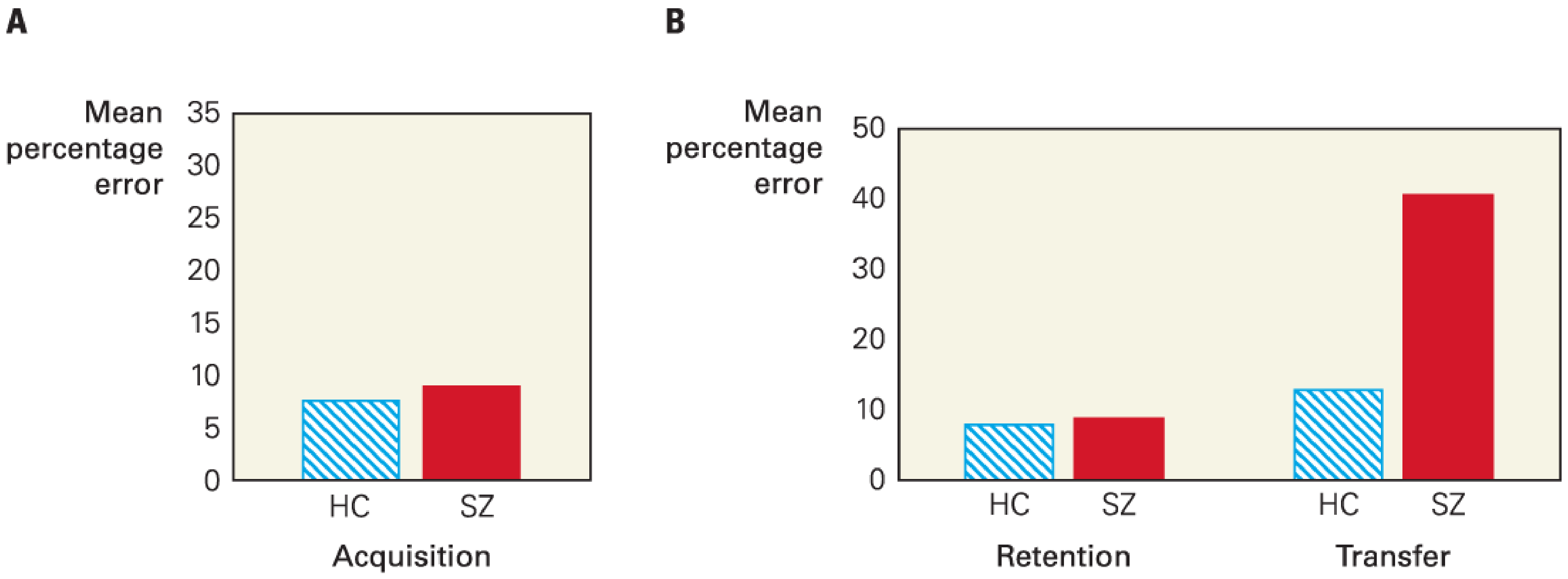
Acquired Equivalence in Schizophrenia

- The deficit observed in the generalization phase in patients with schizophrenia suggests that hippocampal-region–dependent functions are impaired in schizophrenia



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impaired at transitive inference

Altered Generalization in Autism Spectrum Disorder

- Autism spectrum disorder (ASD) is a lifelong neurodevelopmental condition for which there is no known cure
  - Differs greatly from person to person in severity
  - Commonly associated with poor social skills and impaired communication abilities

- inability to process compound cues and cannot integrate multiple sources of information; instead become highly selective, adhering to just one
- exhibit stimulus overselectivity in generalization tasks has been linked to a variety of clinical behaviors associated with ASD, including impaired social skills, language deficits, lack of inhibitory control, and ritualistic behaviors

- a 150-watt red light (visual),
- a 63-decibel white noise (auditory),
- an inflatable blood-pressure cuff (tactile),
- and a variable period during which these cues were presented (temporal).

“tunnel vision”
Hyperfocused

Working memory

H

C

T

D

G

P

L

J

N

U

E

How many letters do you remember?

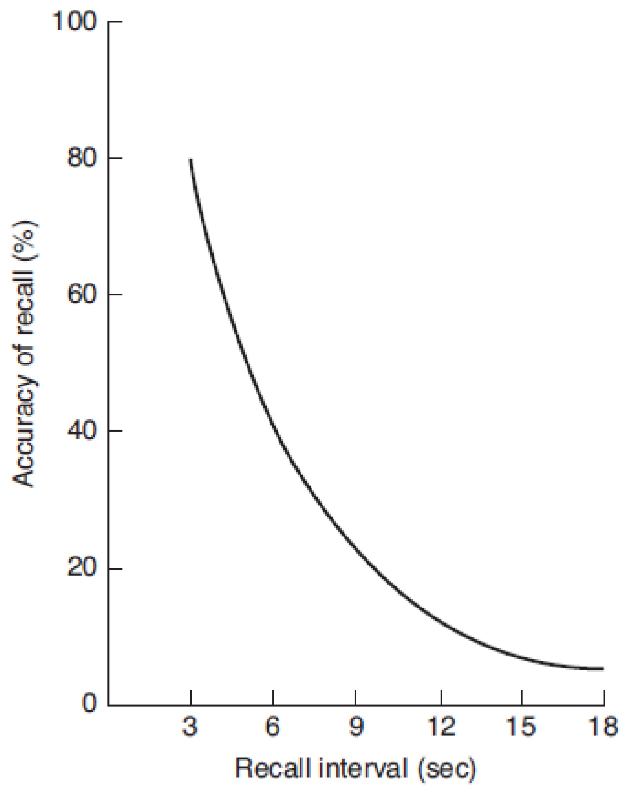
Listen to a list of words

DRUM
CURTAIN
FARMER
SCHOOL
MOON
GARDEN
PARENT
HAT
NOSE
BELL
COFFEE
TURKEY
COLOR
HOUSE
RIVER

Sensory memory

Auditory (echoic) sensory memory

Visual (iconic) sensory memory



Primacy & Recency effect

Try to remember the following list of digits
1 9 2 5 4 9 8 1 1 2 1

Now try to remember them in groups
1 9   2 5   4 9   8 1   1 2 1

Now memorize them using a strategy

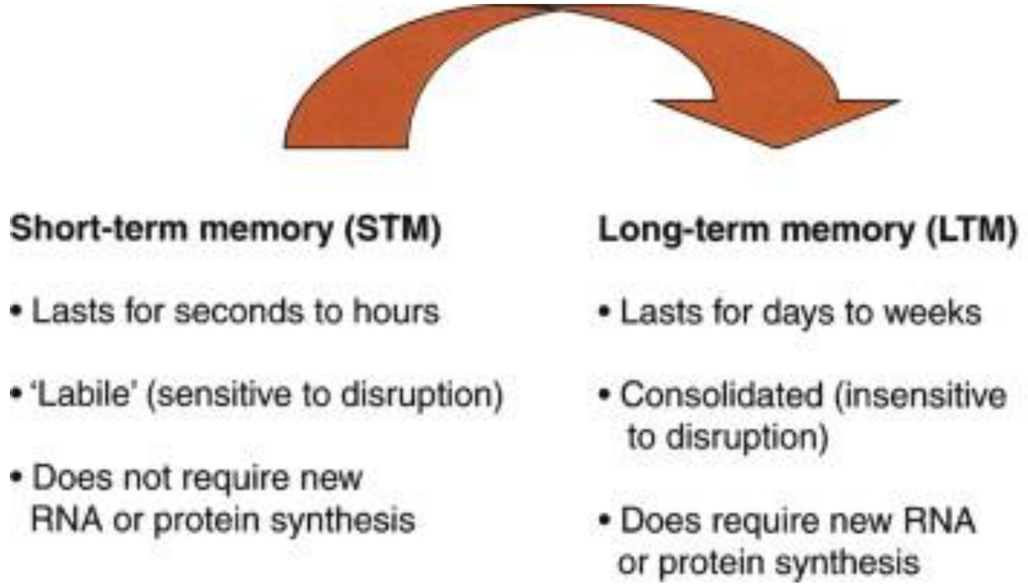
1^2 3^2 5^2 7^2 9^2 11^2

Chunking information helps retention

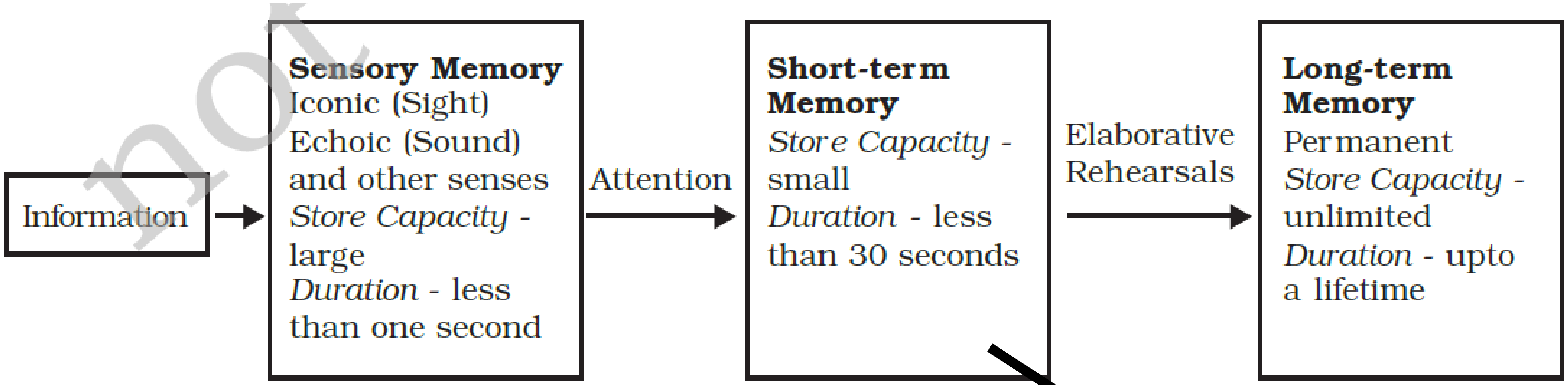
- Indian phone number chunking –   98672-61423
- American phone number chunking –   234-456-8671

Short-Term Memory

- limited capacity
- effortlessly available
- fleeting in contrast to long-term memory

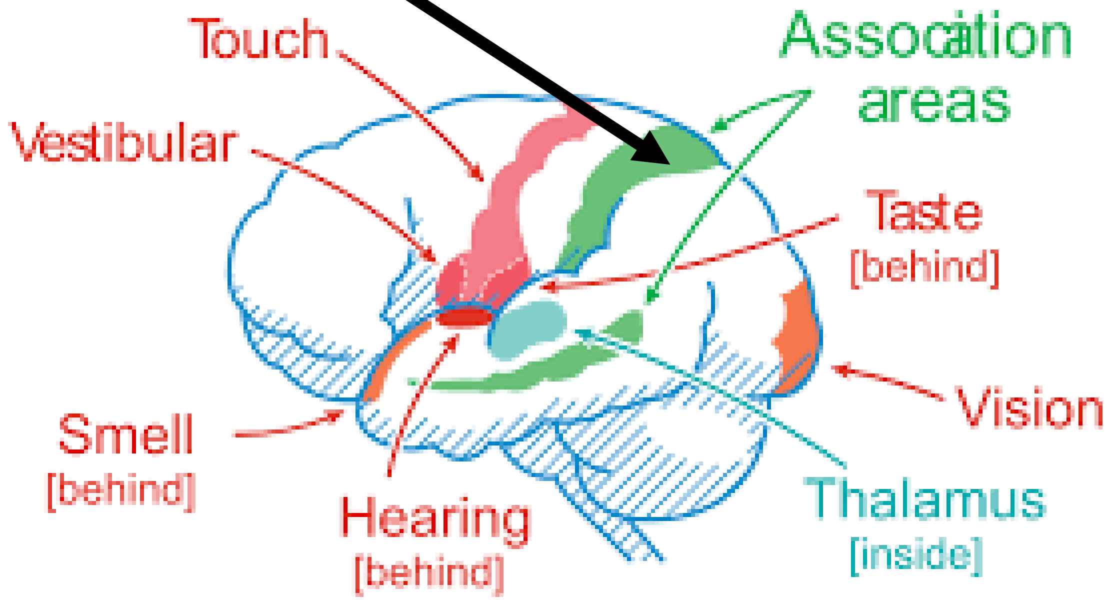


STM	LTM
Active contents of consciousness	Not currently in consciousness
Rapidly accessed	Accessed more slowly
Limited in capacity	Unlimited in capacity
Forgotten quickly	Forgotten more slowly



Outdated concept

Association



IS $(5 \times 3) + 4 = 17$? BOOK

IS $(5 \times 3) + 4 = 17$? BOOK
IS $(6 \times 2) - 3 = 8$? HOUSE

IS	$(5 \times 3) + 4 = 17$?	BOOK
IS	$(6 \times 2) - 3 = 8$?	HOUSE
IS	$(4 \times 4) - 4 = 12$?	JACKET

IS $(5 \times 3) + 4 = 17$?	BOOK
IS $(6 \times 2) - 3 = 8$?	HOUSE
IS $(4 \times 4) - 4 = 12$?	JACKET
IS $(3 \times 7) + 6 = 27$?	CAT

IS $(5 \times 3) + 4 = 17$? BOOK
IS $(6 \times 2) - 3 = 8$? HOUSE
IS $(4 \times 4) - 4 = 12$? JACKET
IS $(3 \times 7) + 6 = 27$? CAT
IS $(4 \times 8) - 2 = 31$? PEN

IS $(5 \times 3) + 4 = 17$?	BOOK
IS $(6 \times 2) - 3 = 8$?	HOUSE
IS $(4 \times 4) - 4 = 12$?	JACKET
IS $(3 \times 7) + 6 = 27$?	CAT
IS $(4 \times 8) - 2 = 31$?	PEN
IS $(9 \times 2) + 6 = 24$?	WATER

List the words in order

- remembering a phone number between the time of hearing it and dialling it
- figuring a tip (15% of total)
- holding the driving directions in mind until you get to the landmarks you’ve been told
- possible sequences of moves in a chess game

- Chimps vs Humans → who is better?

1

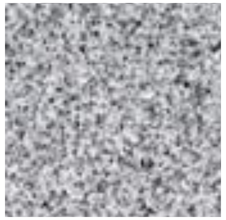
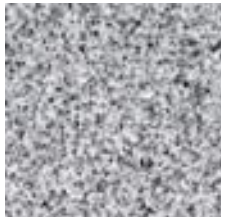
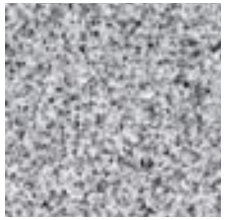
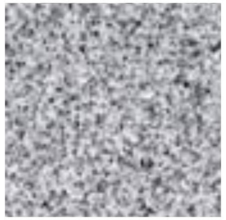
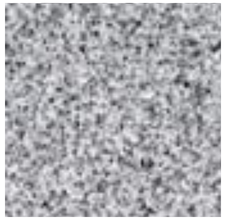
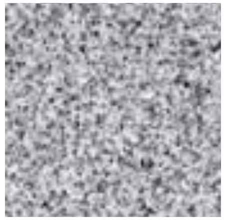
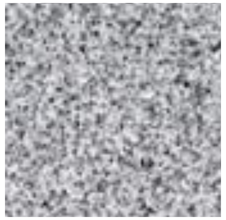
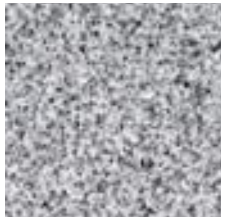
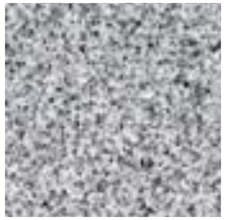
5 8 4 6

9 7

2

3

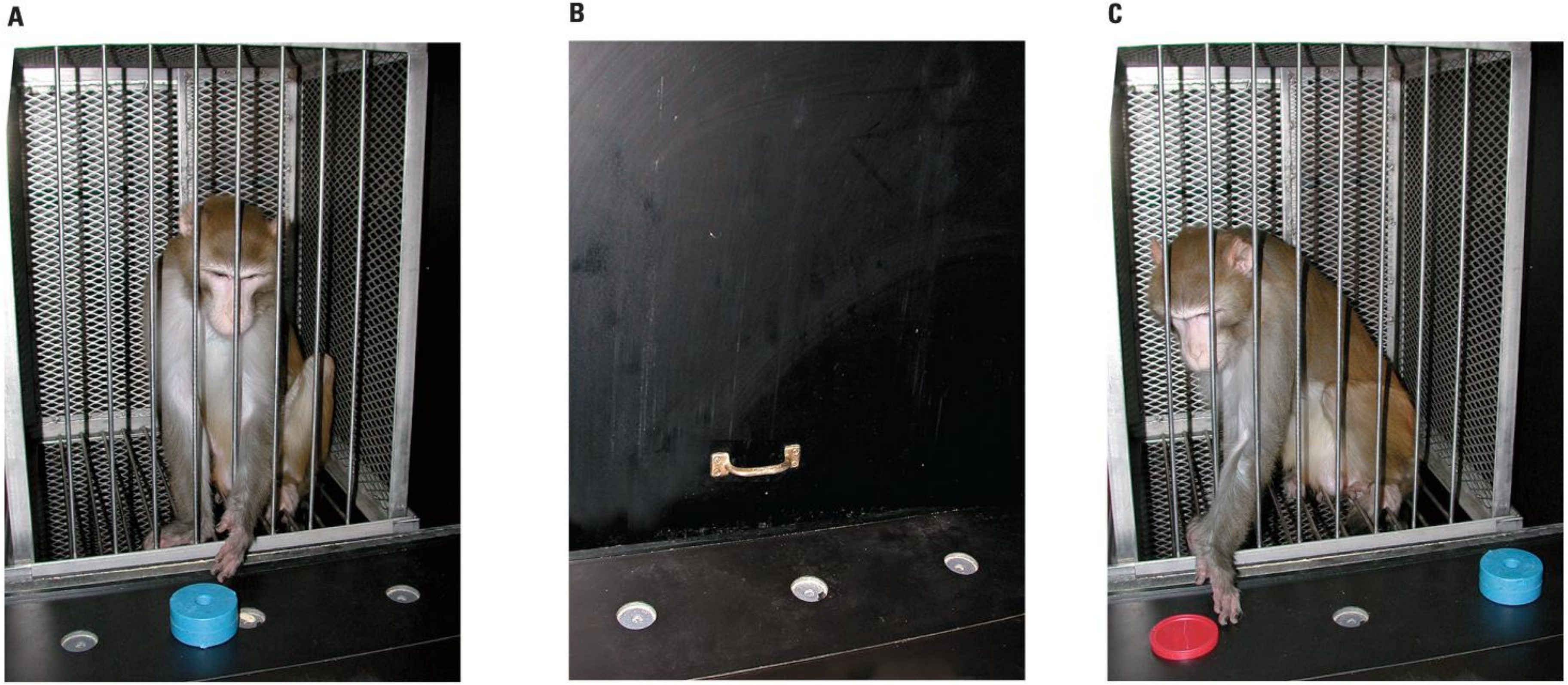
https://www.youtube.com/watch?v=zsXP8qeFF6A https://www.youtube.com/watch?v=nTgeLEWr614

But we don’t just remember information, we use it flexibly?

Where does that fit in?

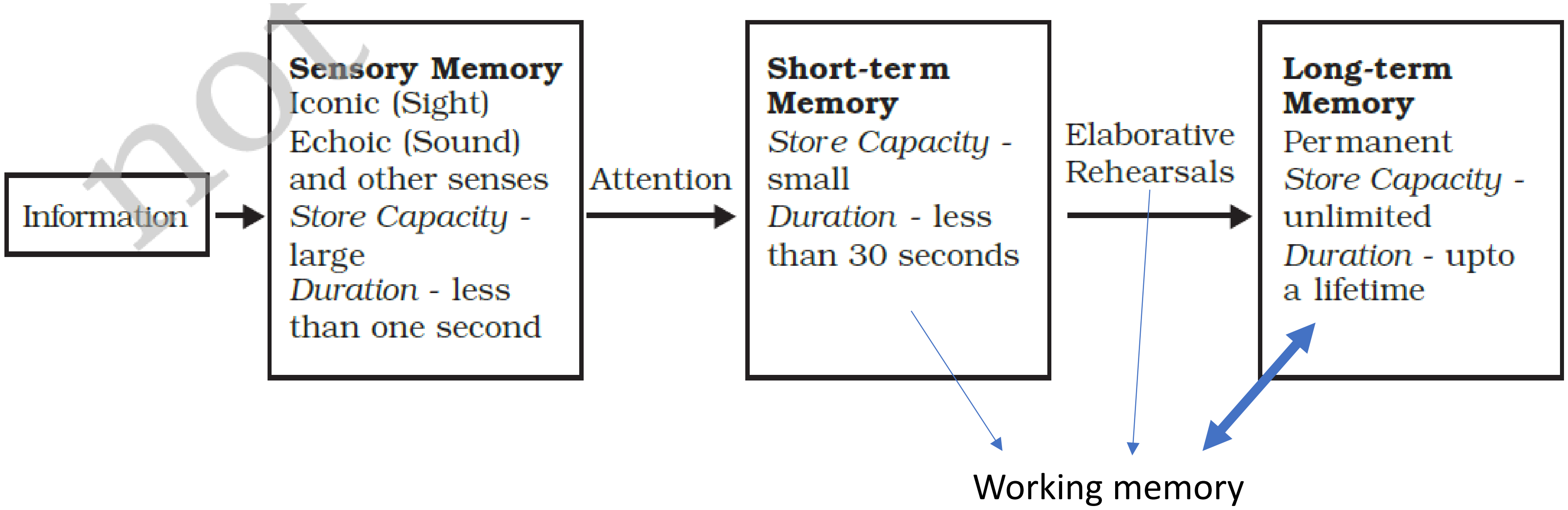
Delayed Nonmatch-to-Sample Task

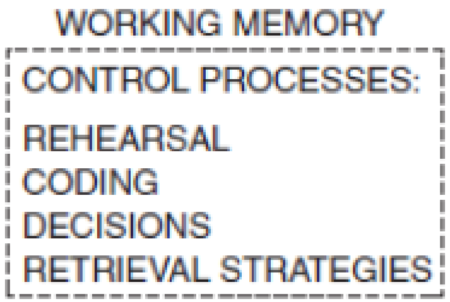


Monkey moves sample object for reward. | Screen obscures monkey's view during delay. | Monkey must choose novel nonmatch object for next reward.

Courtesy of David Yu, Mortimer Mishkin, and Janita Turchi, Laboratory of Neuropsychology, NIMH/NIH/DHHS.

The **delayed nonmatch-to-sample (DNMS)** involves remembering some object seen at the trial's start





Working memory: the active and temporary representation of information that is maintained for manipulation, solving problems, making decisions

The **delayed nonmatch-to-sample (DNMS) task** is a test of visual working memory

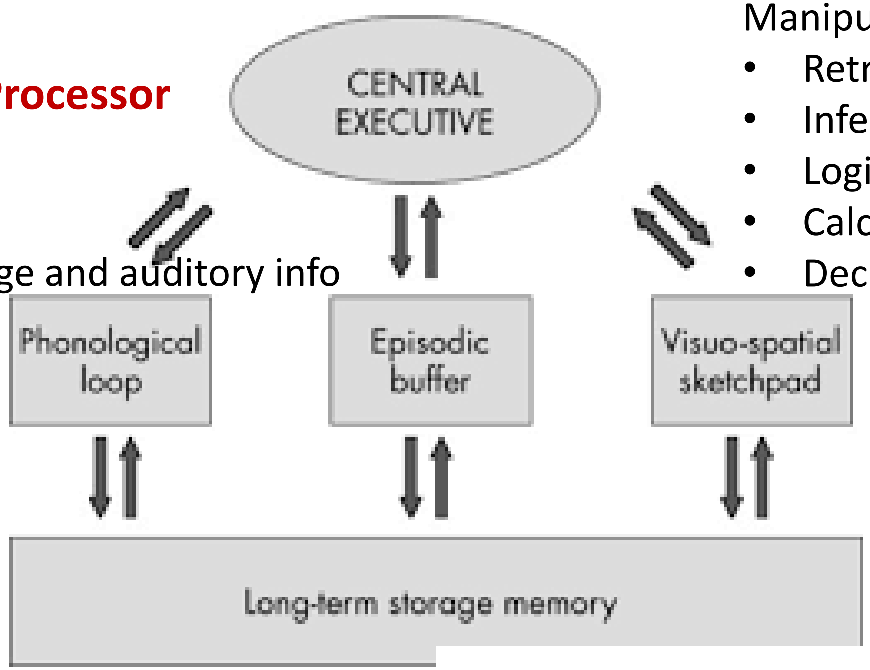
Working memory

Processor

RAM

Hard-disk

Language and auditory info

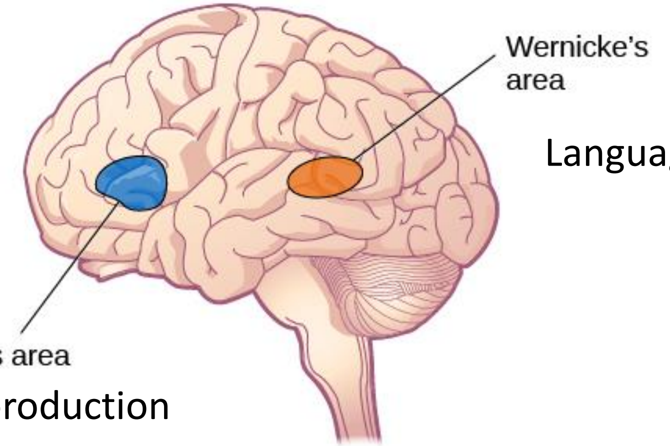


Manipulating information

- Retrieving memories
- Inference
- Logical analysis
- Calculation
- Decisions

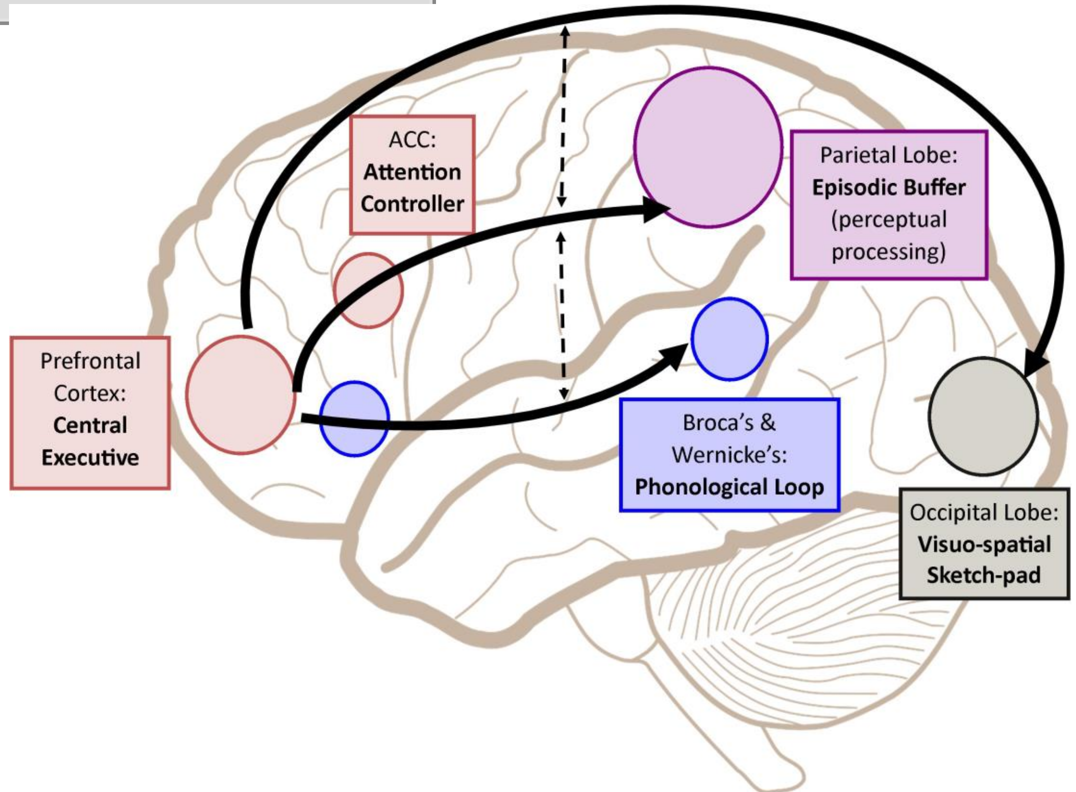
Maintaining information active

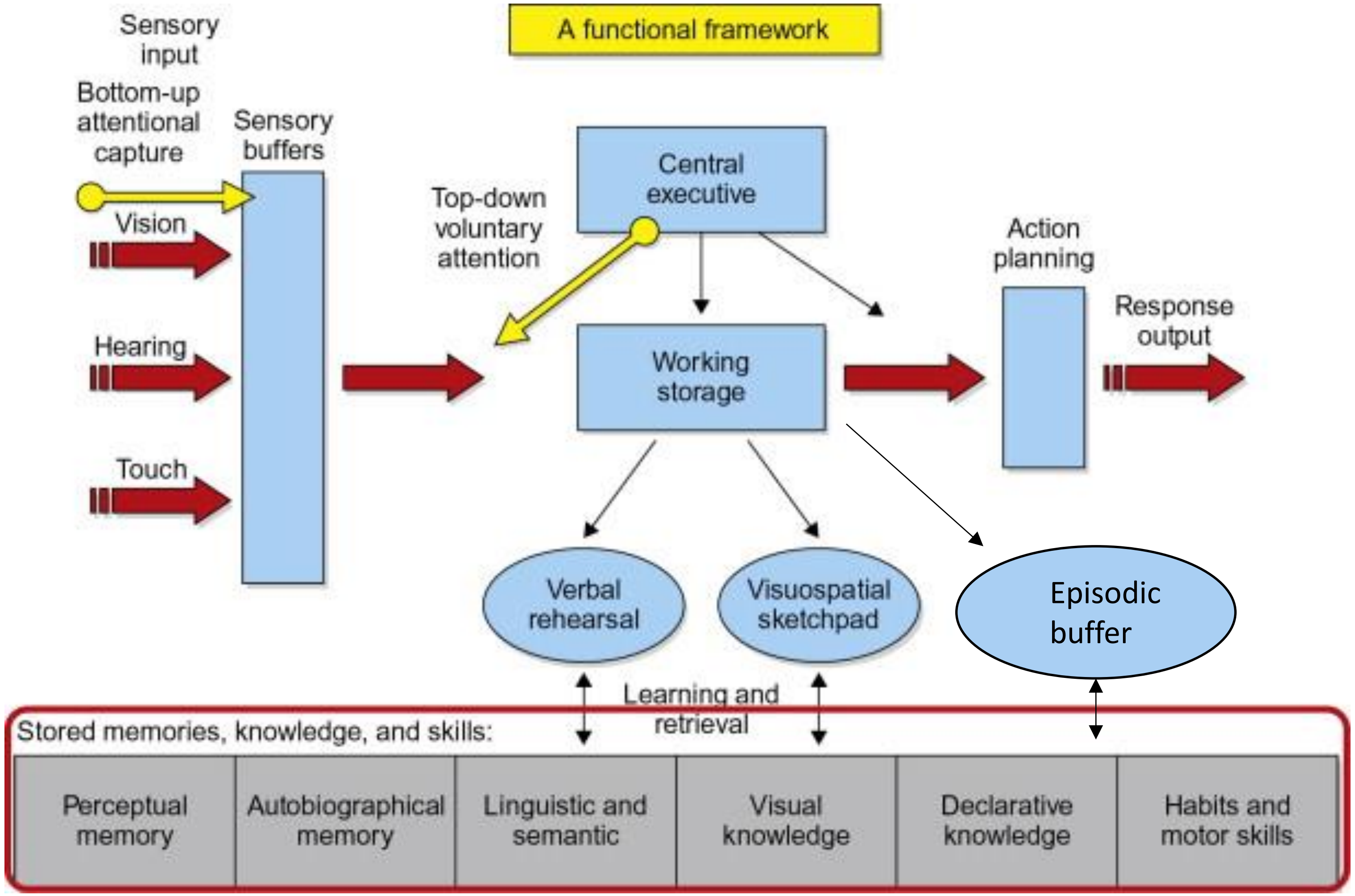
Allan Baddeley's working memory model



Language comprehension

Language production

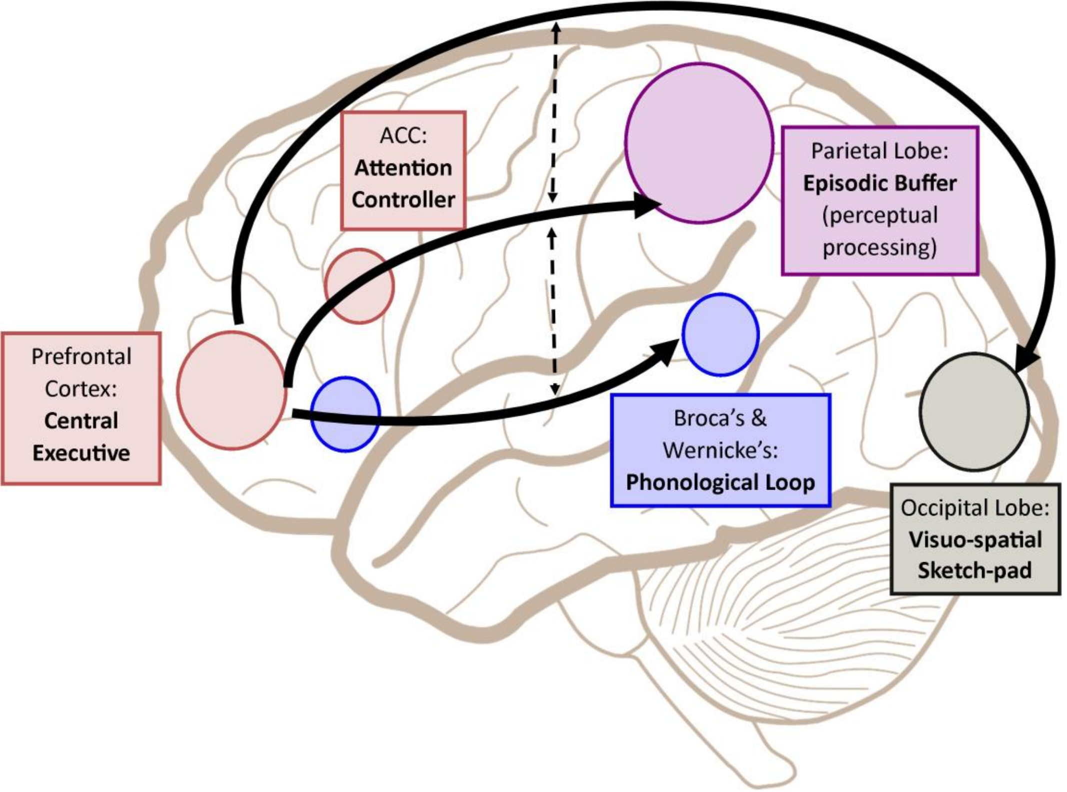


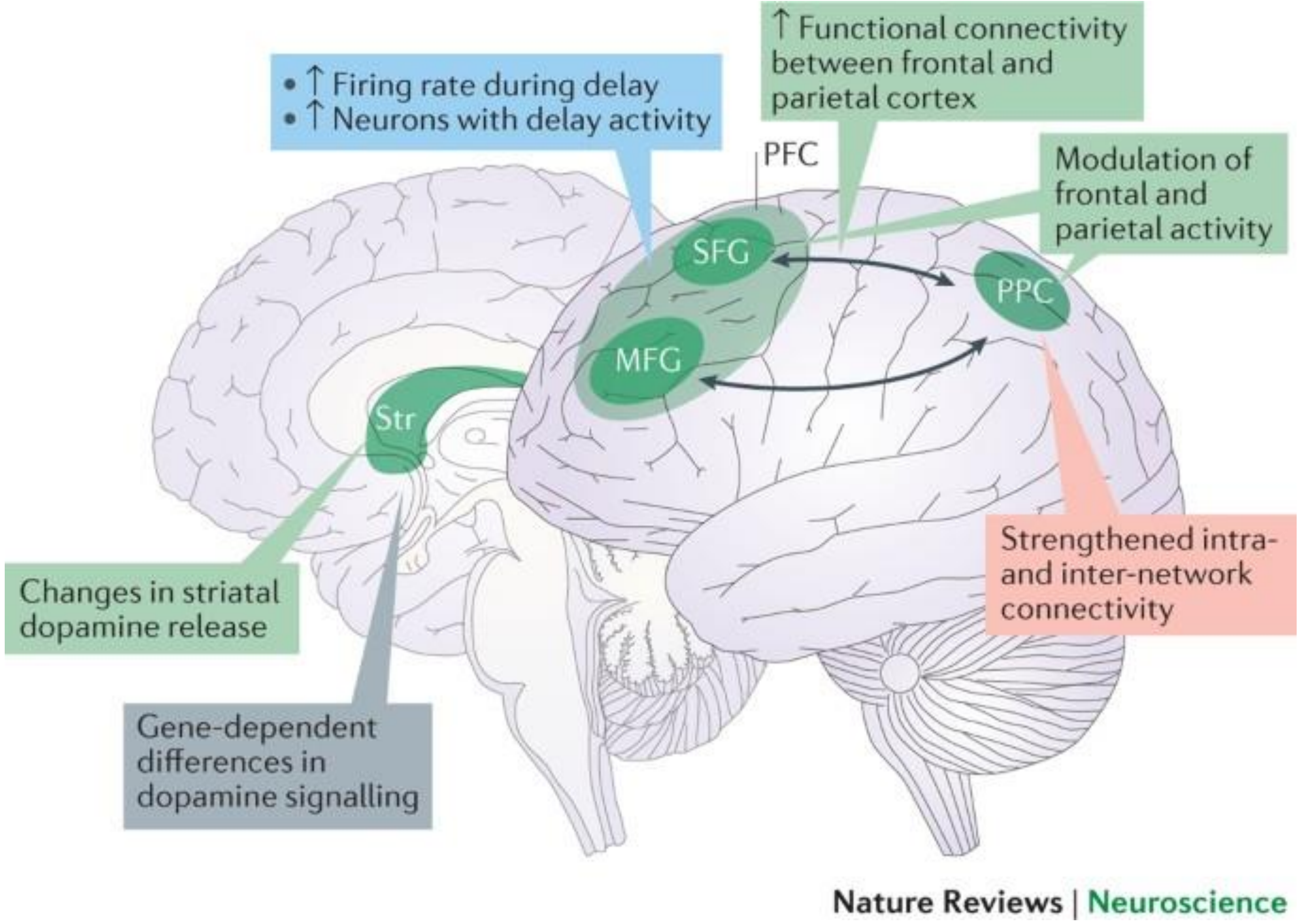

A functional framework
Sensory input
Bottom-up attentional capture
Sensory buffers
Vision
Hearing
Touch
Top-down voluntary attention
Central executive
Working storage
Action planning
Response output
Verbal rehearsal
Visuospatial sketchpad
Episodic buffer
Learning and retrieval
Stored memories, knowledge, and skills:
Perceptual memory
Autobiographical memory
Linguistic and semantic
Visual knowledge
Declarative knowledge
Habits and motor skills

Where is working memory located in the brain?

Is Working Memory a Place or a State?

- Working memory is often conceptualized as the mind's active workspace
- "Working memory" might not, in fact, describe a separate *place* for memories to be moved; rather, it might describe an active *state* for memories otherwise resident in LTM but not accessible to conscious reflection and manipulation until they are activated

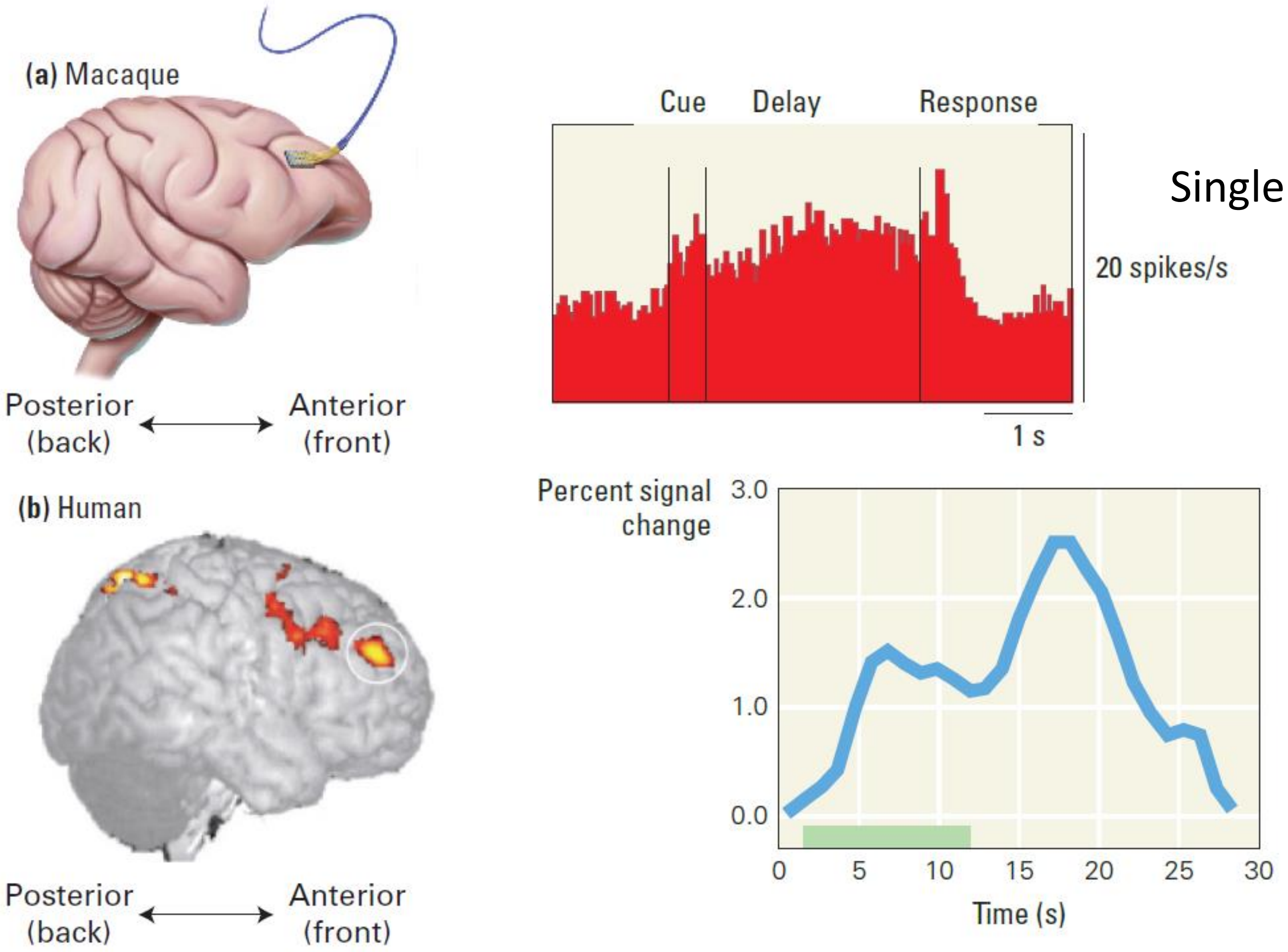




https://www.nature.com/articles/nrn.2016.43

How does the brain maintain information active over time?

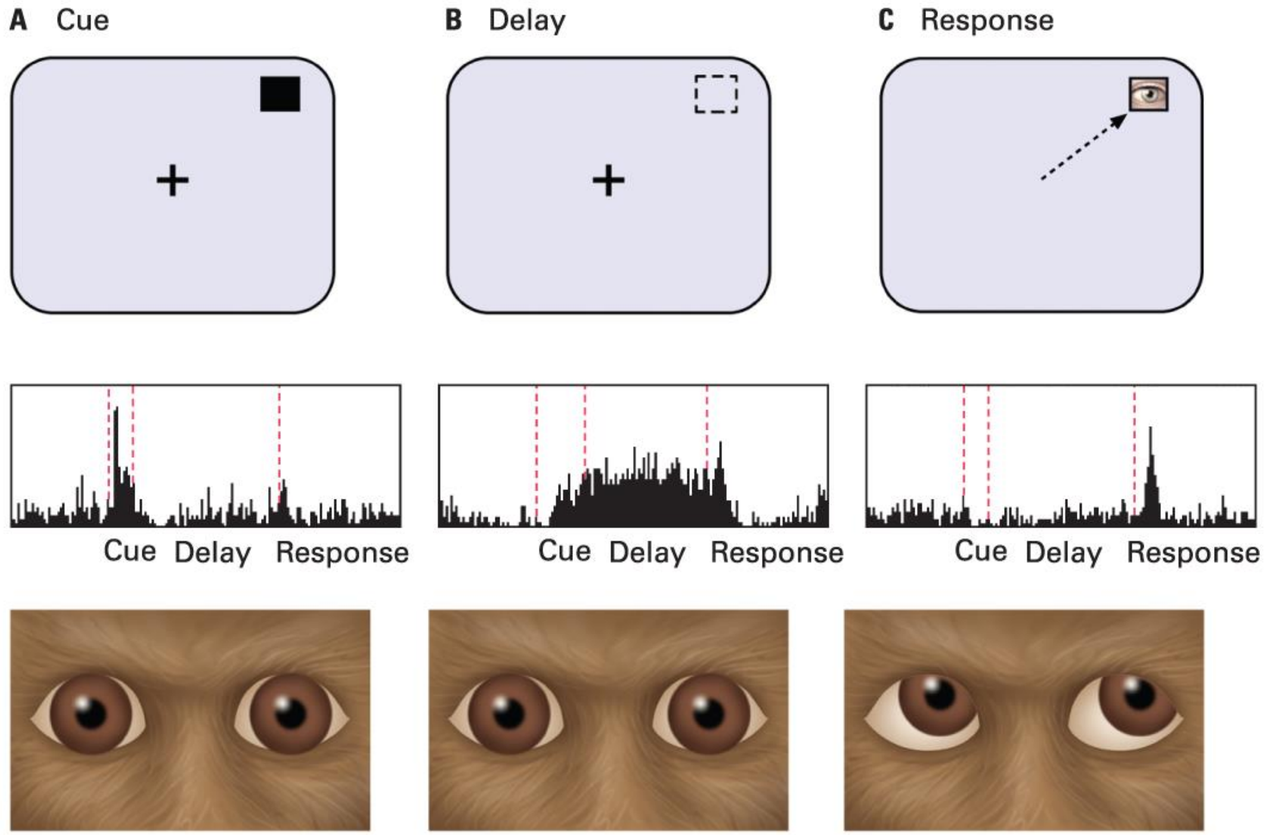
(like rehearsing a phone number in your head)



Single electrode recording

Frontal Brain Activity During Working-Memory Tasks

- Researchers in the early 1970s began to record prefrontal-cortex neural activity during working-memory tasks



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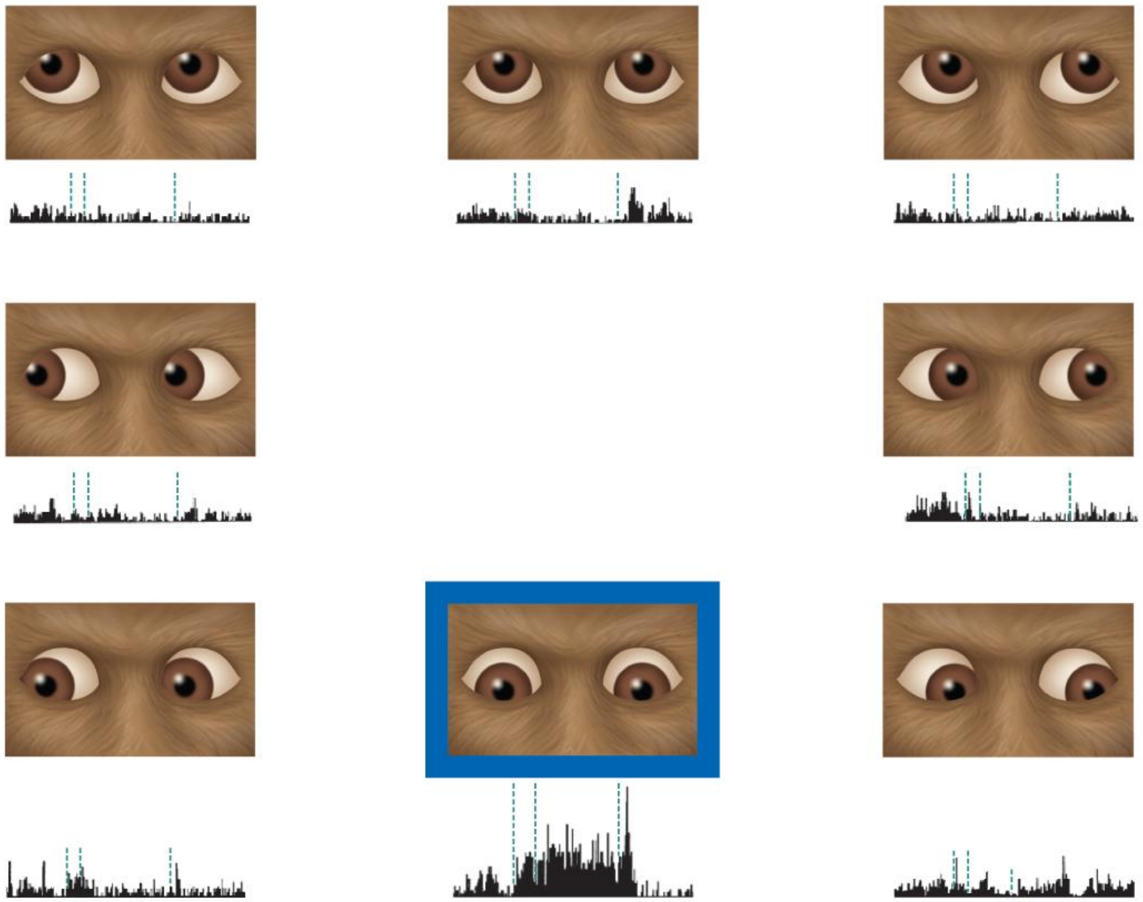
Response of One Prefrontal Cortex Neuron During the Delayed-Response Eye-Gaze Task



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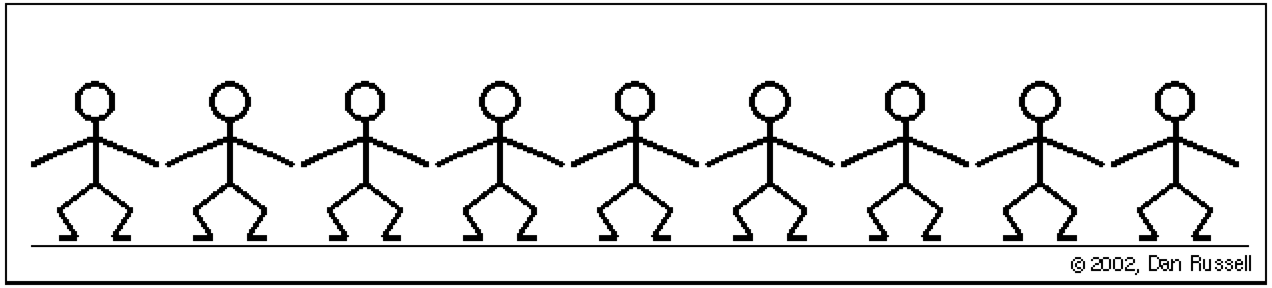
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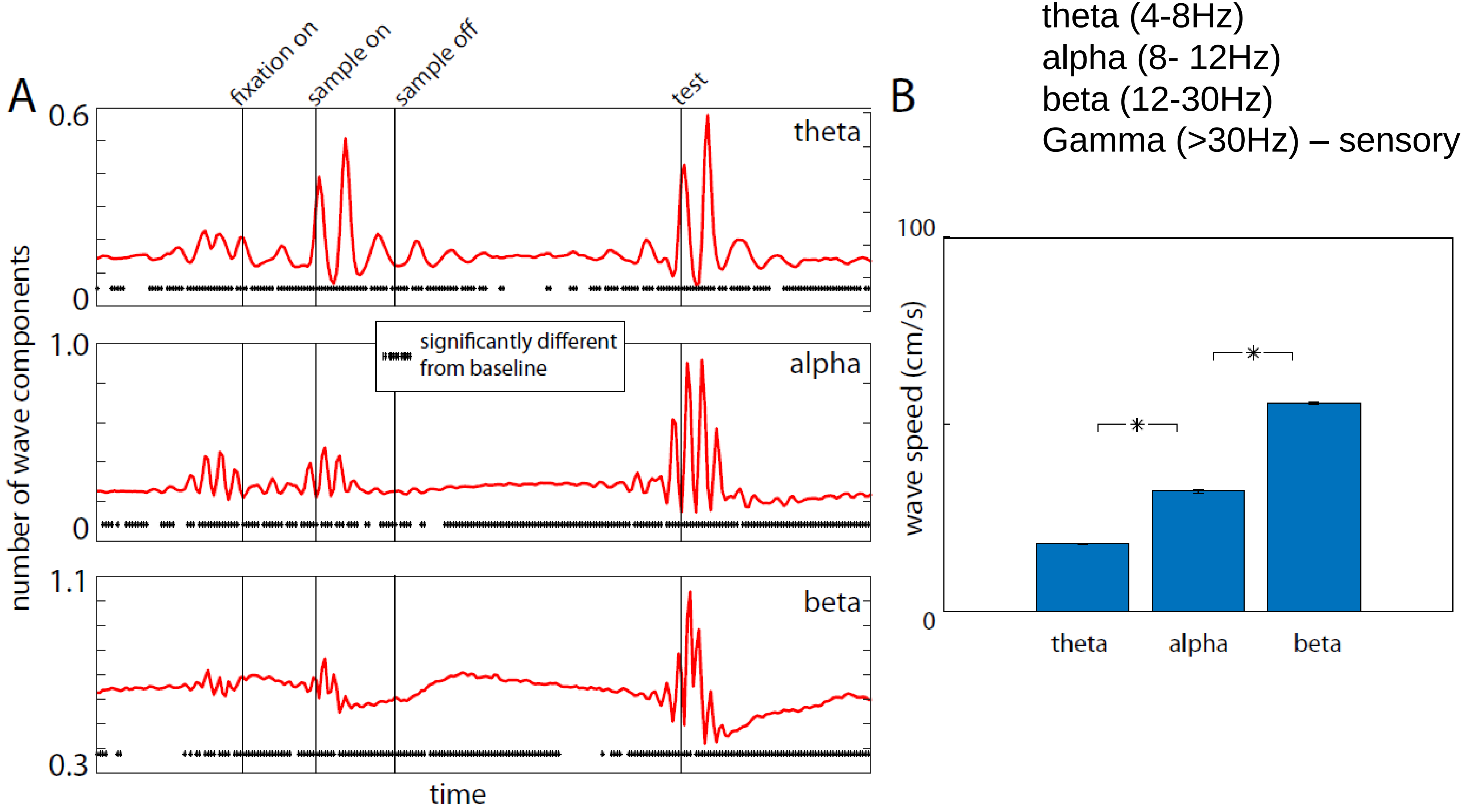
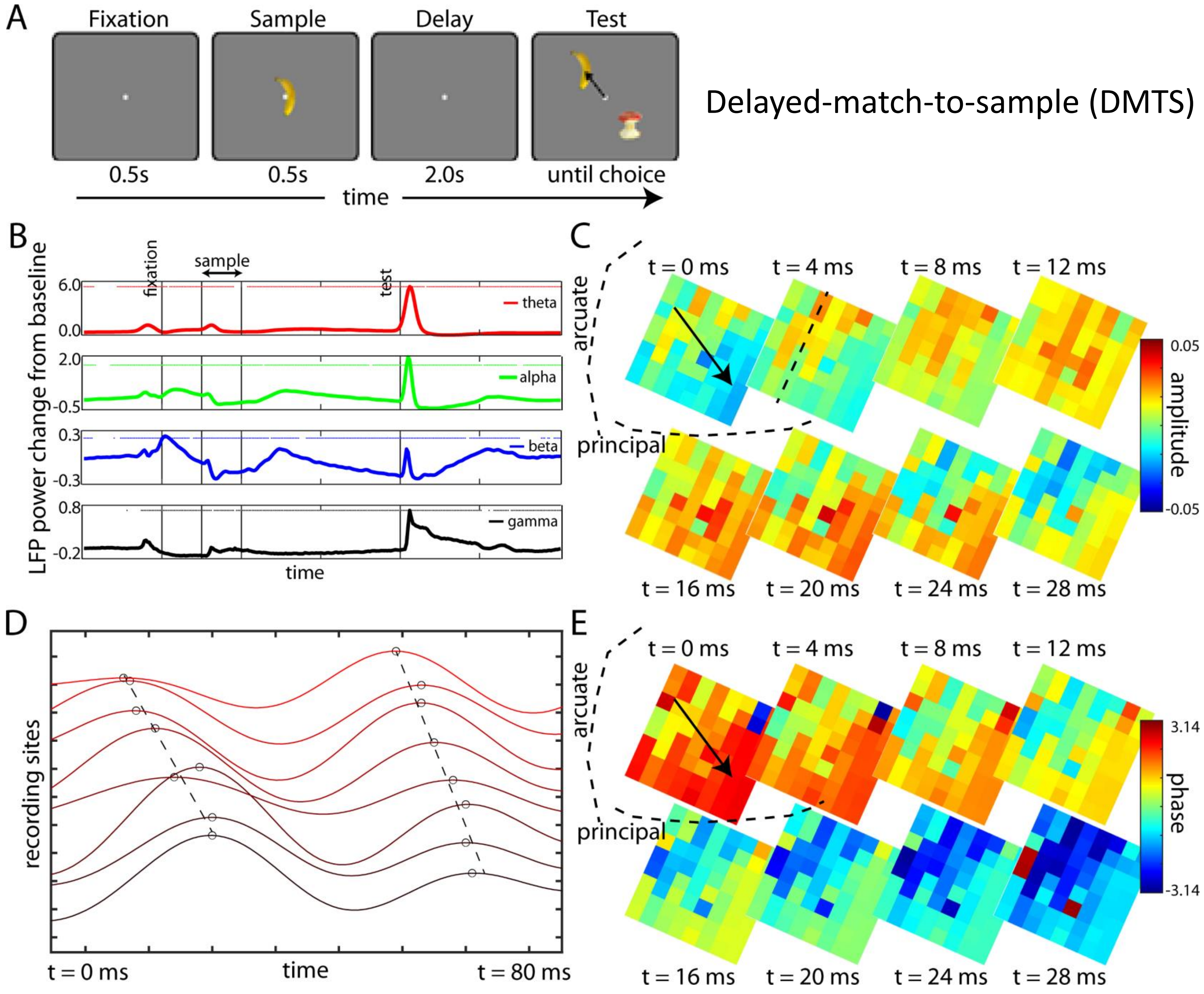
theta (4-8Hz)
alpha (8- 12Hz)
beta (12-30Hz)
Gamma (>30Hz) – sensory input/motor output



Traveling waves in the prefrontal cortex during working memory

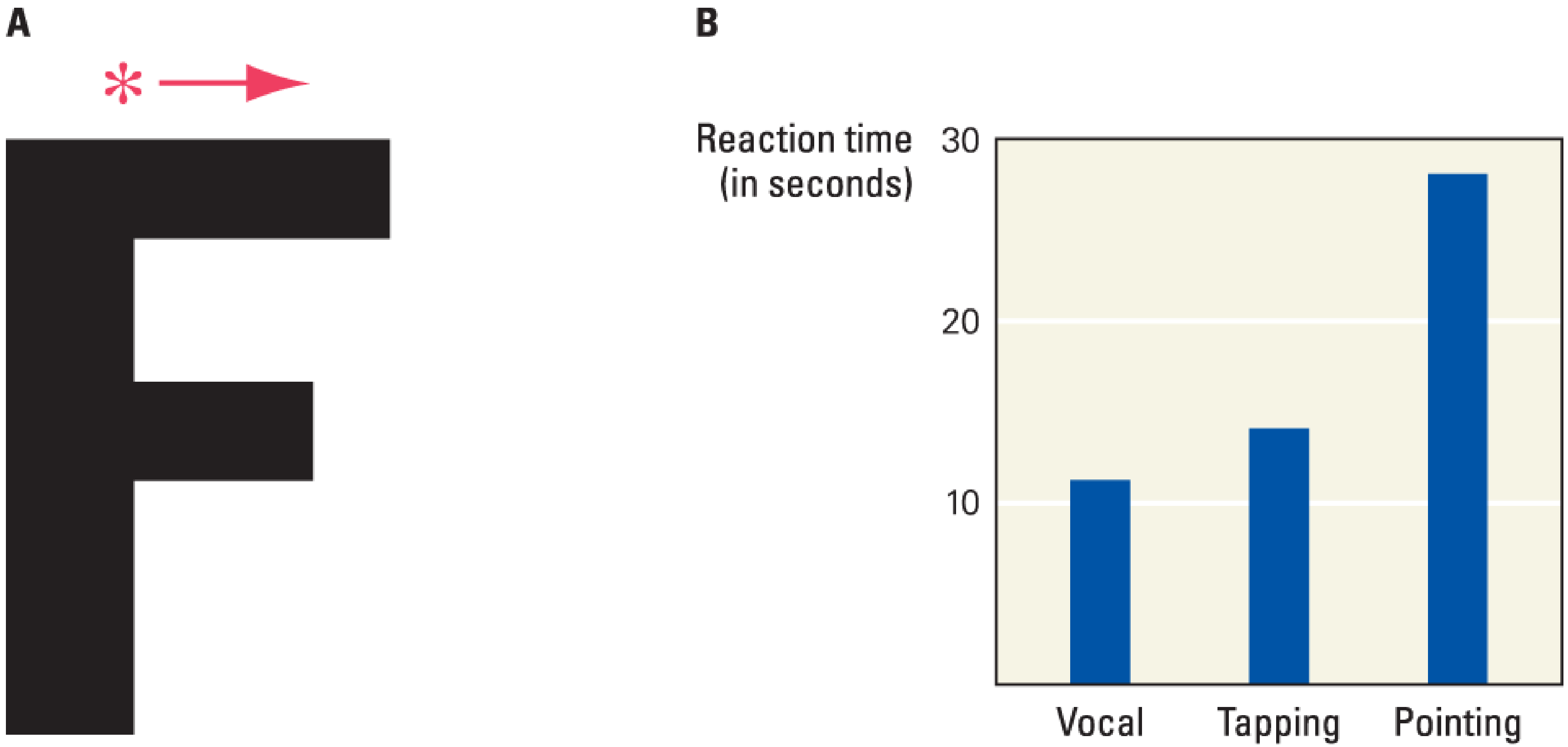


Delayed-match-to-sample (DMTS) working memory task

Traveling waves in the prefrontal cortex during working memory

Can we hold visual, auditory, spatial information active at the same time?

A Dual-Task Experiment



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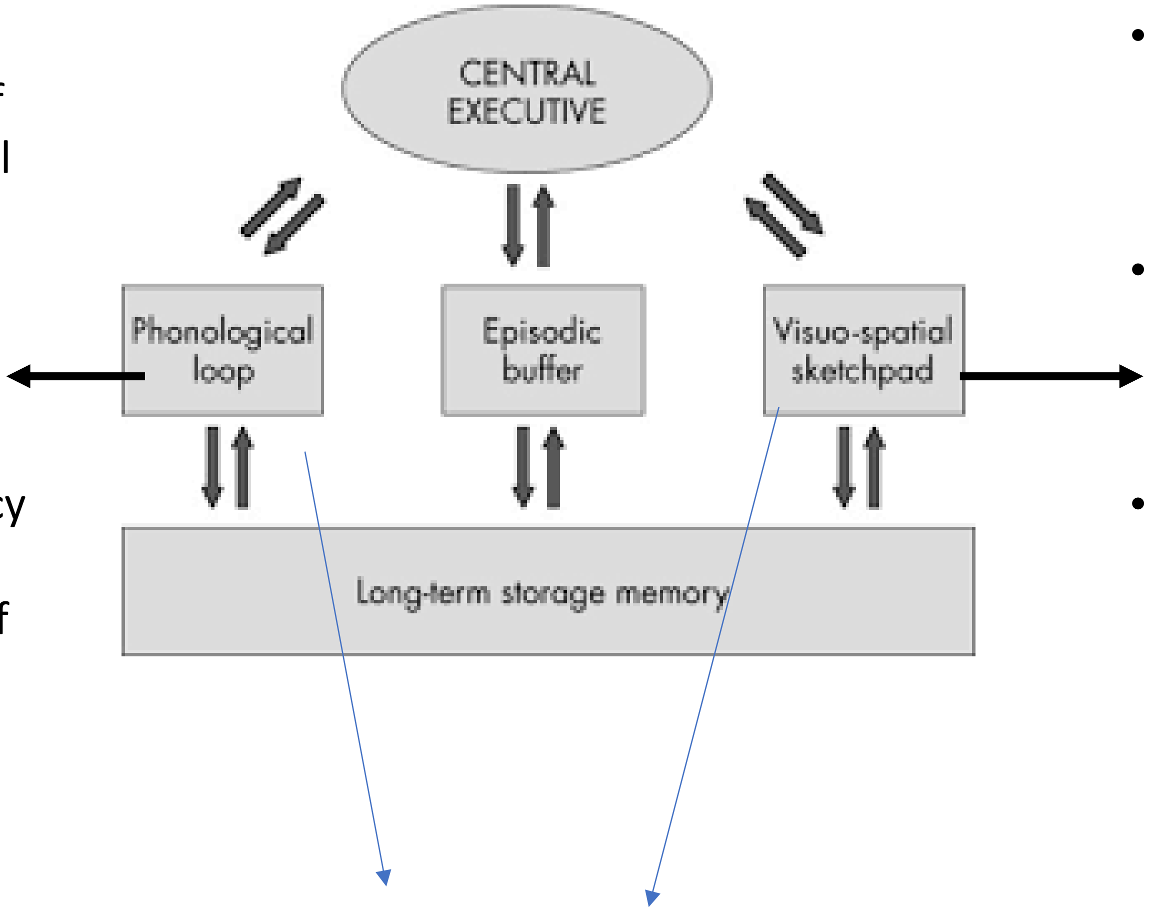
Attention competing

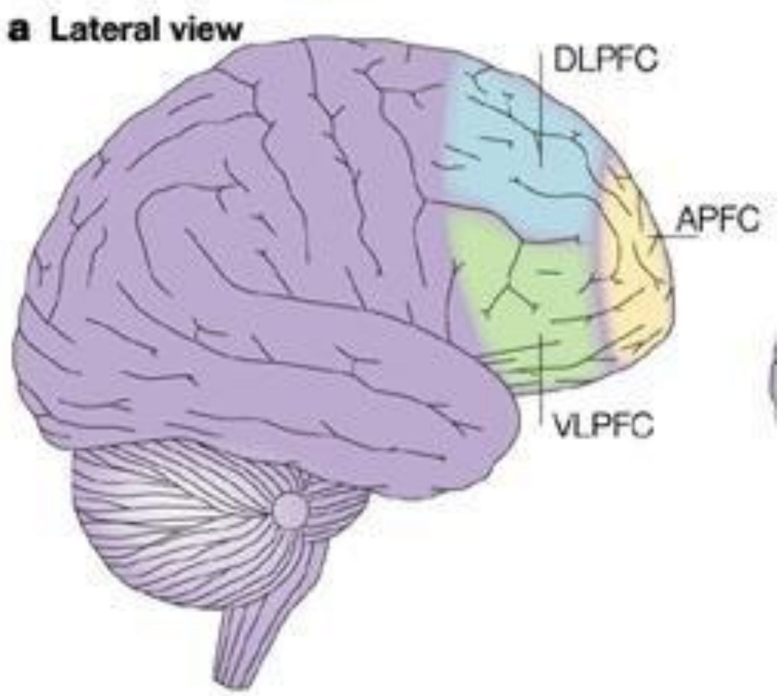
- Scanning for a friend in a large crowd and trying to speak on the phone to another friend with lots of background noise.

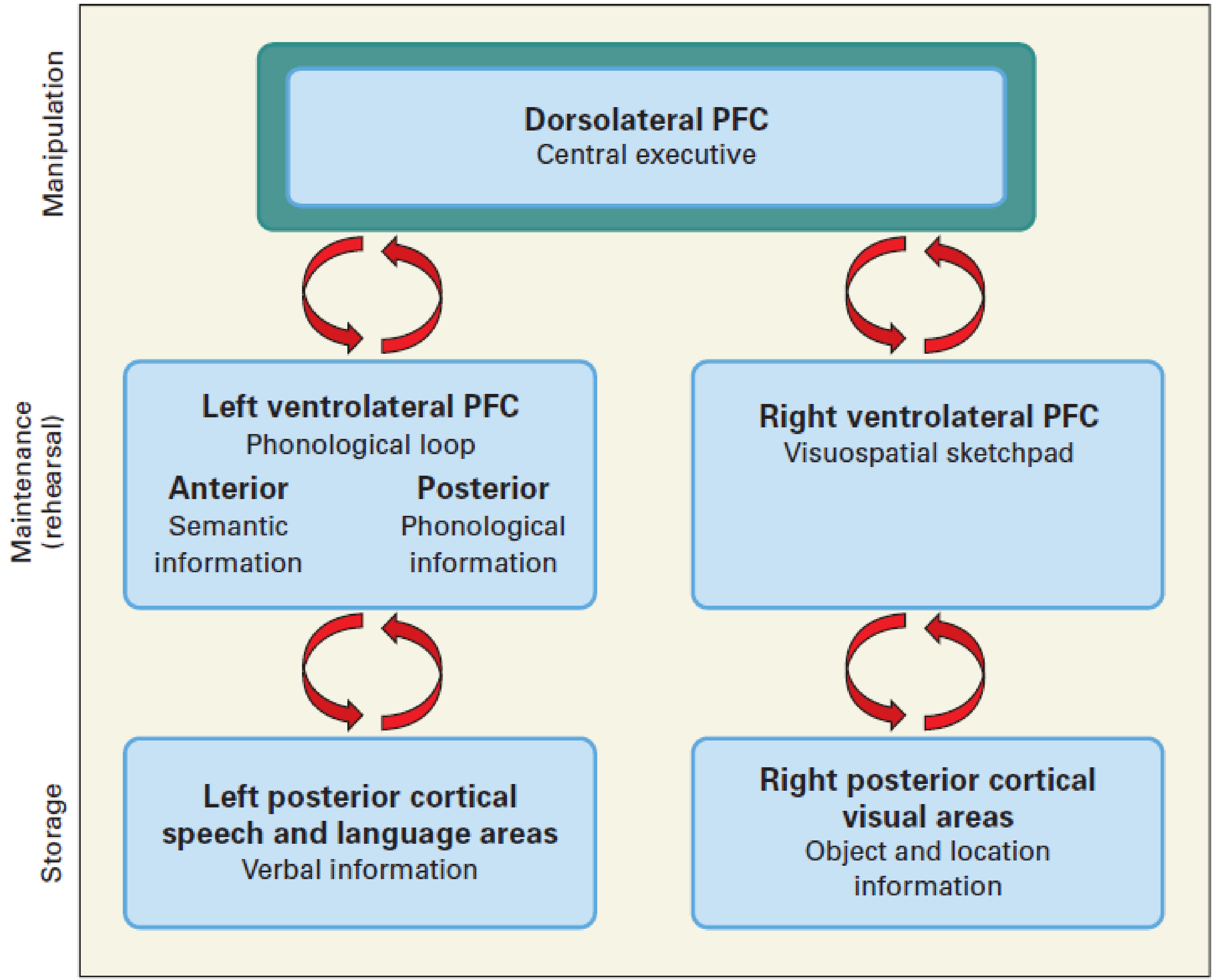
- Without rehearsal, most people retain about 2 seconds’ worth of information in their phonological memory
- Internal, unspoken speech used during rehearsal is vital to the phonological loop and verbal working memory
- **Word-length effect:** the tendency for a person to remember fewer words from a list as the length of the words increases

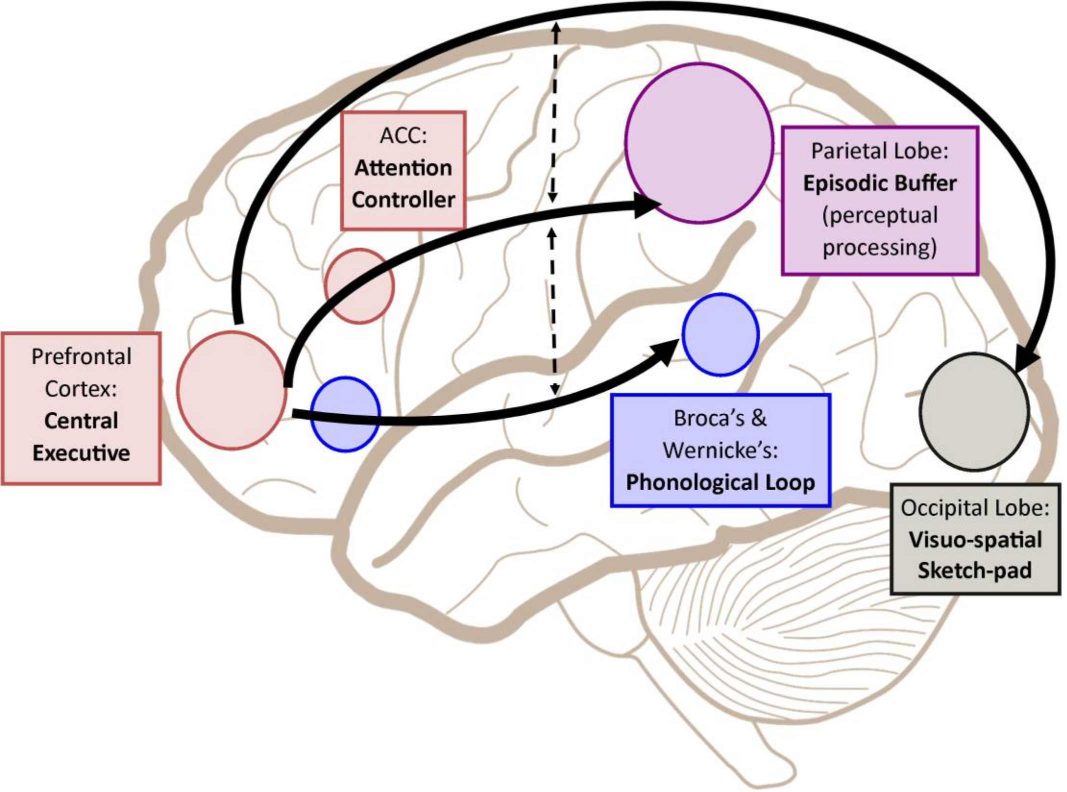


Compete for attention

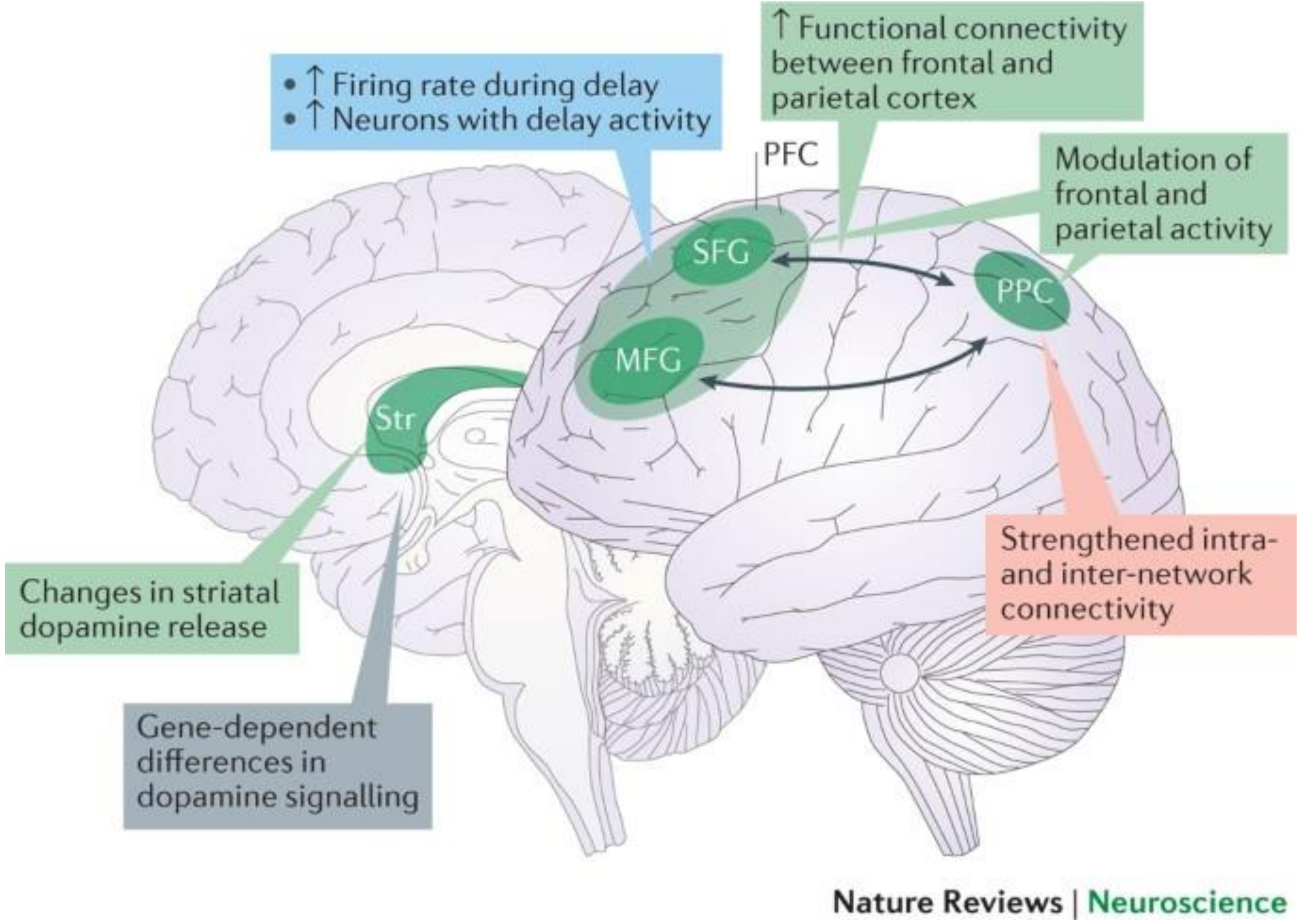
- The visuospatial sketchpad is a mental workspace for storing and manipulating visual and spatial information
- Limited capacity similar to the phonological loop, but these capacities are independent of one another
- Dual-task experiments provide evidence for the independence of these two memory buffers


a Lateral view
DLPFC
APFC
VLPFC


Manipulation
Maintenance (rehearsal)
Storage
Dorsolateral PFC
Central executive
Left ventrolateral PFC
Phonological loop
Anterior
Semantic information
Posterior
Phonological information
Right ventrolateral PFC
Visuospatial sketchpad
Left posterior cortical speech and language areas
Verbal information
Right posterior cortical visual areas
Object and location information



Parietal (sensory cortices) + motor cortices are active during delay periods



https://www.nature.com/articles/nrn.2016.43

- Identify the region of the prefrontal cortex whose activity is most critical for each of the following tasks.

1. Deciding who should sit where around a dinner table set for eight to avoid seating ex-spouses and feuding ex-business partners next to each other

2. Rehearsing the speech you will make at your farewell

3. Remembering where you parked and deciding which way to walk to your parking spot as you exit the mall

If the sensory and motor cortexes can sustain activity during a delay, assuming that sustained activity is indeed critical for working memory, why should the prefrontal cortex (esp dorsolateral PFC) be necessary for working memory to function?

- What difference in performance will you observe in somebody with PFC damage while doing the delay non-match to sample task?

- Let’s design an experiment to study this Q

Working Memory and Cognitive Control

1. Texting while driving
2. Remembering not to call out the name of an old employee while assigning work to a new employee
3. Remembering to pick up fruits, sanitizer, bread, chips, and bathroom supplies while you walk up and down the aisles at a supermarket.
4. Preparing for your friends a meal consisting of a salad, two side dishes, and dessert and having all the dishes ready to serve at the same time
5. Driving and Crossing Roads in India and USA

Cognitive Control

- *Cognitive control*, also known as *executive control* or *executive function*:
  - higher-order cognition, including reasoning, task flexibility, problem solving, and planning

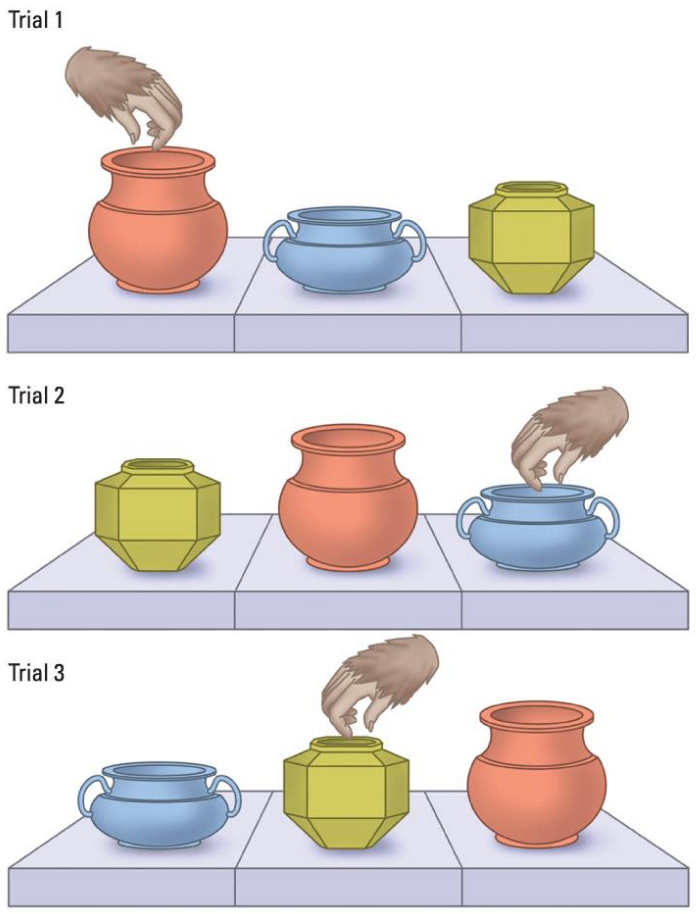
- Classic tasks used to study basic executive function

Behaviors	**Tasks used to explore these behaviors**
Controlled updating of short-term memory	*N*-back task, self-ordered search
Goal setting and planning (goal maintenance)	Tower of Hanoi
Task switching	Wisconsin Card Sorting Test
Stimulus attention and response inhibition	Stroop task

Anyone with an intact brain can do these tasks

Controlled Updating of Short-Term Memory Buffers

Monkey version



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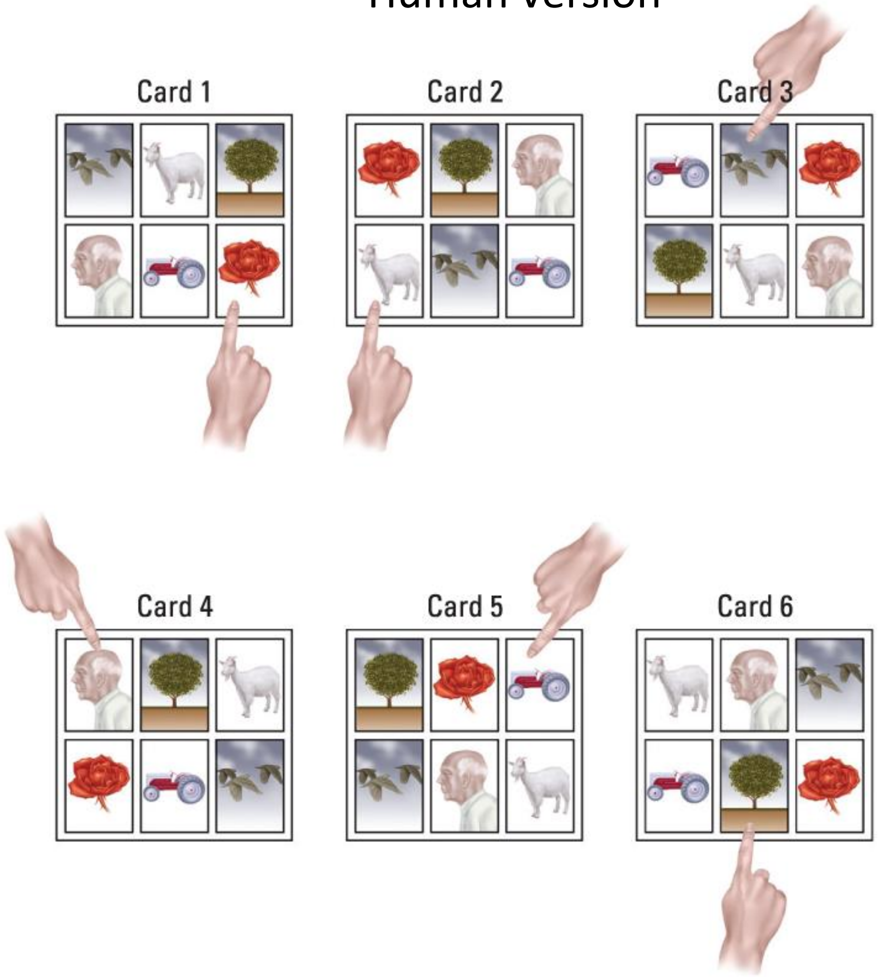
Self-Ordered Memory Task for Monkeys

Self-ordered tasks that ask people to keep track of their previous responses

Mental "To Do" List

Human version



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N-back task

Update contents of WM to keep up with task

3-back task

4 6 5 8 7 3 **9** 1 6 7 0 **3** 5 2 7 5 **1** 4 8 7 8 **9** 5 4 7

Real- life example?

During a conversation, scheduling your project discussions to avoid conflict with class timings and meeting with supervisor

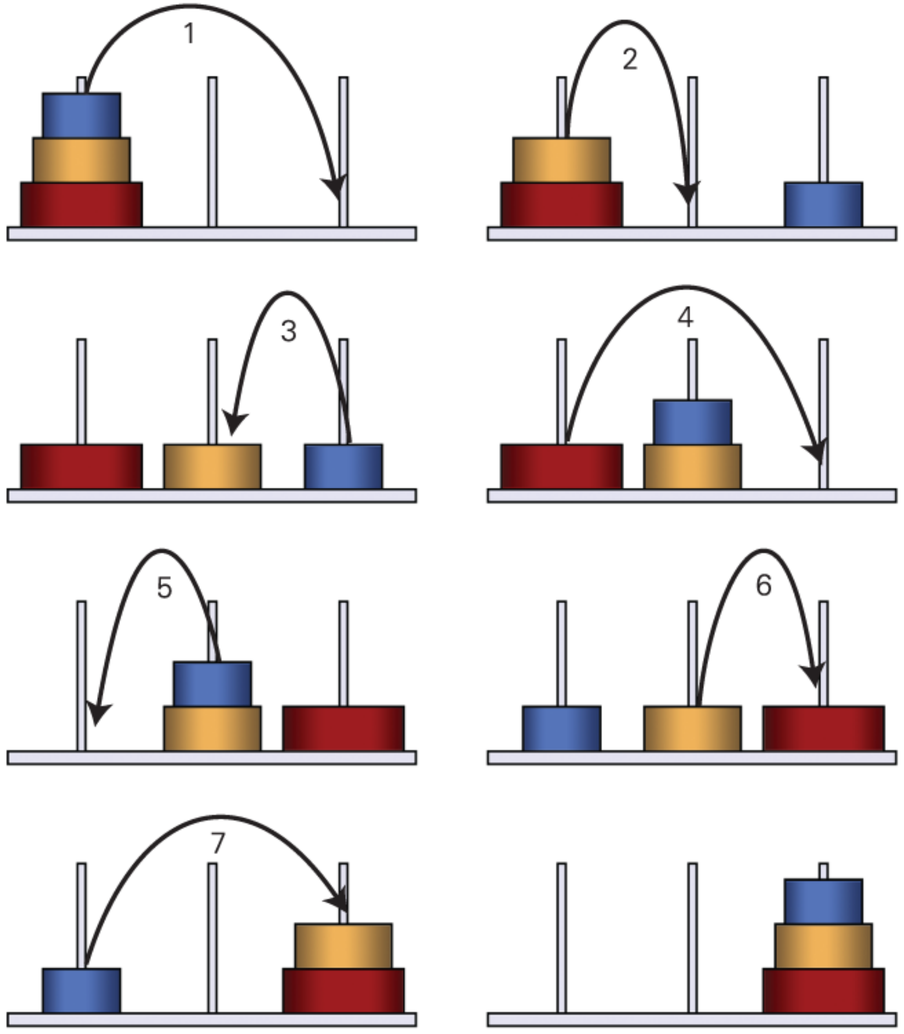
Tower of Hanoi

Goal Setting and Planning

Maintaining a goal in your mind

- Solving the Tower of Hanoi puzzle requires manipulation of working memory because you must remember setting subgoals, tracking completed and remaining goals, planning next goal…

Task originally from a legend of a temple in India
64 gold disks @ 1 per second = 580 billion years!
Adapted by Edouard Lucas in 1883



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Task Switching

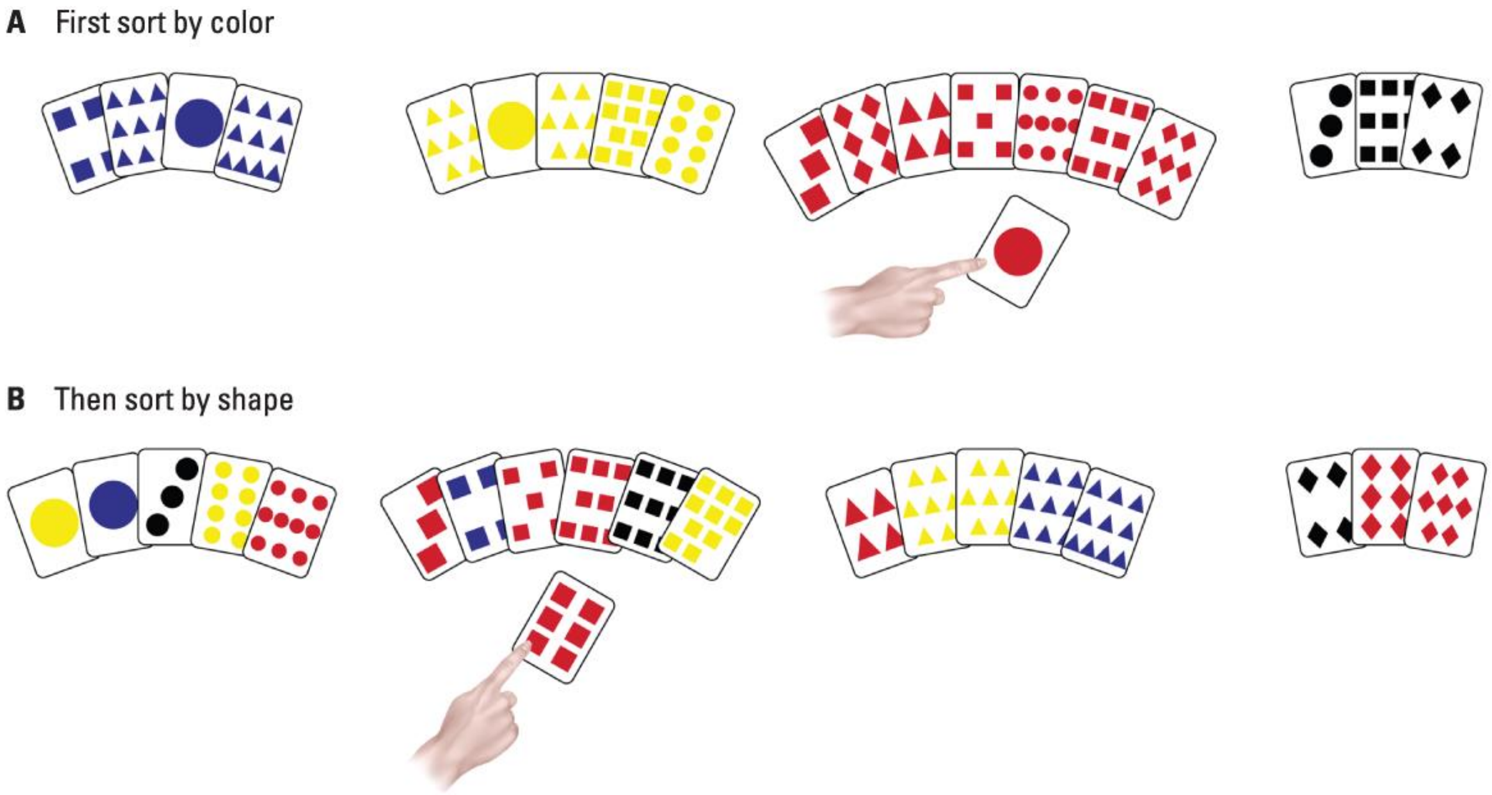
(online exp)

Task switching requires the manipulation of working memory because you must pay attention to the task you are doing at a given moment while at the same time monitoring external cues for information that may signal the need to switch to another task

The Wisconsin Card Sorting Test

- Sorting rule changes without warning
- Maintaining and then switching a rule
- Frontal patients and perseveration (Roberts et al., 1996)

Real life E.g.?



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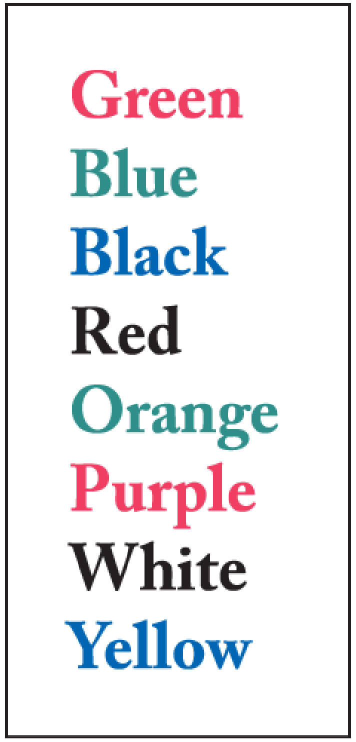
Stimulus Selection and Response Inhibition

- Automatic processes are triggered by situational cues
- Willed, or controlled, actions are mediated by the *supervisory attentional system*
- A well-known test of how well a person's control processes can direct attention to stimuli and inhibit inappropriate automatic responses is the **Stroop task**
  - The Stroop task illustrates the fundamental competition within our brains over the control of our behaviors and thoughts

The Stroop Task



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- The names of colors are printed from top to bottom, each in a color that does not correspond to the name
- The task is to recite the colors that the words are printed in (color of ink) without being distracted by what the words say

Stroop task

Real life E.g.?

- Imagine a 4 × 4 grid (16 squares) with a 1 in the second column of the second row.
- Place a 2 to the right of the 1.
- In the square above the 2, put a 3.
- To the right of the 3, put a 4.
- Below the 4, put a 5.
- Below that, put a 6.
- Then to the left of that, a 7.
- What number is above the 7?

		3	4	
	1	2	5	
		7	6	

Visuospatial Sketchpad + updating short-term buffer

For more online experiments

- https://www.psytoolkit.org/c/3.4.2/library

1. Texting while driving
2. Remembering to pick up fruits, sanitizer, bread, chips, and toothpaste while you walk up and down the aisles at a supermarket.
3. Preparing for your friends a meal consisting of a salad, two side dishes, and dessert and having all the dishes ready to serve at the same time
4. Remembering not to call out the name of an old employee while assigning work to a new employee
5. Driving and turning on roads in India and USA

- CHOICES:
- **A.** *Updating of short-term memory buffers*
- **B.** *Setting goals and planning*
- **C.** *Task switching*
- **D.** *Stimulus selection and response inhibition*

Multi-tasking can drain your working memory

- talk on the phone, listen to music, and surf the Internet at the same time
- Driving and talking/texting on the phone (banned by LAW)

- Too much multitasking can exhaust you mentally

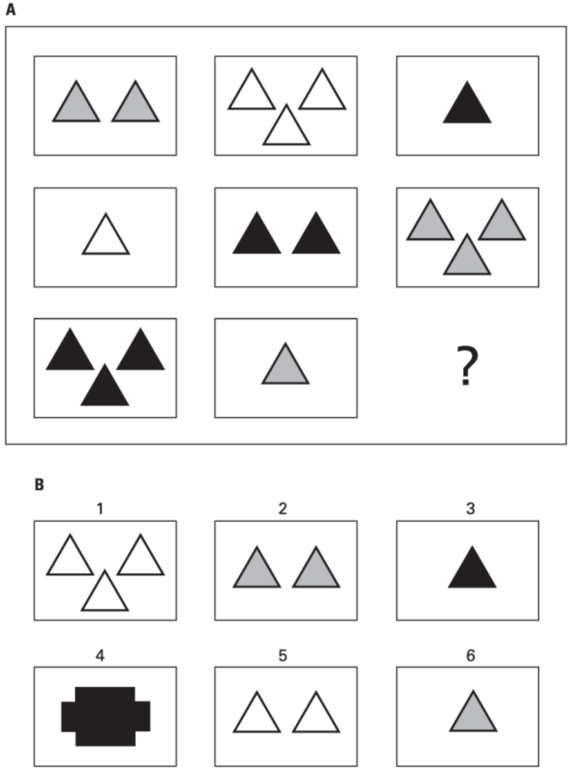
Executive Function and Intelligence

Are Working Memory and Cognitive Control the Keys to Intelligence?

Working memory capacity

Ability control and manipulation of larger numbers of rules, concepts, goals, and ideas

Raven Progressive Matrix Test



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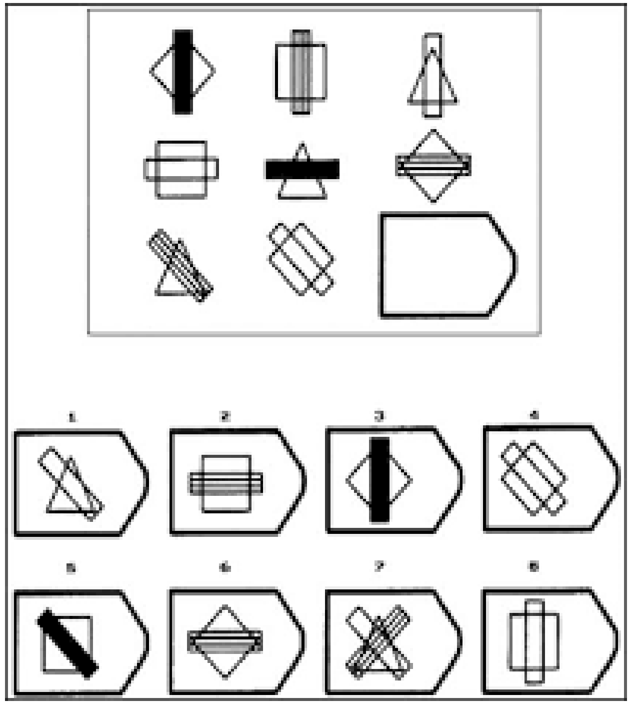
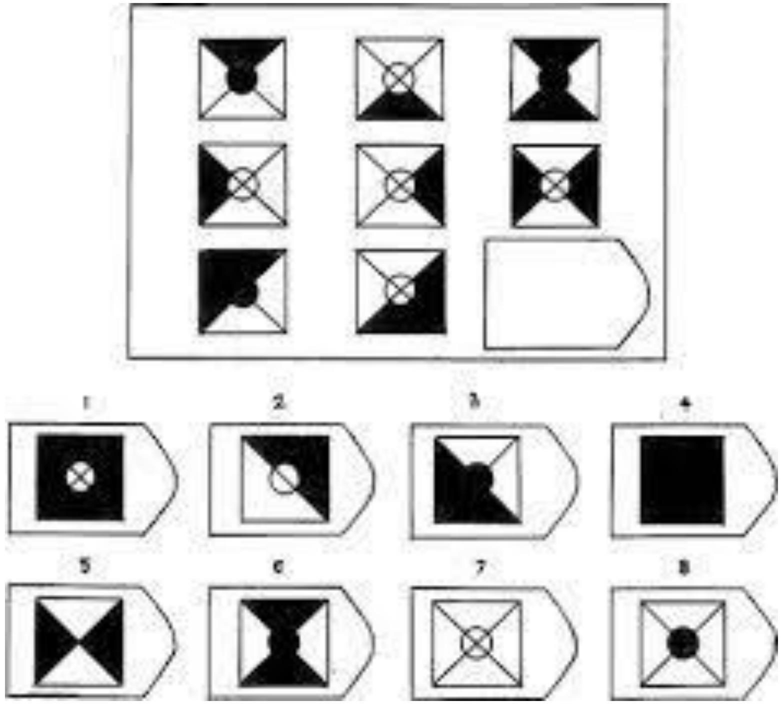
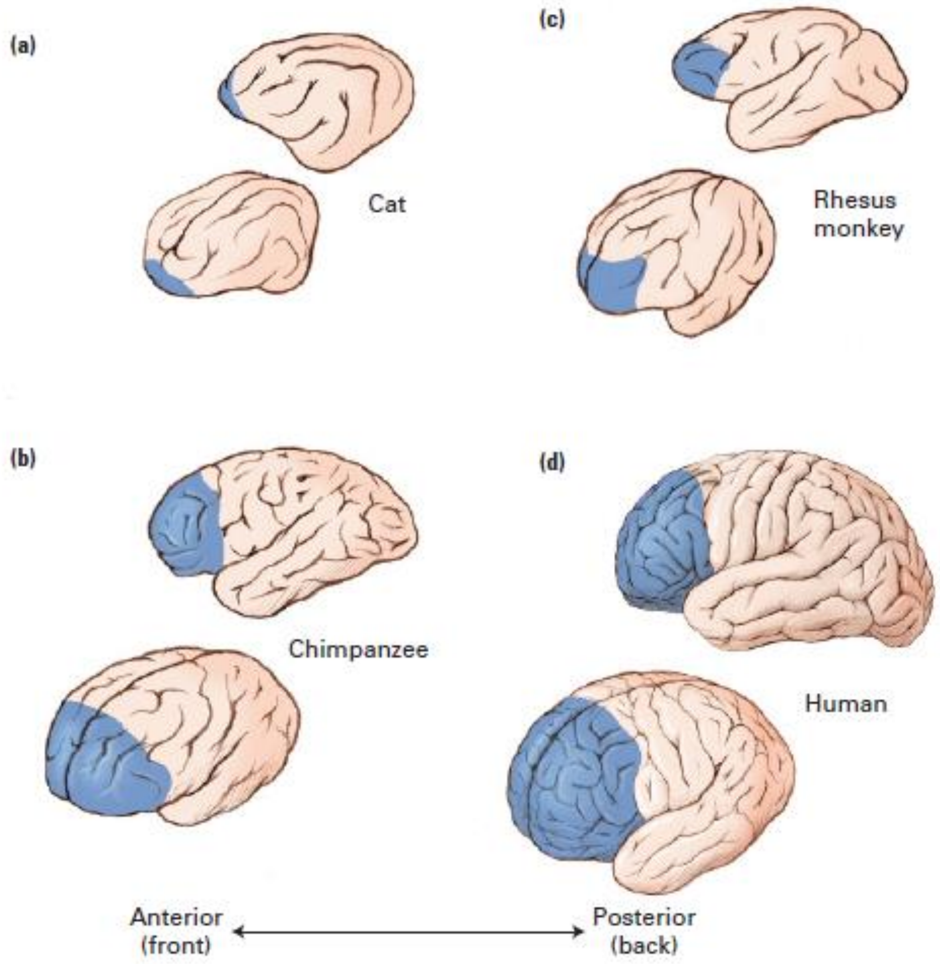




Can we train and improve WM?

- WM capacity is predictive of performance in higher cognitive abilities.
- WM has been shown to improve with training. Importantly, improvement in WM can transfer between trained and non-trained tasks.
- prefrontal neurons play the most important part in the maintenance of information in WM.
- Effects of WM training
    - increases in the activity of neurons in the prefrontal cortex,
    - increases in the strength of connectivity within the prefrontal cortex and between the prefrontal cortex and other areas.
- Neural changes after training are found in cortical areas that process spatial information in WM and attention, potentially providing a basis for transfer to other cognitive and behavioural tasks that rely on spatial WM and spatially selective attention.



https://www.nature.com/articles/nrn.2016.43

Without an intact frontal lobe?

Boxers
Rugby players
Stroke
Tumour
Schizophrenia

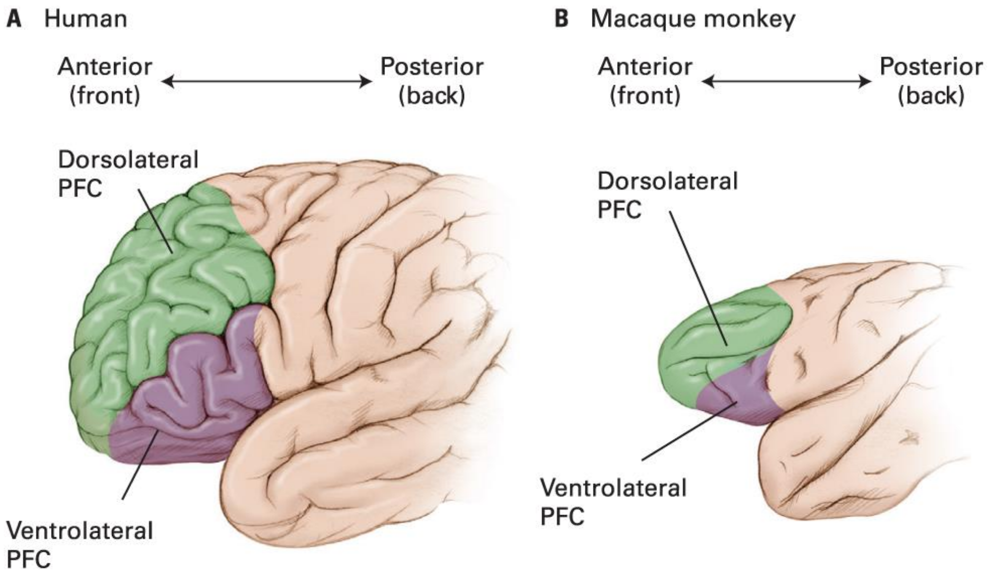
- World War II Vets (Pfiefer, 1922)
- Baddeley's (1986) patient RJ
  - Bilateral Frontal Lesions

perseveration. A failure to learn a new response, especially as demonstrated by continued adherence to an old, no longer valid response rule. (Task for testing?)

Dysexecutive syndrome: a disrupted ability to think and plan (Task for testing?

Working memory – Frontal Lobe

- Studies of animals and humans implicate the frontal lobes—especially the **prefrontal cortex (PFC)**, the most anterior (farthest forward) section of the frontal lobes—as being critical for working memory and executive control
- In humans, the prefrontal cortex encompasses approximately one-third of the cerebral cortex



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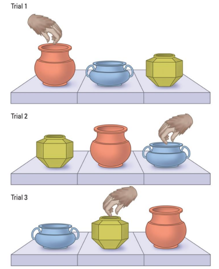
How are the frontal lobes organized?
How does working memory actually work?

Divisions of the Prefrontal Cortex



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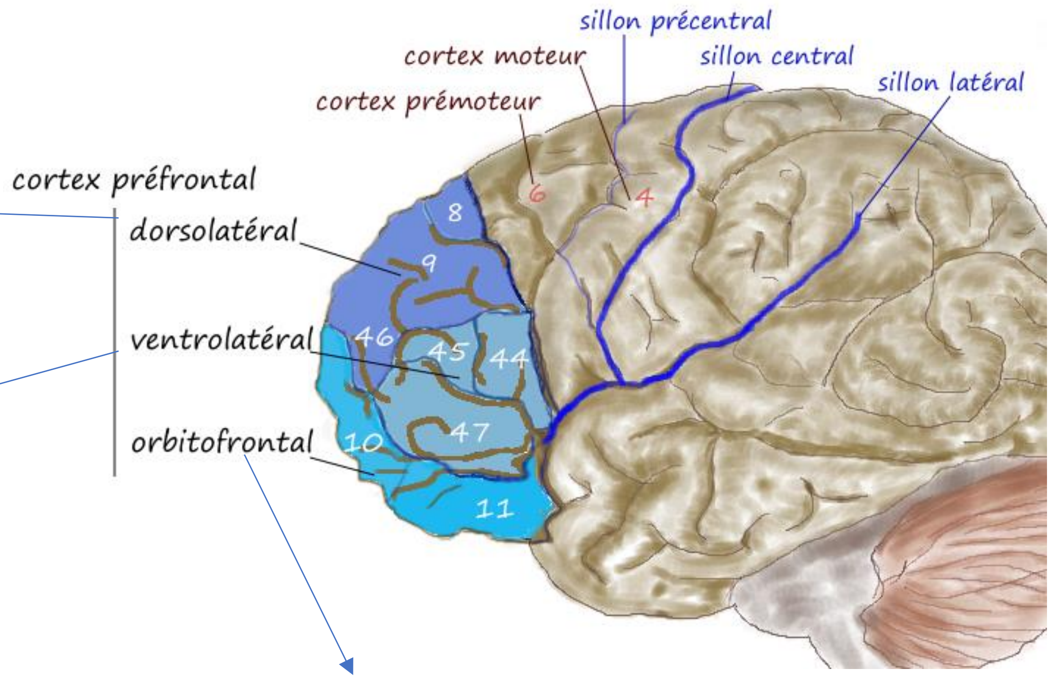
Supports higher-order executive-control functions such as monitoring and manipulating of stored information, thus doing the job of Baddeley's central executive

Left vlPFC – phonological
Right vlPFC – visuospatial

Supports encoding and retrieval of information (including rehearsal for maintenance), performing as the visuospatial sketchpad and phonological rehearsal loop proposed by Baddeley

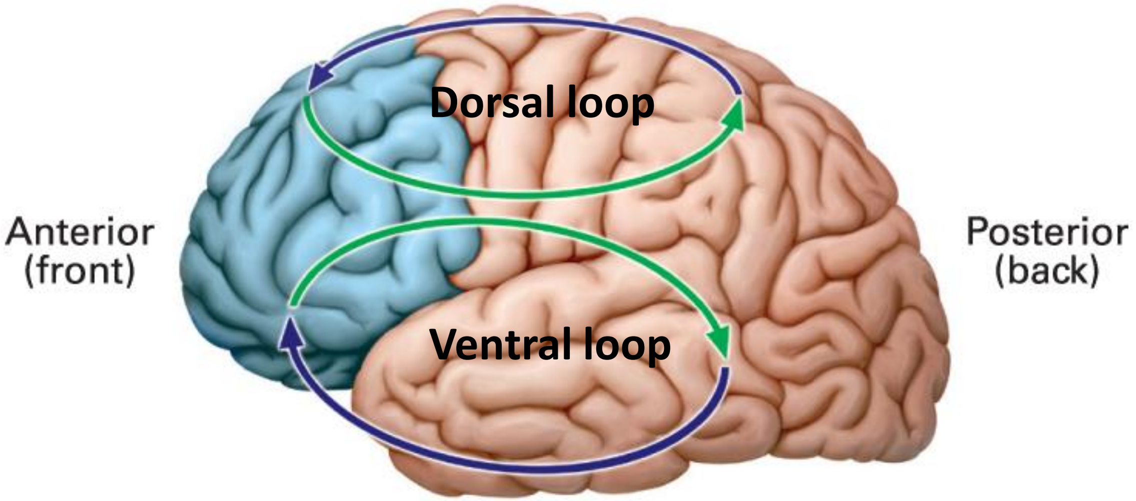


Decision making, prediction, reward evaluation, etc.

- The prefrontal cortex can be divided into three main regions
  - Orbitofrontal cortex (OFC)
  - **Dorsolateral prefrontal cortex (DLPFC):** the left and right sides of the topmost part of the prefrontal cortex (PFC)
  - **Ventrolateral prefrontal cortex (VLPFC):** the lower left and right sides of the PFC

Maintenance in Working Memory Through Frontal-Posterior Circuits

- Frontal-cortex activations reflect the executive *processes* that are needed to maintain the representations of memory items in posterior areas of cortex, where they are permanently stored (Long term memory & working memory areas overlap)
- Working memory emerges from a network of brain regions, all of which send and receive information to and from the prefrontal cortex
- Together, these networks accomplish the active maintenance of internal representations necessary for goal-directed behavior



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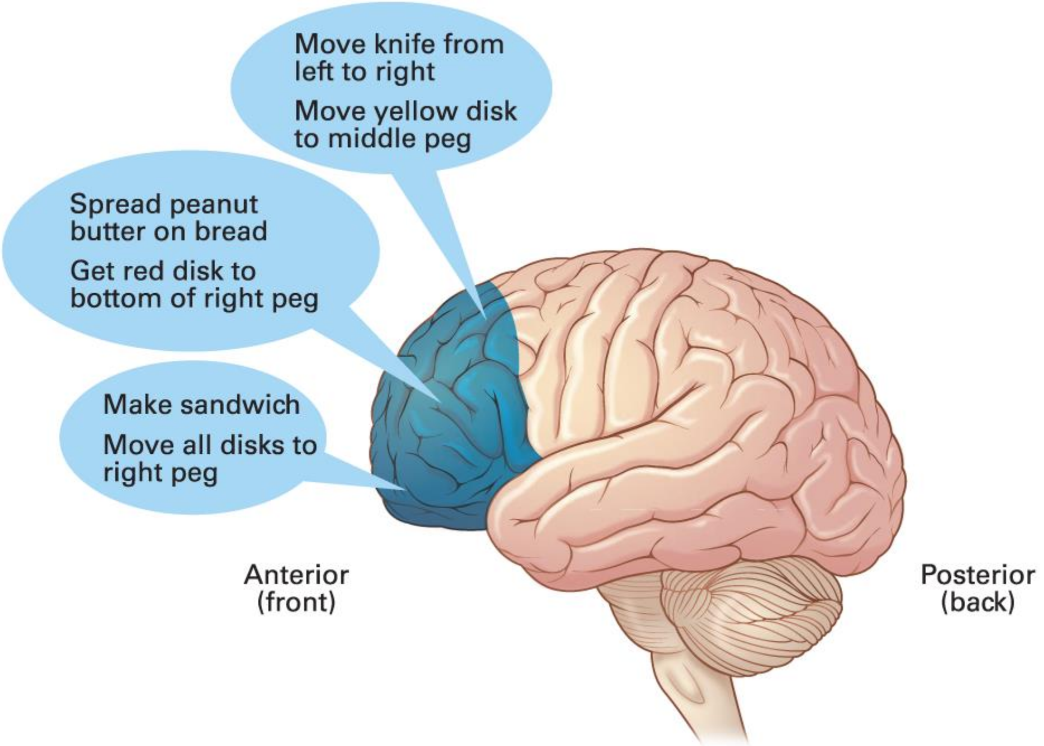
Goal Abstraction and Frontal-Lobe Organization

- The gradient of abstraction from general plans and goals to more specific action plans follows a physical gradient beginning at the front of the frontal lobes and moving back - flow of control goes from the most anterior regions (big picture goal) toward the back of the frontal lobes (specific subgoals)



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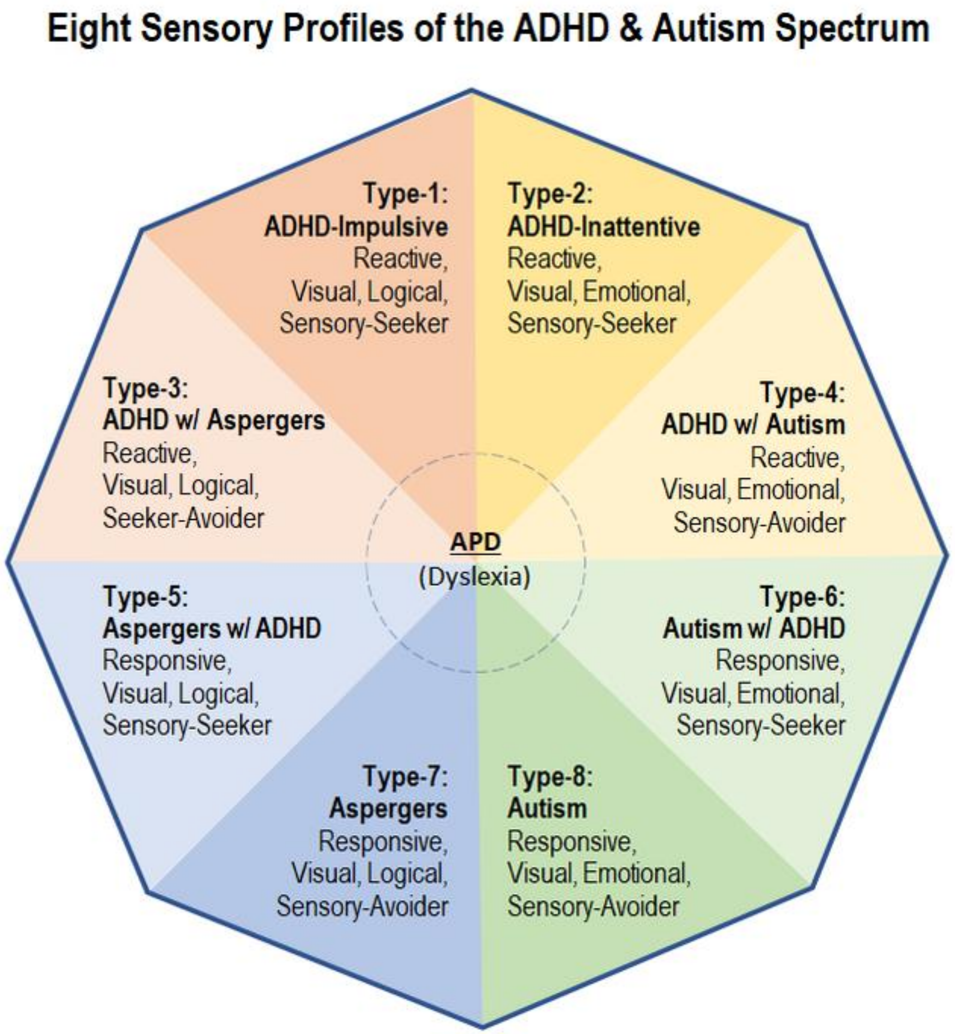
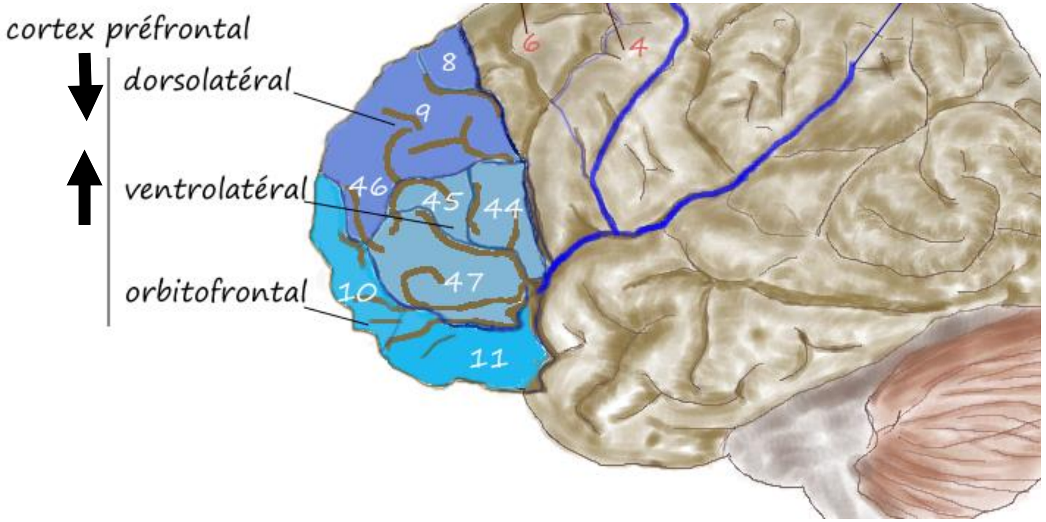
Attention-Deficit/Hyperactivity Disorder (ADHD)

- difficulty with cognitive-control processes such as planning, organizing their time, keeping attention focused on a task, and inhibiting responses to distracting stimuli
- Studies show children with ADHD have a small right prefrontal cortex, the region associated with spatial attention and working memory
  - poor prefrontal activity
  - Drugs to increase dopamine are prescribed – to compensate



The Prefrontal Cortex in Schizophrenia



- disturbances in working memory and executive control
  - Almost normal performance on phonological or visuospatial memory tasks (vlPFC)
  - Impaired at visuospatial working- memory tasks when these tasks involve the manipulation or updating of information in working memory (dlPFC)

- Extra info on schizophrenia begins (not in the syllabus)

What might cause schizophrenia?

- Other factors that may play a role in schizophrenia susceptibility–
  - paternal age
  - maternal stress or malnutrition
  - prenatal infections (viral infections in mother)
  - urban birth or residing in an urban setting – higher rate of viral infections
  - childhood adversity
  - Substance abuse

Positive symptoms

Due to excessive dopaminergic activity – as seen in substance abuse

- ***Delusions.*** Delusions of being controlled (e.g., "Aliens are making me steal"), delusions of persecution (e.g.,"My mother is poisoning me"), or delusions of grandeur (e.g., "Narendra Modi admires my drawings").
- ***Hallucinations.*** Imaginary voices making critical comments or telling patients what to do.
- ***Inappropriate affect.*** Reacting with an inappropriate emotional response to positive or negative events.
- ***Disorganized speech or thought.*** Illogical thinking, peculiar associations among ideas, belief in supernatural forces.
- ***Odd behavior.*** Talking in rhymes, difficulty performing everyday tasks.

Negative symptoms

- *Affective flattening.* Diminished emotional expression
- *Avolition.* Reduction or absence of motivation.
- *Catatonia.* Remaining motionless, often in awkward positions for long periods.
- poverty of speech
- inability to experience pleasure (anhedonia)
- social withdrawal

Due to degeneration or impaired development. Common in brain damage disorders, especially to frontal lobes

Cognitive symptoms

- difficulty sustaining attention
- low *psychomotor speed* (for example, in movements that include a cognitive element, such as reaction time, connecting numbers or letters in sequence, or alternating numbers and letters),
- deficits in learning and memory,
- poor abstract thinking, and poor problem solving

The frequent recurrence of any two of these symptoms for 1 month is currently sufficient for the diagnosis of schizophrenia—provided that one of the symptoms is delusions, hallucinations, or disorganized speech.

- Depression, anxiety, substance abuse, and smoking are also very common in schizophrenia.

- The symptoms of schizophrenia typically appear gradually, over a period of several years.
  1. first clinical symptoms of schizophrenia tend to be symptoms of depression,
  2. followed by social withdrawal (negative symptoms) and
  3. cognitive difficulties (cognitive symptoms),
  4. positive symptoms

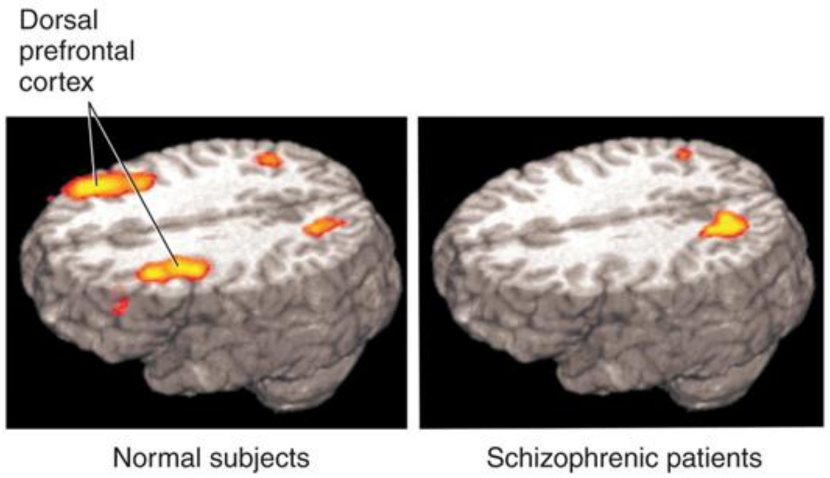
Interview: Catatonic Schizophrenic

Psychiatric Interviews for Teaching: Psychosis

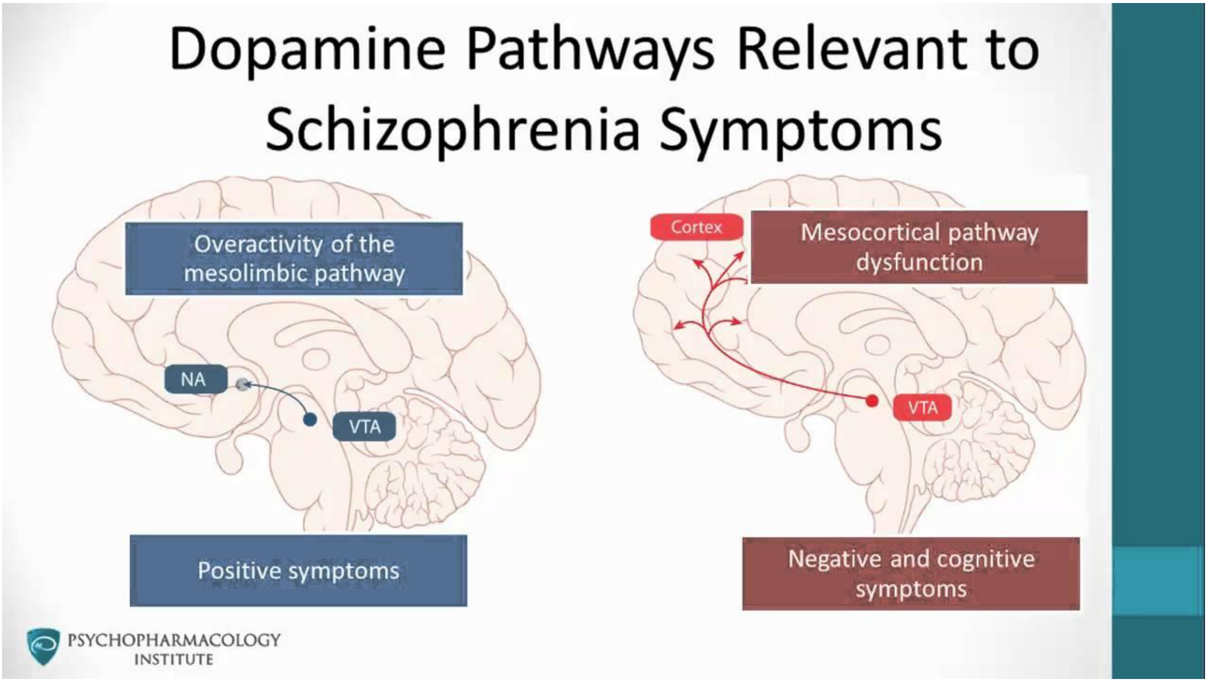
https://www.youtube.com/watch?v=iGH7hGkkMrU&ab_channel=NorthwesternMedicine

http://schizophrenia.com/diag.php#

Hypofrontality in Schizophrenia

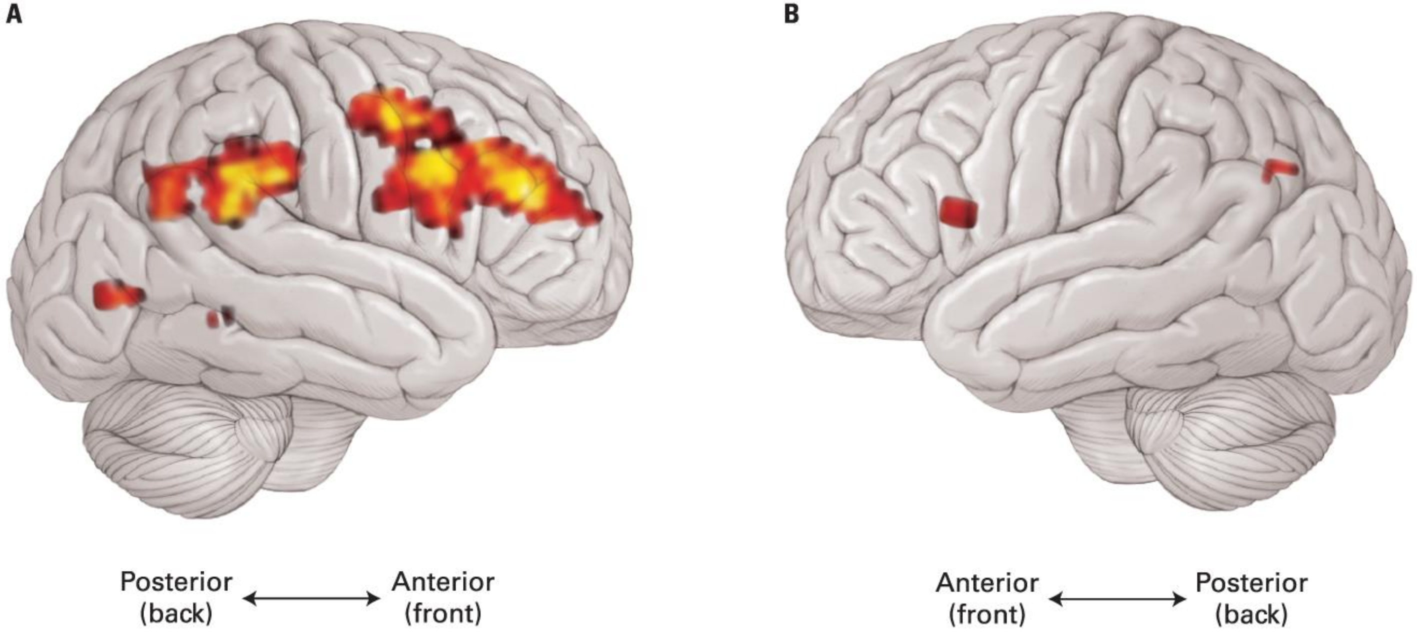


- Hypofrontality – structural changes in frontal lobe
  - fewer number of glutamate and dopamine receptors in the PFC
  - may be driven by prenatal environment (maternal viral infections)
  - may alter the brain development leading to smaller frontal regions and decreased activity during adolescence.



Dopamine and the Genetics of Schizophrenia

- Increased prefrontal activation is thought to reflect inefficient function in the prefrontal areas, such that the increased activity is necessary to support a given level of performance



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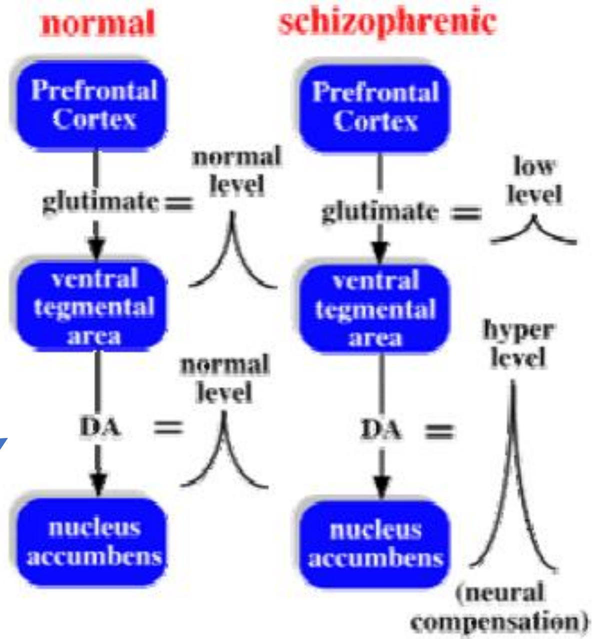
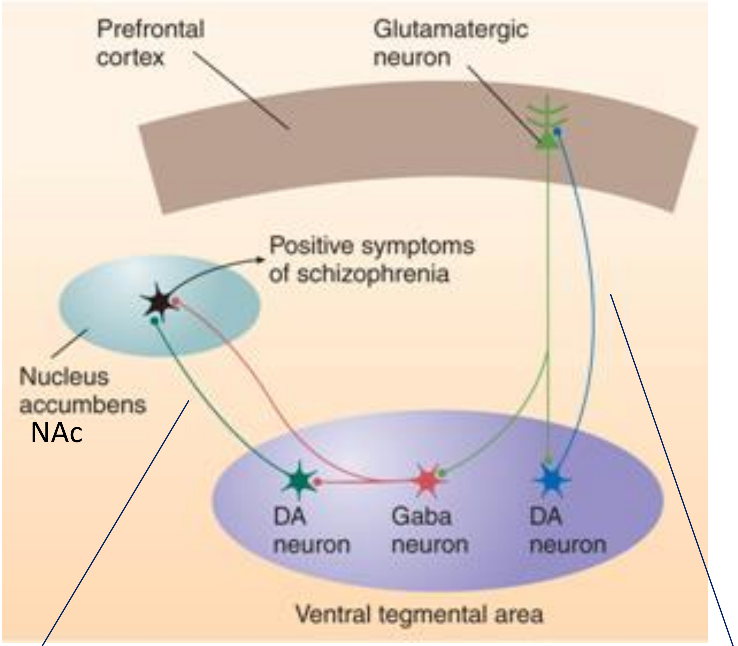
The schizophrenia network in the brain

- The prefrontal cortex (PFC) and excitatory (glutamatergic) and inhibitory (GABAergic) connections to the VTA
- Normally, at resting state, basal or spontaneous release of a neurotransmitter occurs constantly in the nervous system, independent of any environmental stimuli.
- Hypofrontality reduces the basal release of glutamate from the PFC to the VTA. This leads to lower basal release of dopamine in the VTA which in turn cause dopamine receptors in the VTA to become supersensitive, so they over react to environmental stimuli (neural compensation)
- Hypofrontality also lessens the inhibition from PFC to VTA, leading to hyperactivity in dopaminergic neurons from VTA to Nac.
- Thus overall, there is excess of dopamine released from VTA to NAc – resulting in positive symptoms (similar to those seen in substance abuse)
- The dopamine increase in NAc affects other brain areas it is connected to, especially amygdala, resulting in exaggerated positive symptoms (neutral faces look angry, delusions, etc.)
- Dopaminergic neurons also project back to the PFC – but due to hypofrontality (fewer dopamine receptors) the dopamine effect is low - the cause of negative and cognitive symptoms





Mesolimbic pathway

Mesocortical pathway

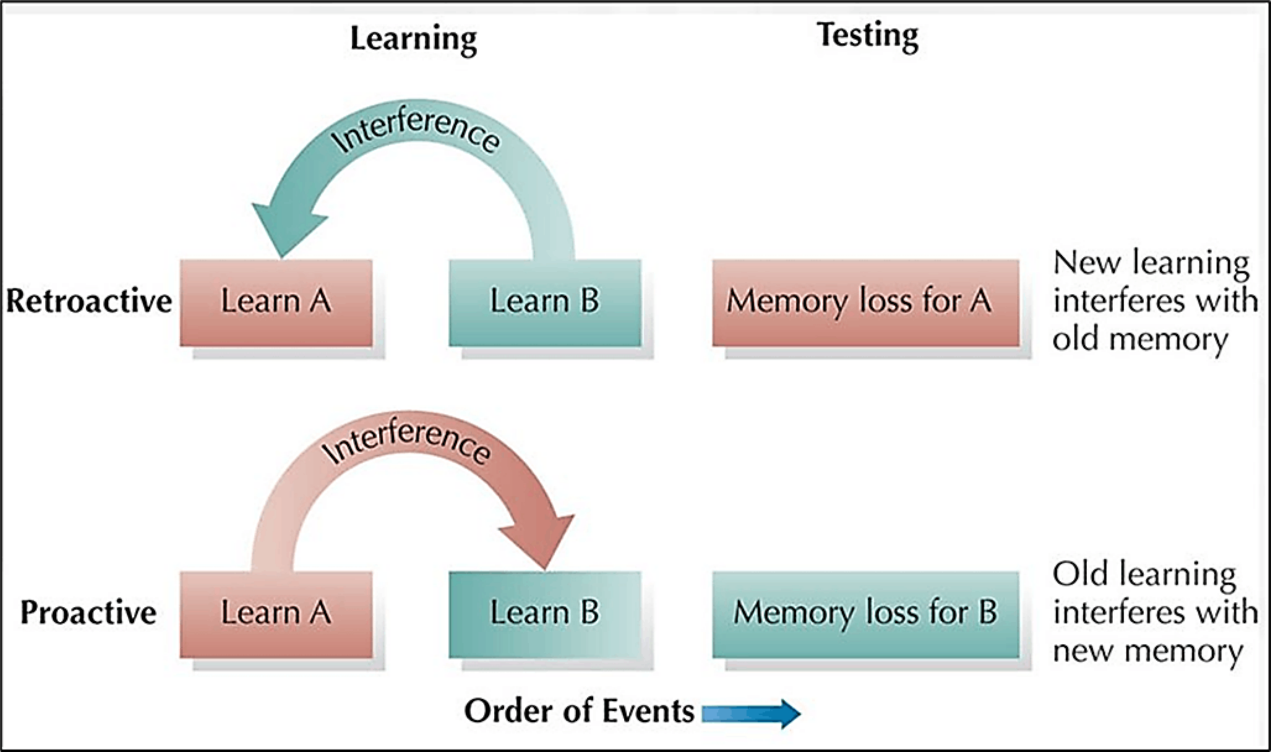
Long Term Memory

Dog - Balloon
Wine - Pencil
Hammer - Football
Moon - Chair
Carrot - Fence
Baby - Market
Parcel - Lamp
River - Cheese

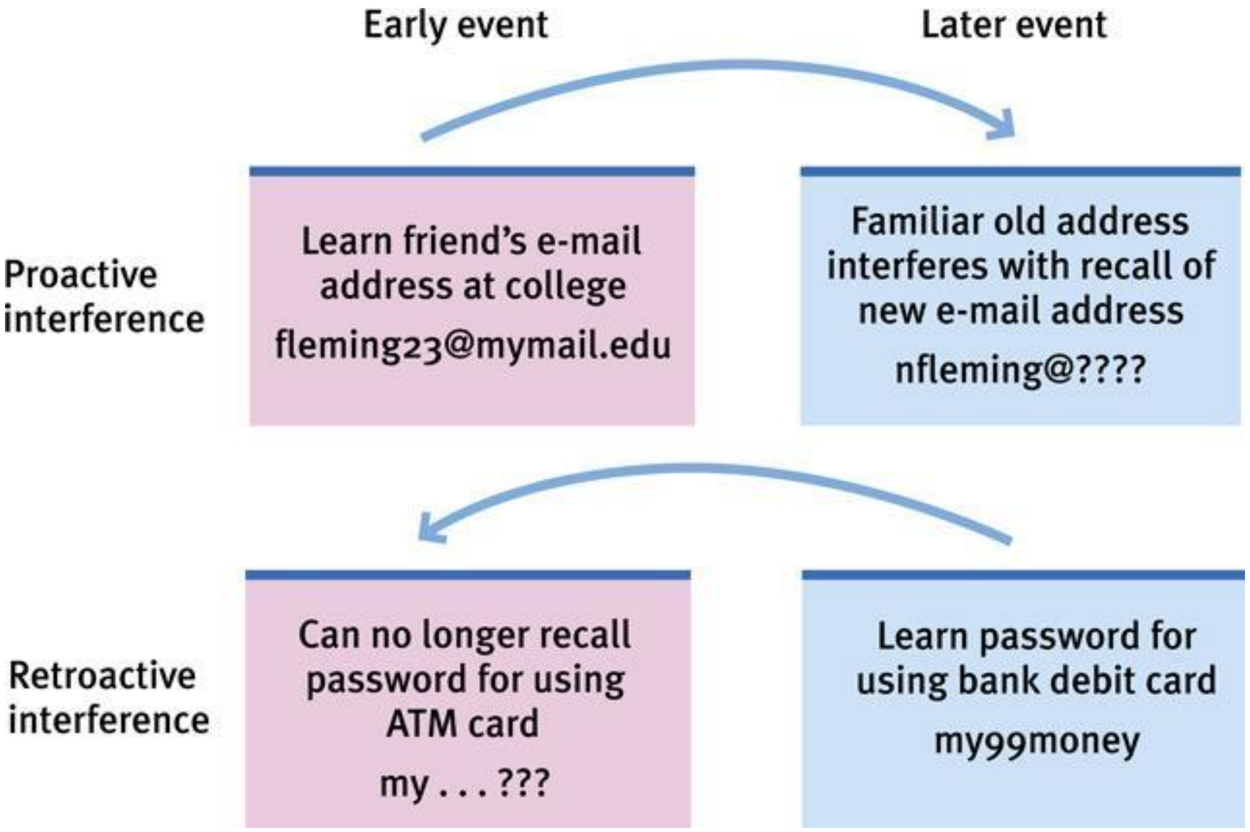
Parcel - Water
Carrot - Milk
River - Book
Moon - Ankle
Baby - Petal
Hammer - Sky
Dog - Paper
Wine - Cat

Baby - ?
Dog - ?
Wine - ?
Hammer - ?
Carrot - ?
Parcel - ?
River - ?
Moon - ?

Dog - Balloon	Parcel - Water	Baby - ?
Wine - Pencil	Carrot - Milk	Dog - ?
Hammer - Football	River - Book	Wine - ?
Moon - Chair	Moon - Ankle	Hammer - ?
Carrot - Fence	Baby - Petal	Carrot - ?
Baby - Market	Hammer - Sky	Parcel - ?
Parcel - Lamp	Dog - Paper	River - ?
River - Cheese	Wine - Cat	Moon - ?

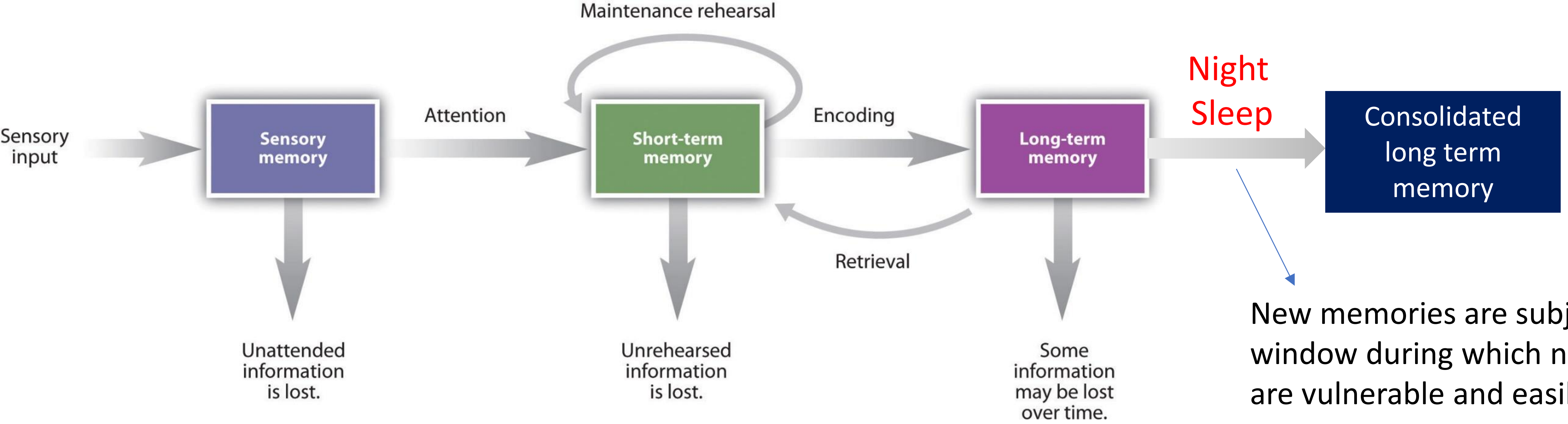


Interference
Proactive interference
Retroactive interference



We learn everyday…

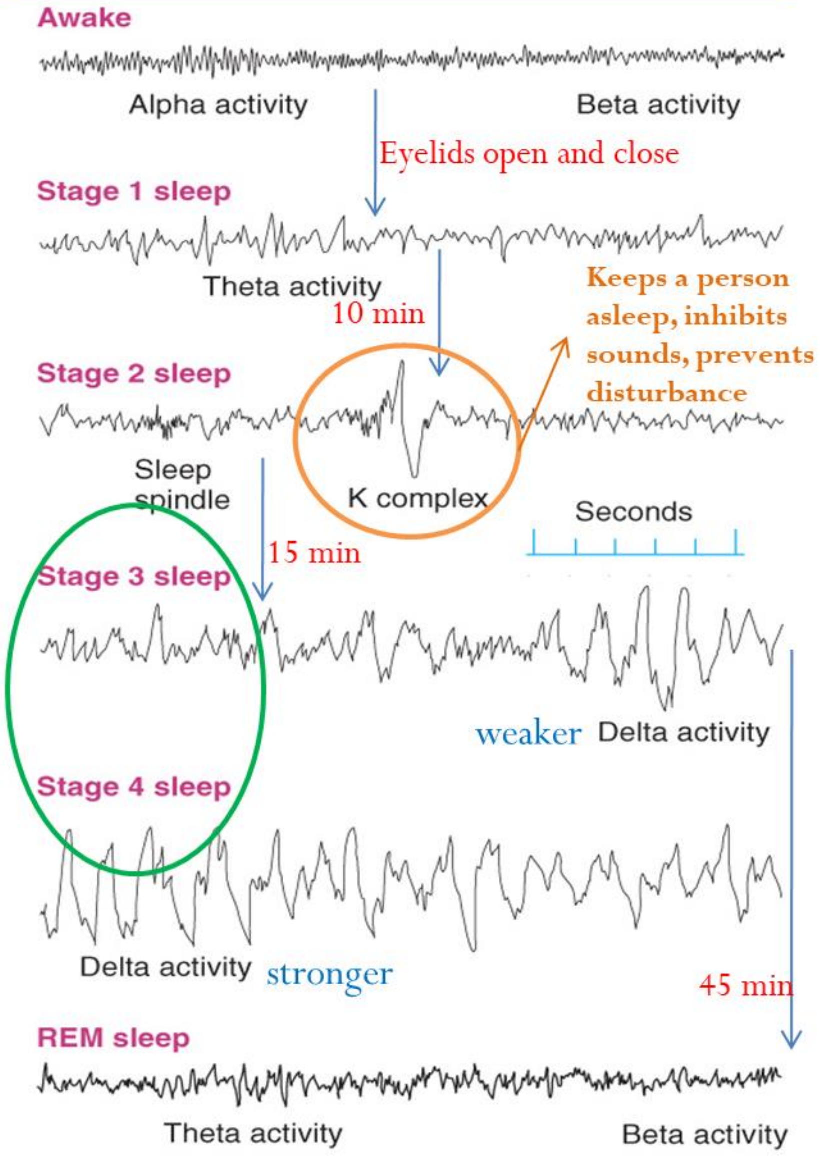
How does our brain prevent interference?

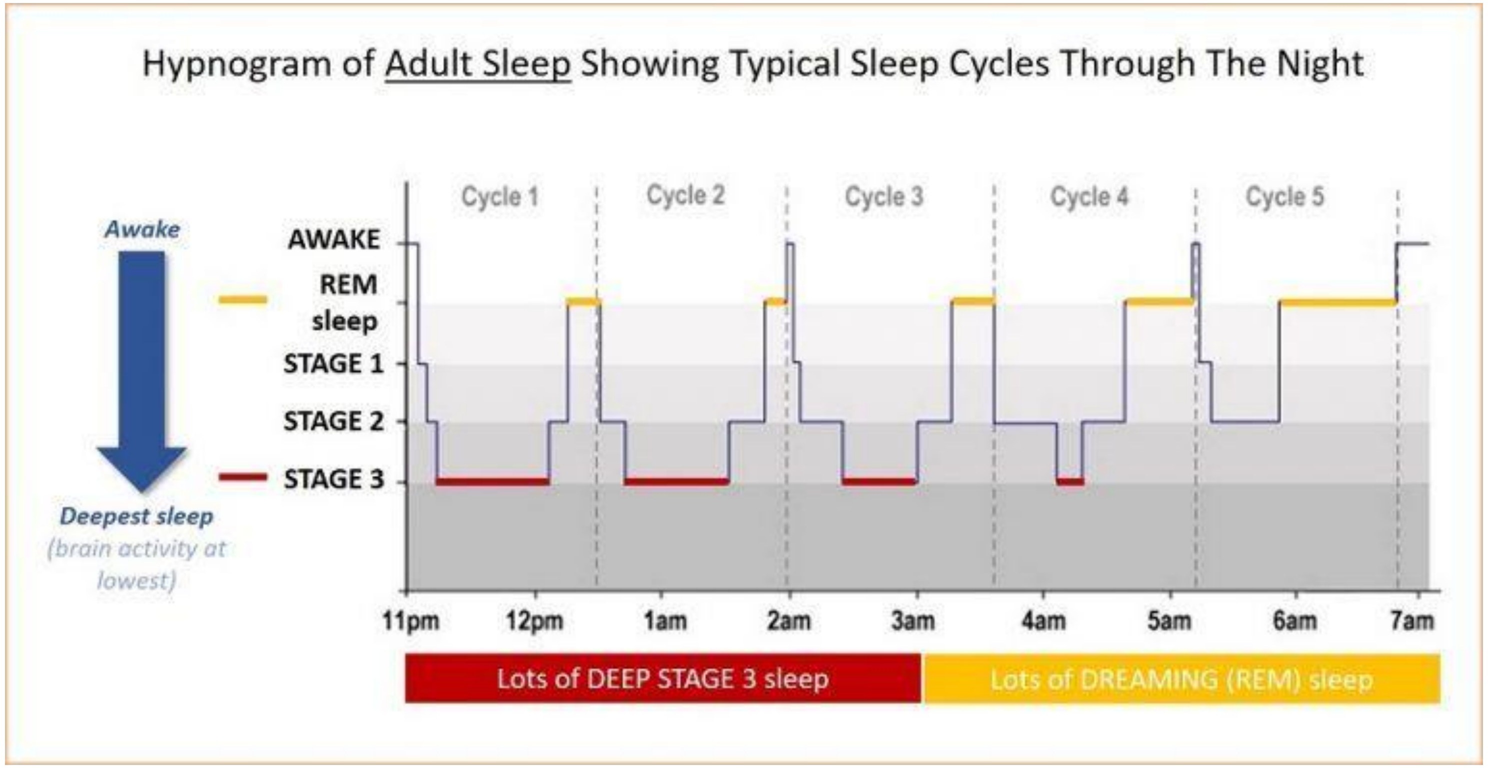


New memories are subject to a time window during which new memories are vulnerable and easily lost

Consolidation

Non-REM sleep: All stages of sleep except REM sleep.



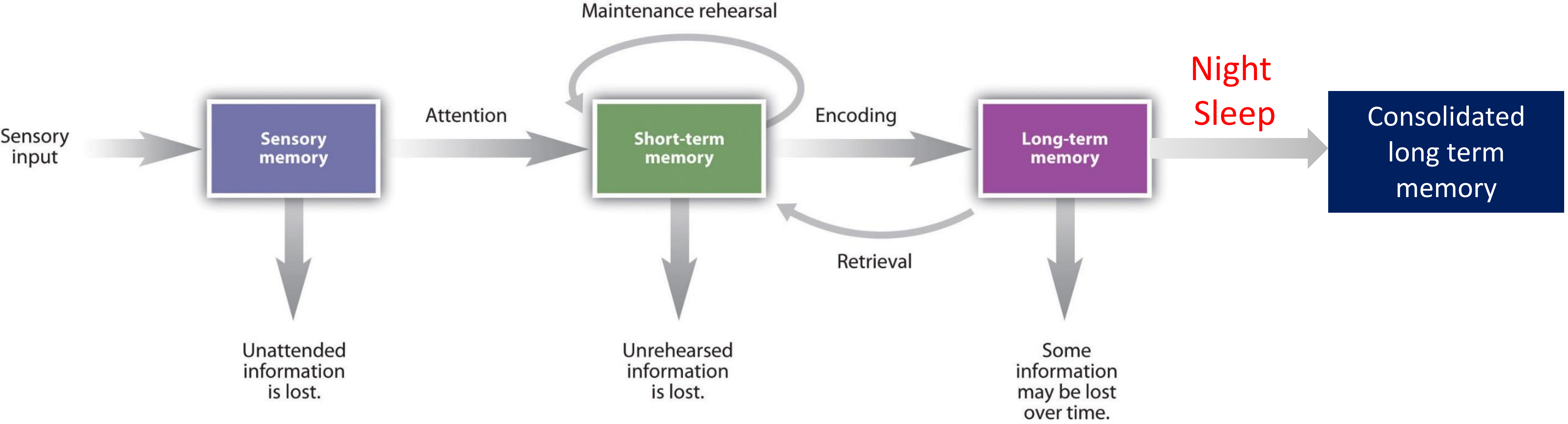


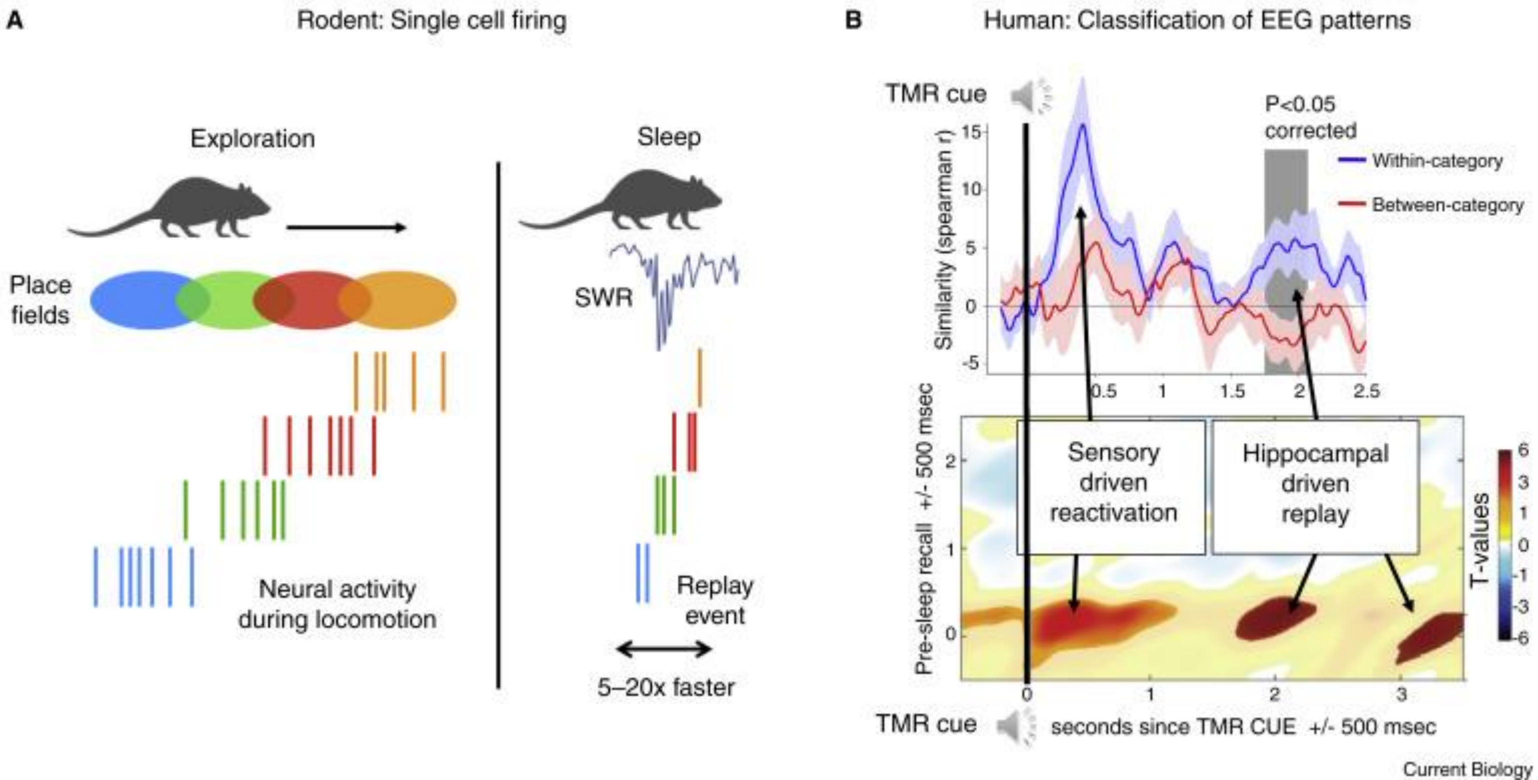
- ***Alpha activity:*** A smooth electrical activity of 8–12 Hz recorded from the brain; generally associated with a state of relaxation.

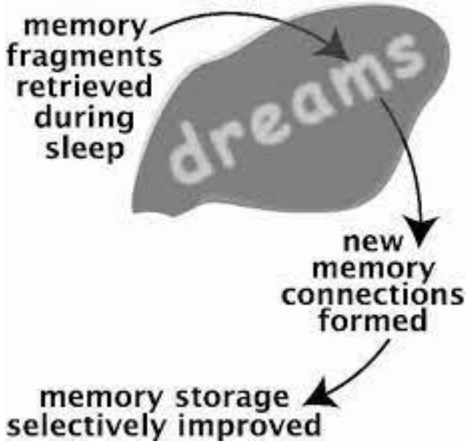
- ***Beta activity:*** Irregular electrical activity of 13–30 Hz recorded from the brain; generally associated with a state of arousal.

- ***Theta activity:*** EEG activity of 3.5-7.5 Hz that occurs intermittently during early stages of slow-wave and REM sleep, a transition between sleep and wakefulness.

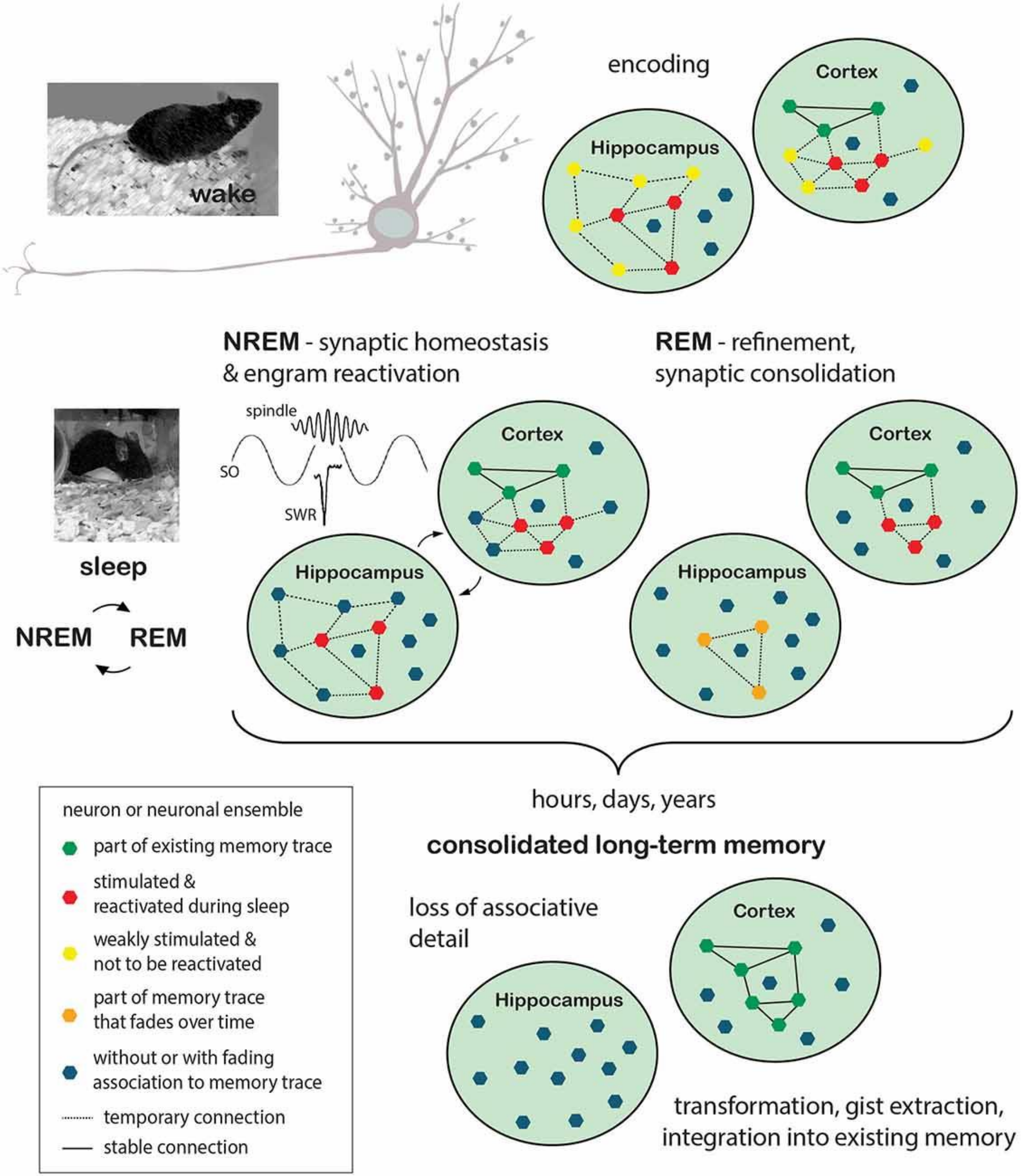
- ***Delta activity:*** Regular, synchronous electrical activity of less than 4 Hz recorded from the brain; occurs during the deepest stages of slow-wave sleep.





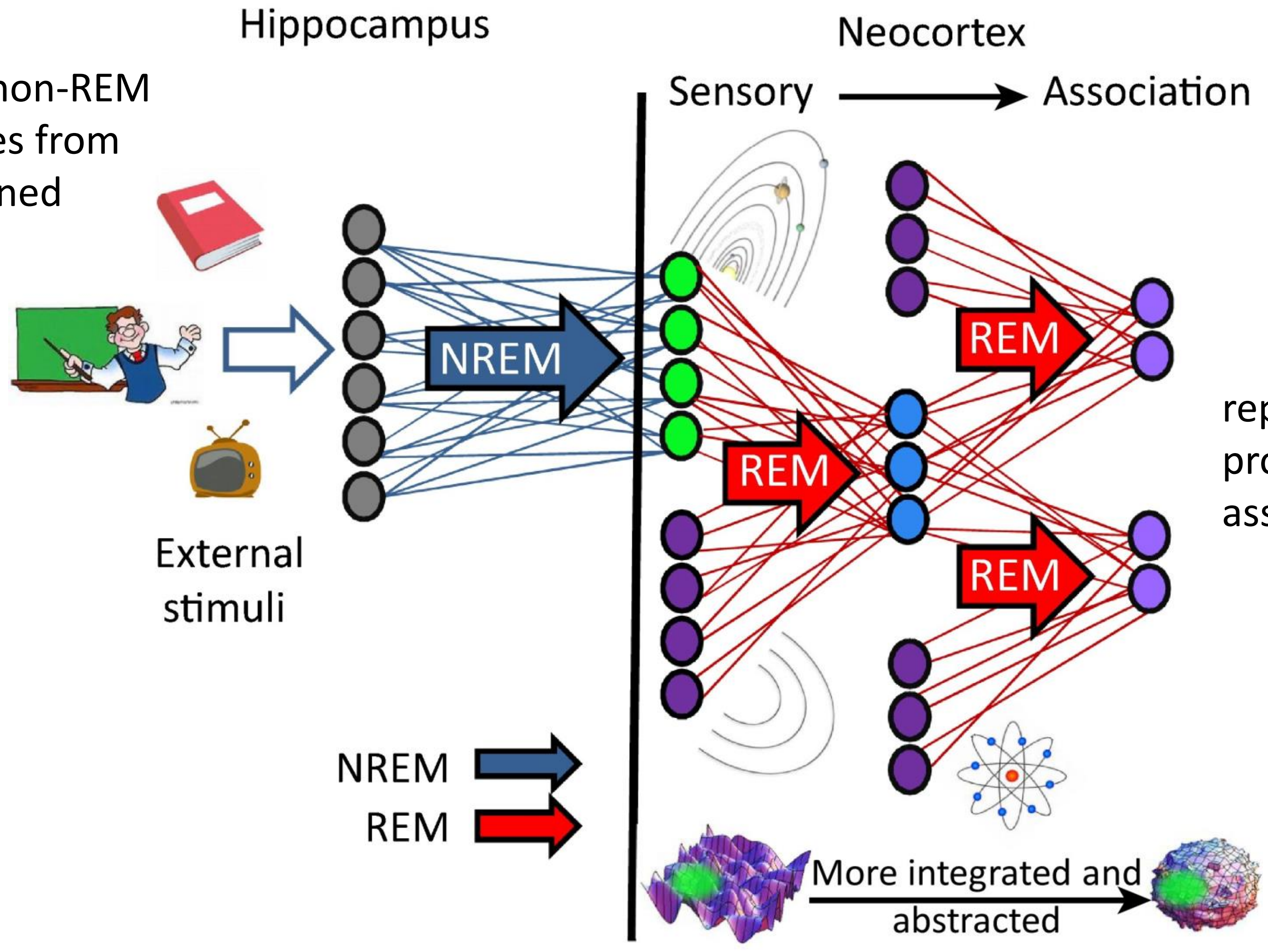


https://www.sciencedirect.com/science/article/pii/S0960982219310358#fig1


wake
encoding
Hippocampus
Cortex
NREM - synaptic homeostasis
& engram reactivation
REM - refinement,
synaptic consolidation
spindle
SO
SWR
sleep
NREM
REM
Cortex
Hippocampus
Cortex
Hippocampus
hours, days, years
consolidated long-term memory
loss of associative
detail
Cortex
Hippocampus
transformation, gist extraction,
integration into existing memory
neuron or neuronal ensemble
part of existing memory trace
stimulated &
reactivated during sleep
weakly stimulated &
not to be reactivated
part of memory trace
that fades over time
without or with fading
association to memory trace
temporary connection
stable connection

How Memory Replay in Sleep Boosts Creative Problem-Solving

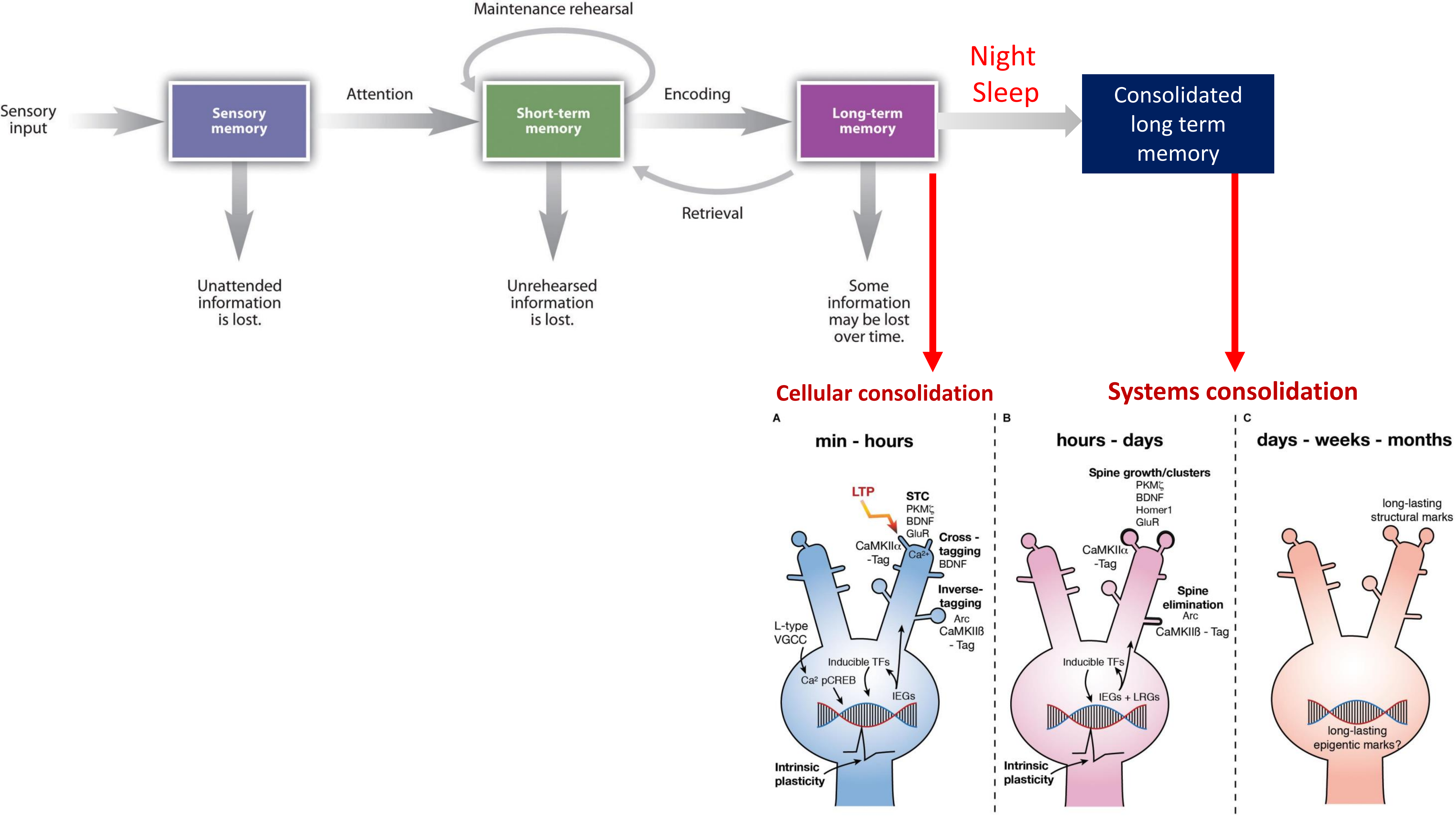
Memory replay mechanisms in non-REM can abstract rules from corpuses of learned information

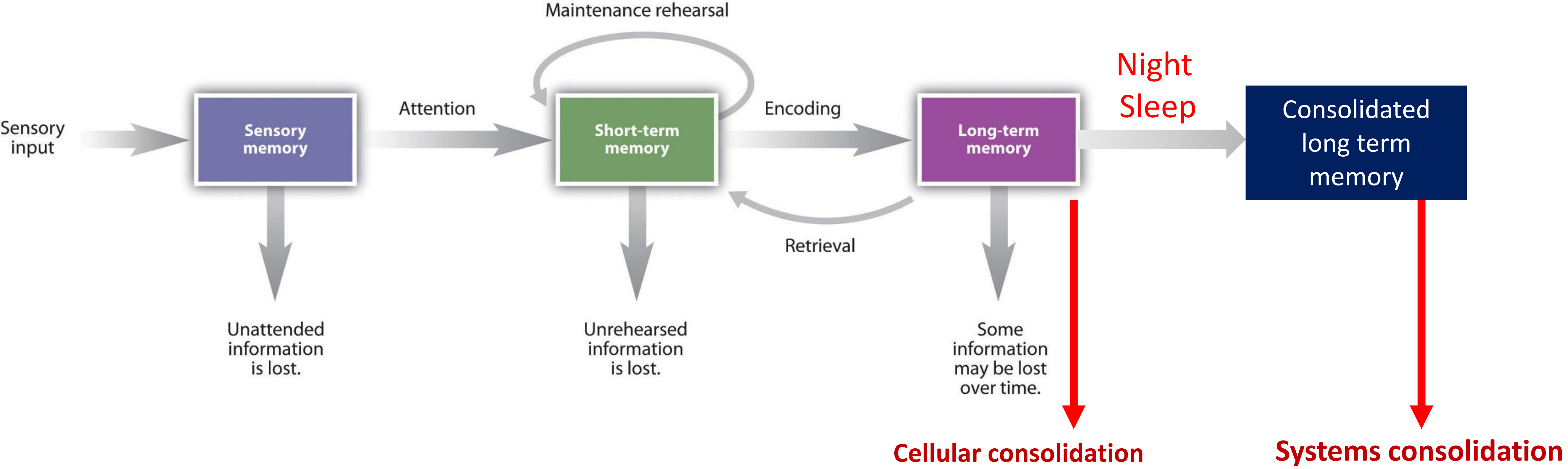


replay in REM may promote novel associations

iterative interleaving of REM and non-REM across a night boosts the formation of complex knowledge frameworks, and allows these frameworks to be restructured, thus facilitating creative thought.

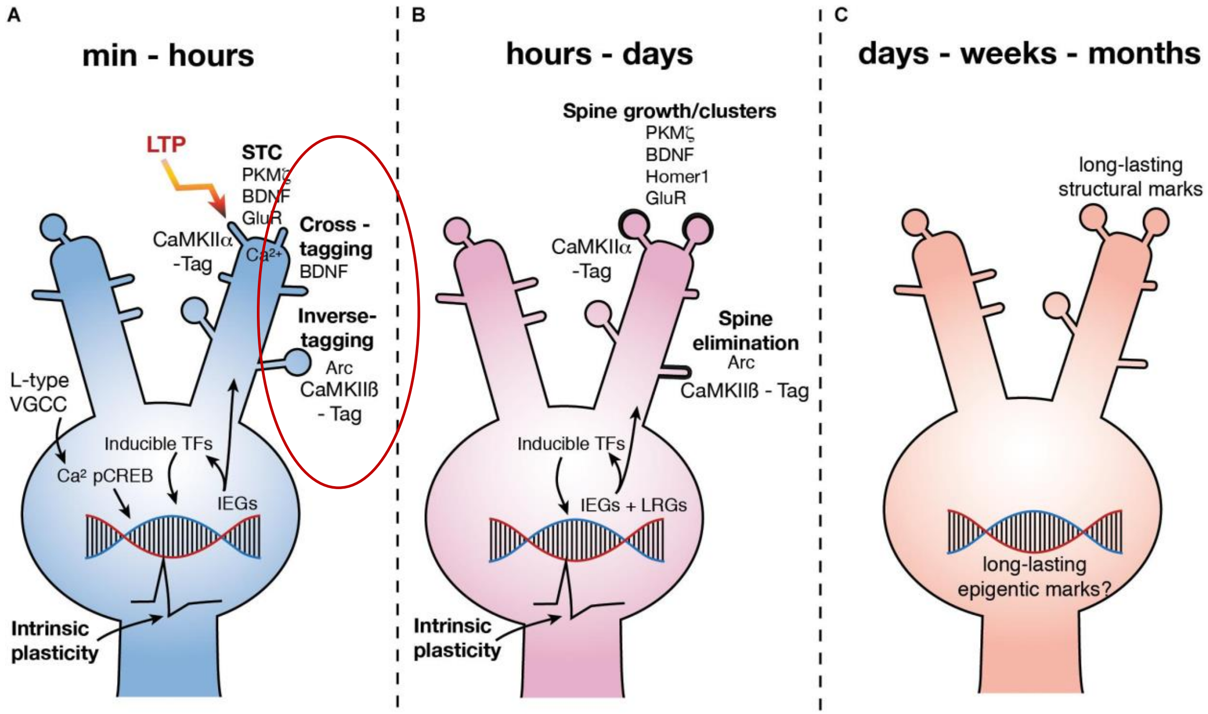
https://somby.ceu.edu/sites/somby.ceu.edu/files/attachment/basicpage/6/knoblich2018howmemoryreplayinsleepboostscreativeproblem-solving.pdf

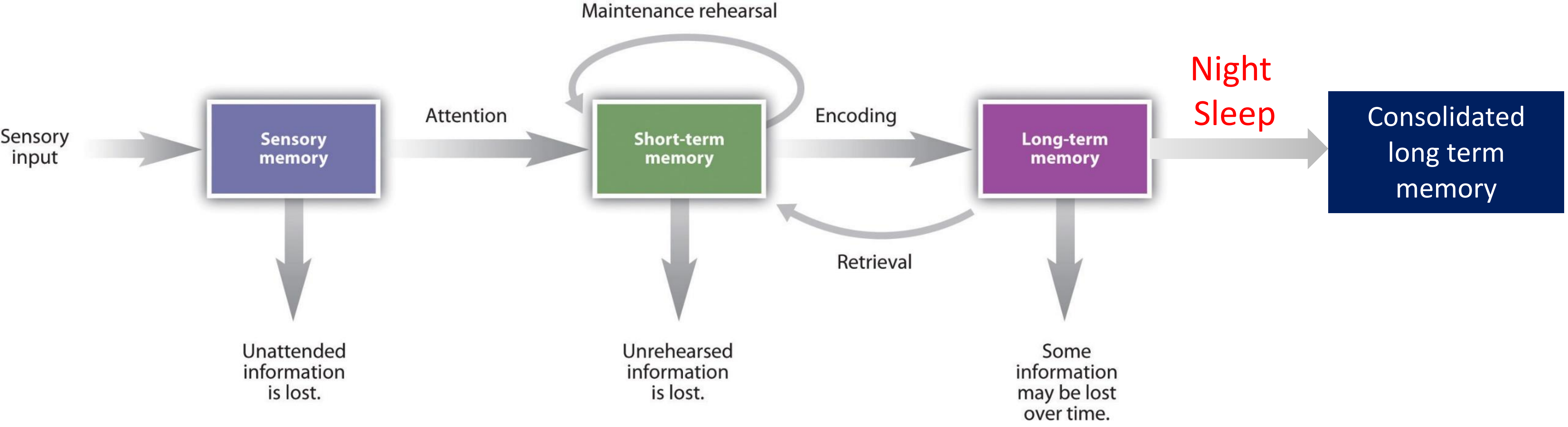

Maintenance rehearsal
Sensory input
Sensory memory
Attention
Short-term memory
Encoding
Long-term memory
Night Sleep
Consolidated long term memory
Retrieval
Unattended information is lost.
Unrehearsed information is lost.
Some information may be lost over time.
Cellular consolidation
Systems consolidation
A
min - hours
LTP
STC
PKMζ
BDNF
GluR
CaMKIIα -Tag
Ca^{2+}
Cross - tagging
BDNF
Inverse-tagging
Arc
CaMKIIβ - Tag
L-type VGCC
Inducible TFs
Ca² pCREB
IEGs
Intrinsic plasticity
B
hours - days
Spine growth/clusters
PKMζ
BDNF
Homer1
GluR
CaMKIIα -Tag
Spine elimination
Arc
CaMKIIβ - Tag
Inducible TFs
IEGs + LRGs
Intrinsic plasticity
C
days - weeks - months
long-lasting structural marks
long-lasting epigentic marks?



Experiments strongly suggest that the frontal lobes help determine what new information gets encoded and what gets forgotten

Maintain a balance between remembering and forgetting

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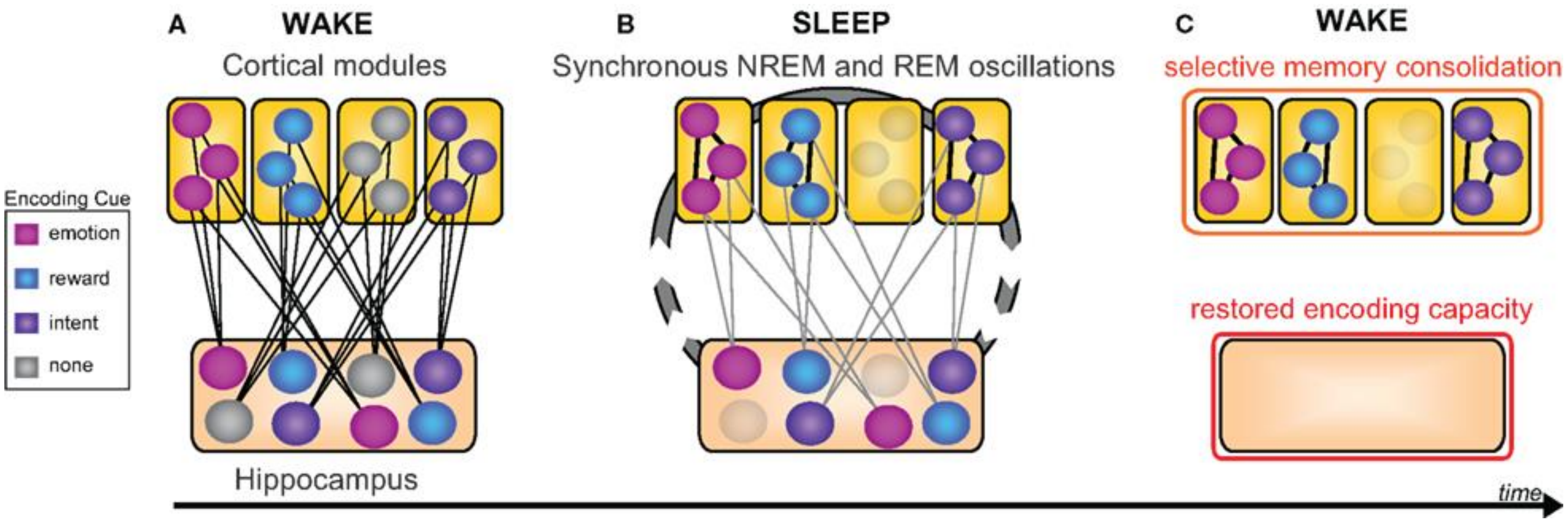
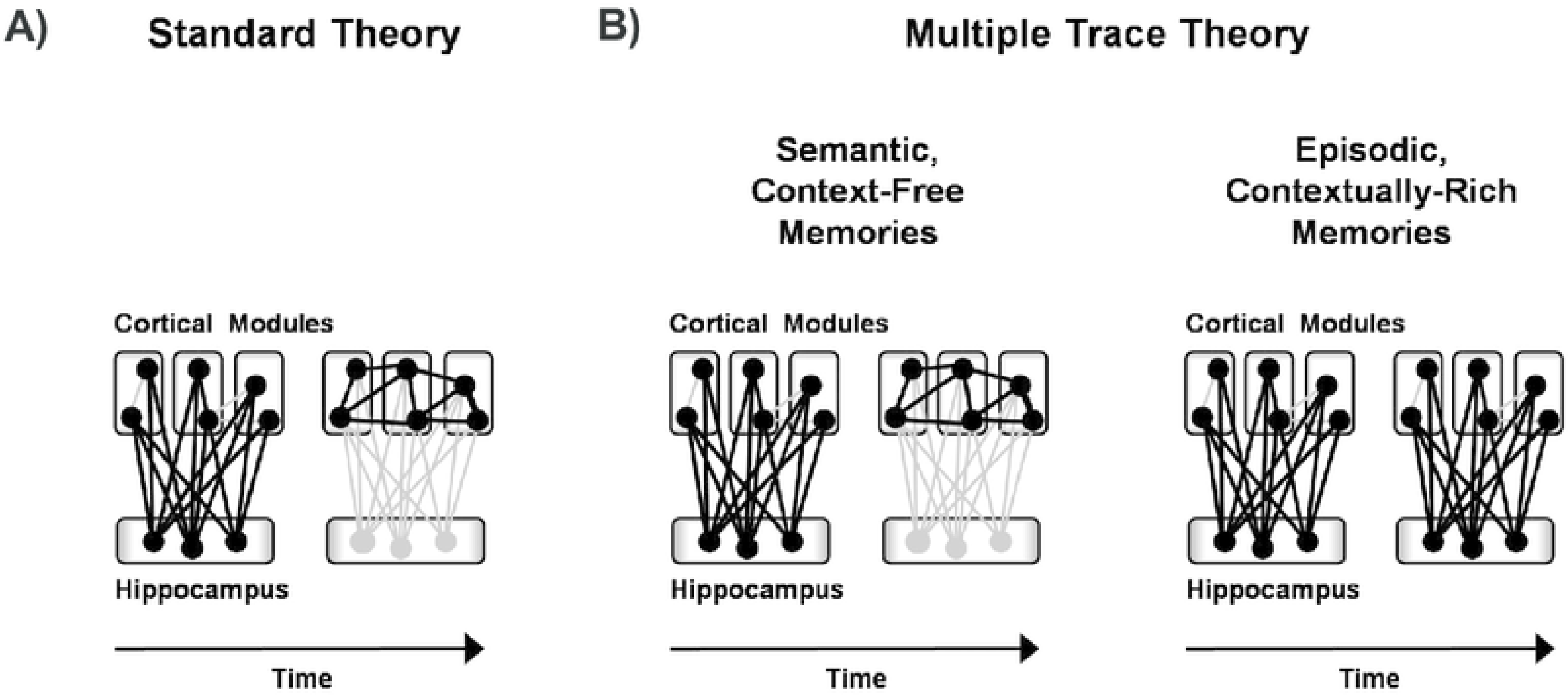
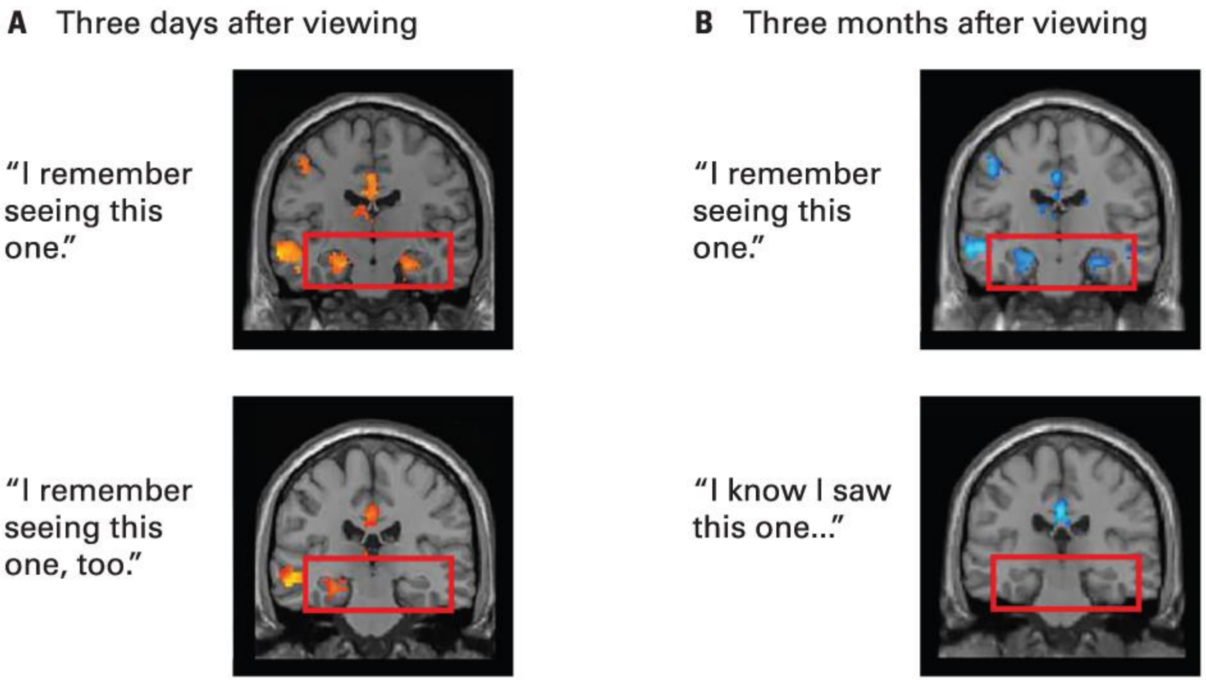

A
WAKE
Cortical modules
B
SLEEP
Synchronous NREM and REM oscillations
C
WAKE
selective memory consolidation
Encoding Cue
emotion
reward
intent
none
restored encoding capacity
Hippocampus
time

Memory Consolidation Theory



Evidence from Healthy Brains



Harand C, Bertran F, La Joie R, Landeau B, Mézenge F, Desgranges B, et al. (2012) The Hippocampus Remains Activated over the Long Term for the Retrieval of Truly Episodic Memories. PLoS ONE 7(8).

In adult humans with normal memory function, fMRI shows that the hippocampus is active even for retrieval of very old episodic information (Ryan et al., 2001). Does this prove that episodic memories always remain at least partially dependent on the hippocampus?

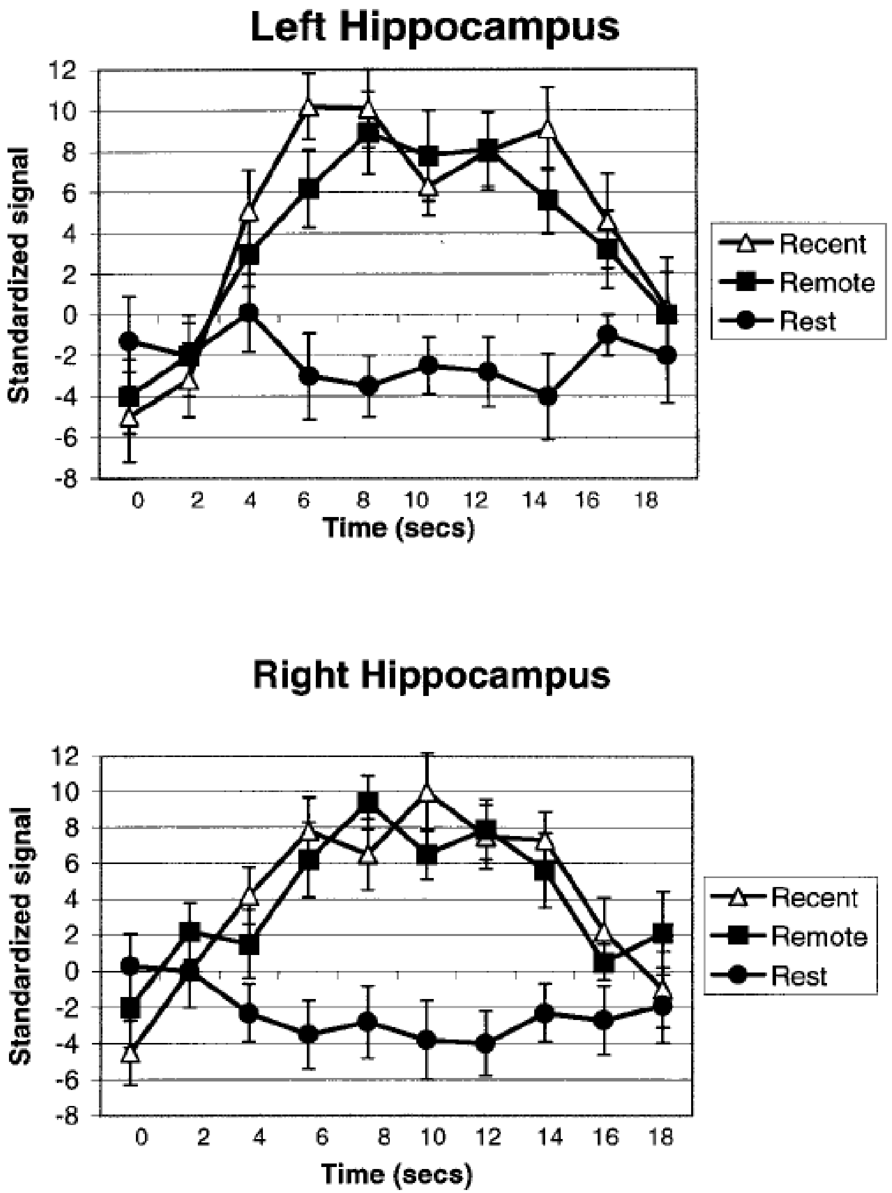


FIGURE 3. Mean (SEM) activations in left and right hippocampus for recollection of recent events, remote events, and rest, from three subjects who were unaware of the event cues that were to be presented in the scanner.

- Do we remember as it was learned?
- Can you trust your memory?

Hot
Snow
Warm
Winter
Ice
Wet
Frigid
Chilly
Heat
Weather
Freeze
Air
Shiver
Arctic
Frost


TS10EU1297

Word list memory

Cold

DRM (Deese-Roediger-Mc Dermott) – Paradigm

(Deese, Roediger, & McDermott, 1995)

Hot
Snow
Warm
Winter
Ice
Wet
Frigid
Chilly
Heat
Weather
Freeze
Air
Shiver
Arctic
Frost

→ **COLD**

(critical lure)

False Memory

Incorrectly associating words or experiences to our memories

Mental context that links all the words

- Color of the two cars in the picture?
- What was written on the building behind?
- Car number?

[Elizabeth Loftus]

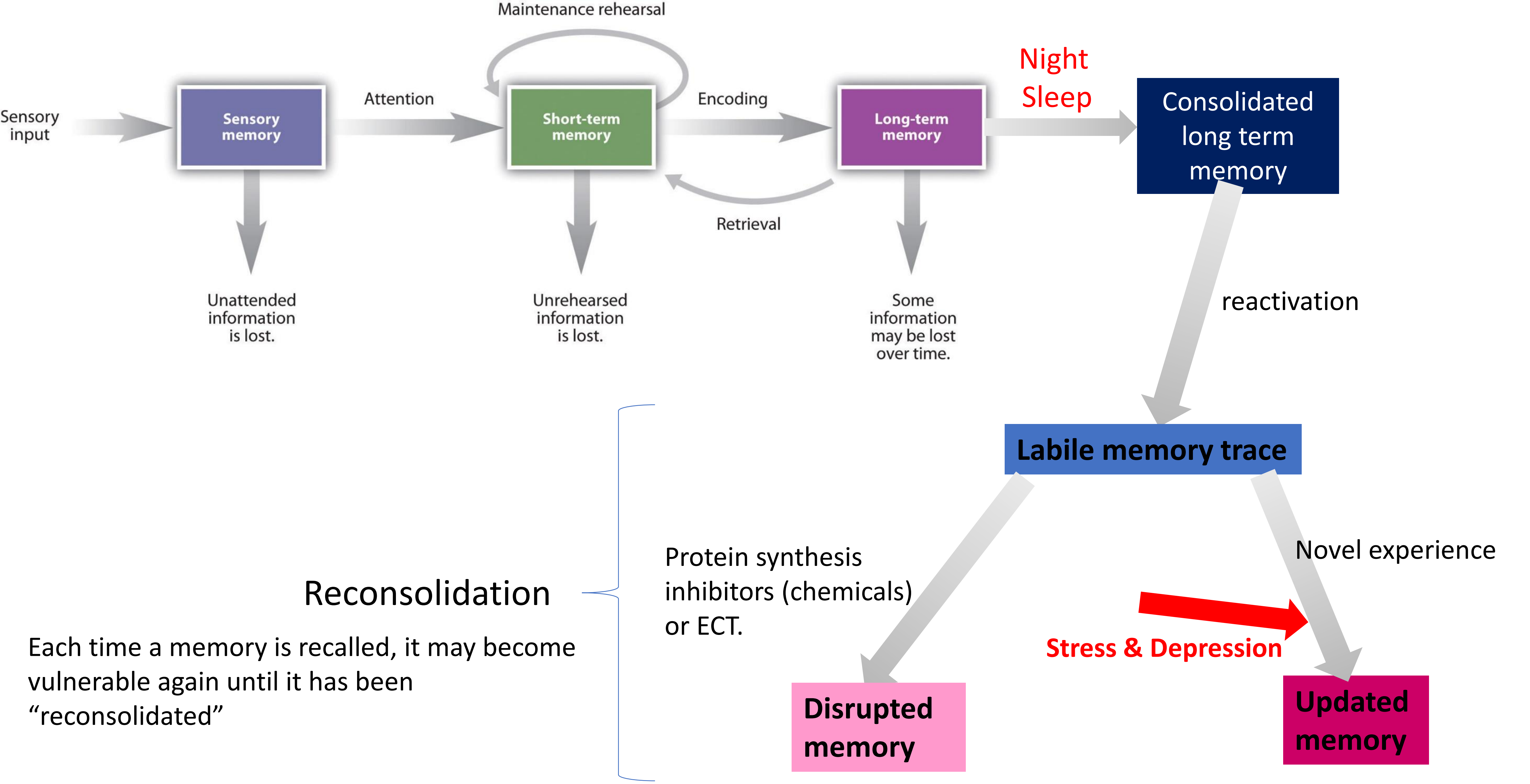
Instances of false memory – eye witness testimony

[Crime, law, memory – Ted talk]

Creating False Memories in the Real World

A B

Photo illustration by Slate, original images by Getty; left: SAUL LOEB/AFP/Getty Images, right: JUAN BARRETO/AFP/Getty Images.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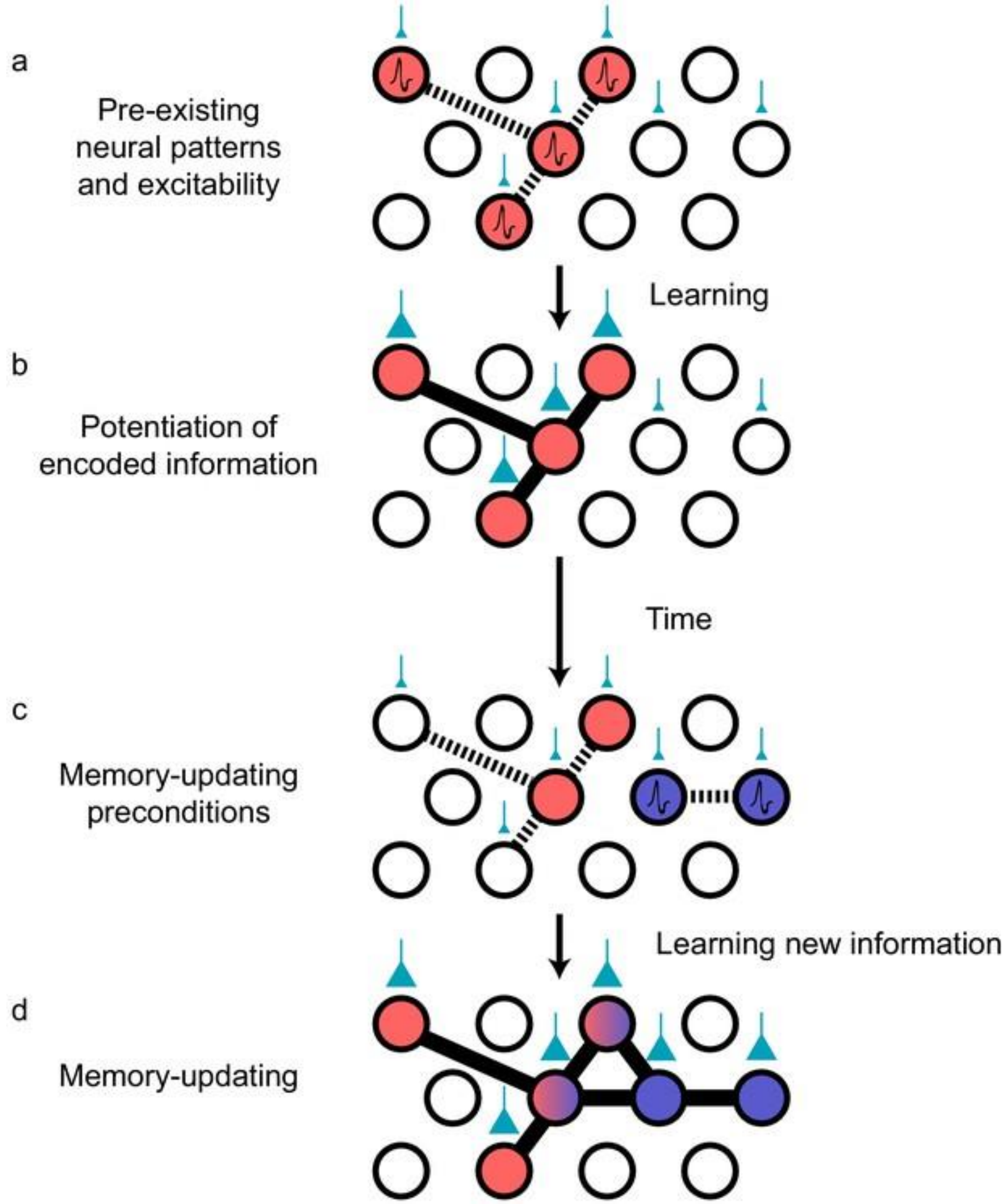
Sensory input
Sensory memory
Attention
Short-term memory
Encoding
Long-term memory
Night Sleep
Consolidated long term memory
Retrieval
Unattended information is lost.
Unrehearsed information is lost.
Some information may be lost over time.
reactivation
Labile memory trace
Protein synthesis inhibitors (chemicals) or ECT.
Novel experience
Stress & Depression
Disrupted memory
Updated memory
Reconsolidation
Each time a memory is recalled, it may become vulnerable again until it has been “reconsolidated”



Memory Updating

https://elifesciences.org/articles/63550