The Neuroscience of Learning

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Key Information

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Course Outline

Week One: How We Learn
- Topic 1. Repetition and Hebbian Learning
- Topic 2. Feedback and Types of Learning

Week Two; How We Learn
- Topic 1. Long Term Potentiation and Synaptic Plasticity
- Topic 2. Dopamine and the Basal Ganglia

Week Three: What We Learn
- Topic 1. Explicit Memory
- Topic 2. Implicit Memory

Week Four: What We Learn
- Topic 1. Neural Basis of Memory
- Topic 2. Internal Models

Week Five: How We Can Improve Learning
- **Topic 1. Distributed Practice, Random Practice, Variable Practice**
- **Topic 2. Specificity of Practice, Part-Whole Practice, Mental Imagery**

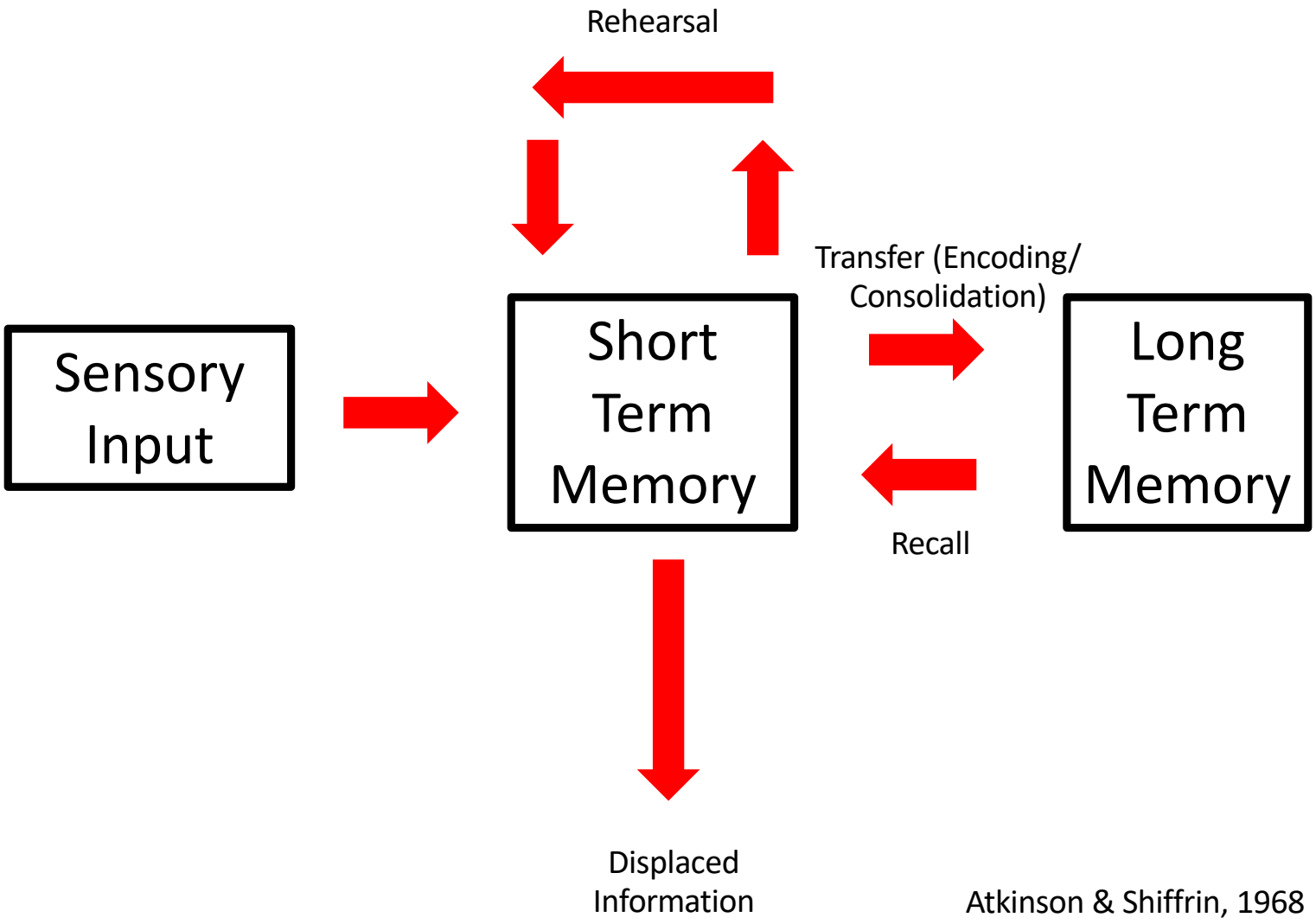
Week Six: How We Can Improve Learning
- **Topic 1. Sleep, Diet, and Exercise**
- **Topic 2. Age, Learning Disorders**

How do we learn?

REPETITION and FEEDBACK

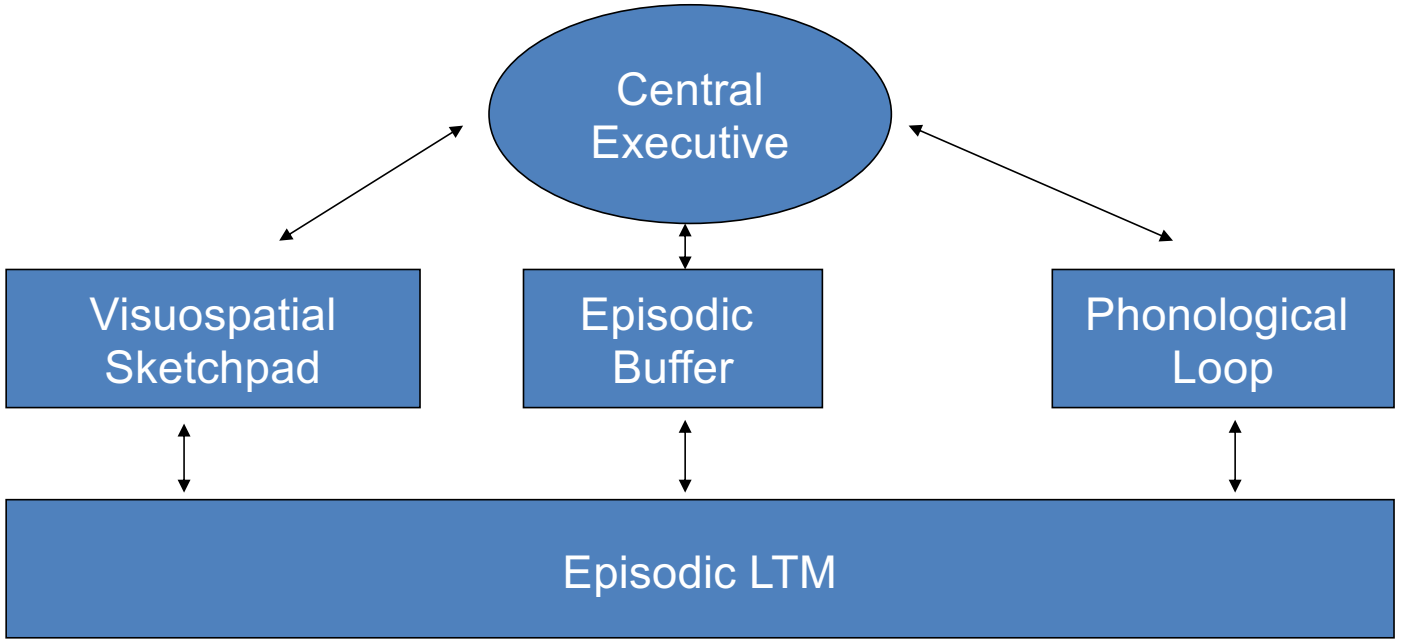
What do we learn?

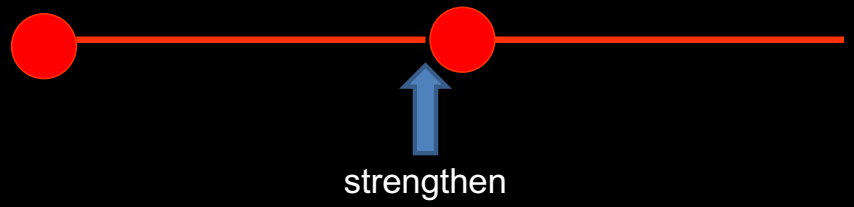
EXPLICIT and IMPLICIT MEMORIES

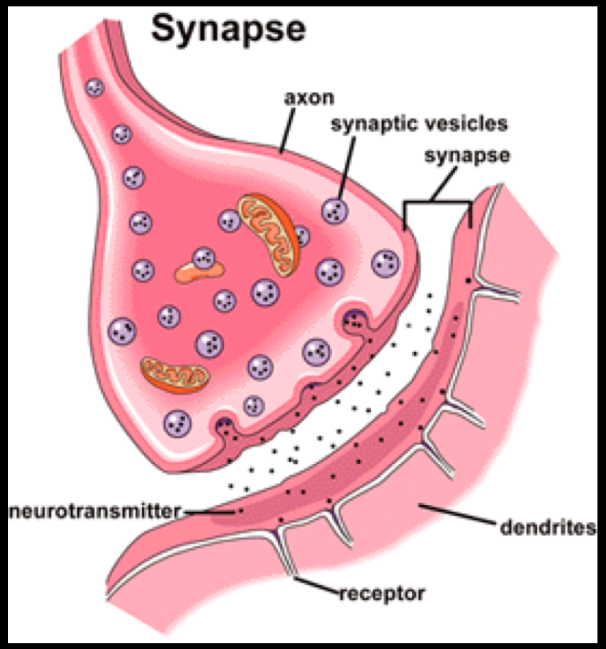


Atkinson & Shiffrin, 1968

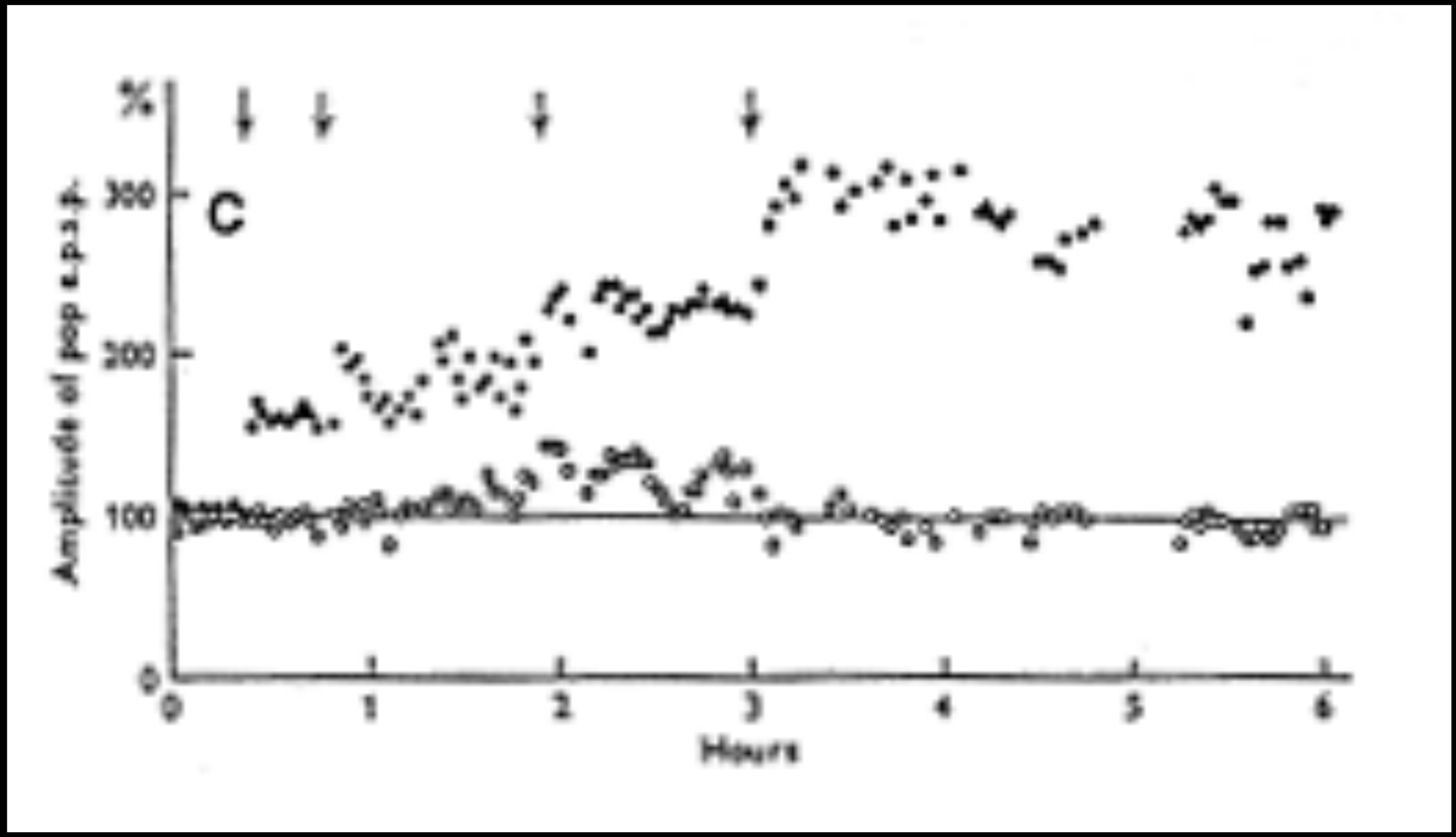
4-Component Model of Working Memory

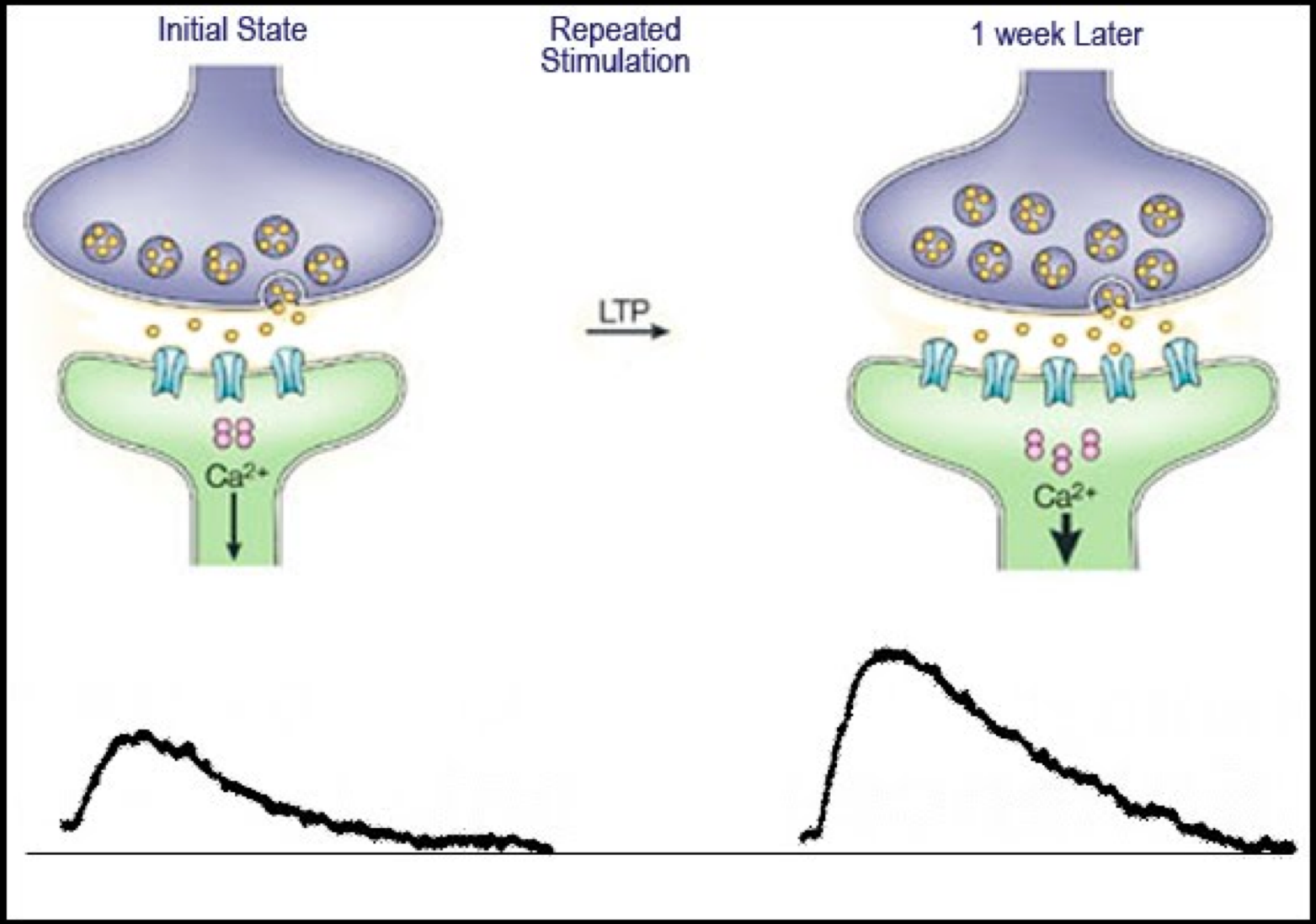



strengthen

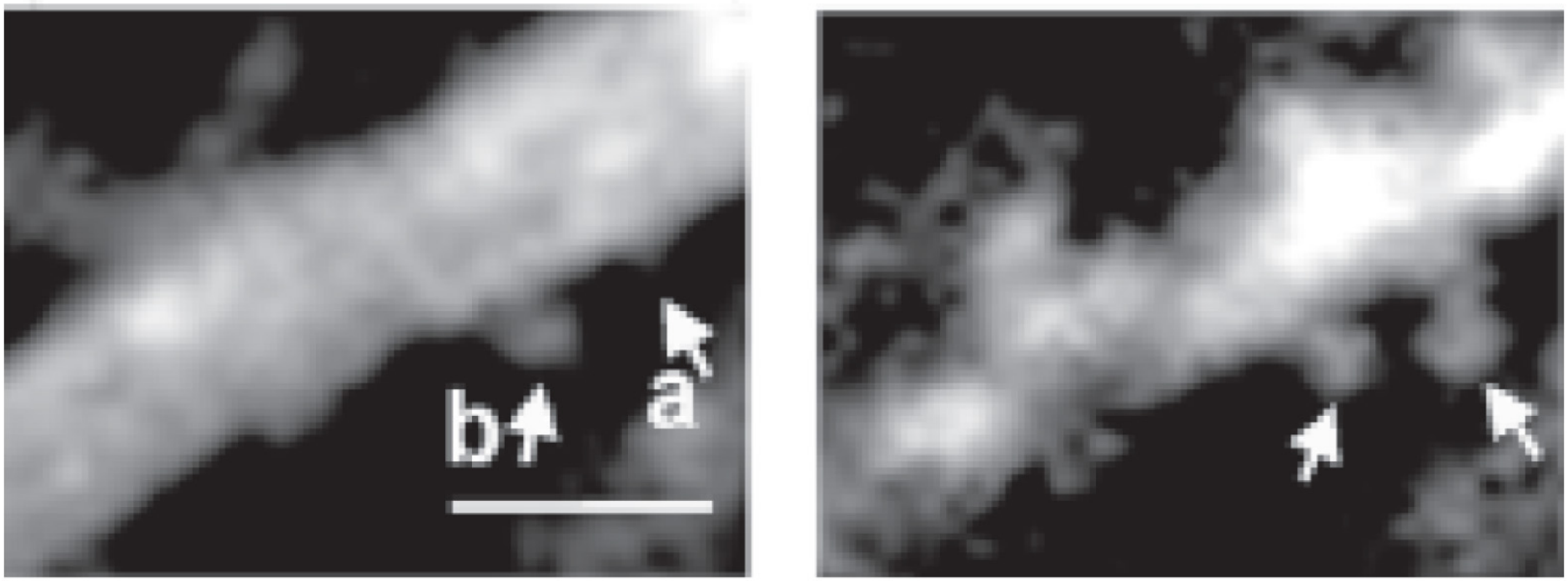

Synapse
axon
synaptic vesicles
synapse
neurotransmitter
dendrites
receptor

Bliss and Lomo's First Published LTP Experiment



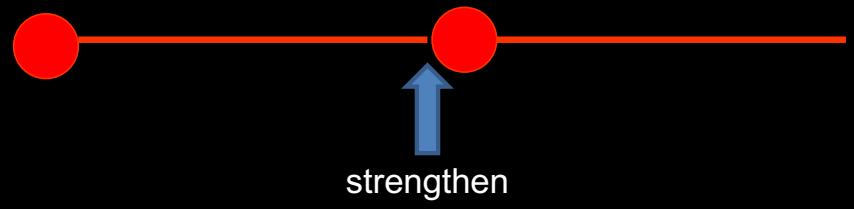

Initial State
Repeated Stimulation
1 week Later
LTP
Ca2+
Ca2+

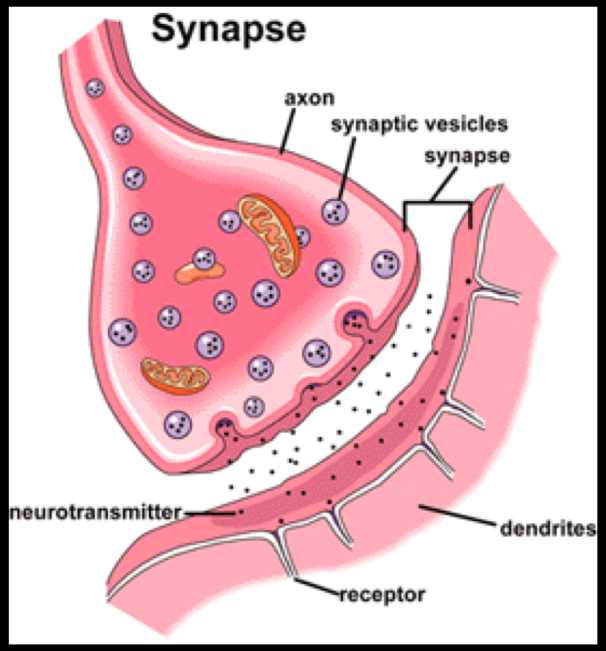
C7B12F10.eps



Before LTP

After LTP

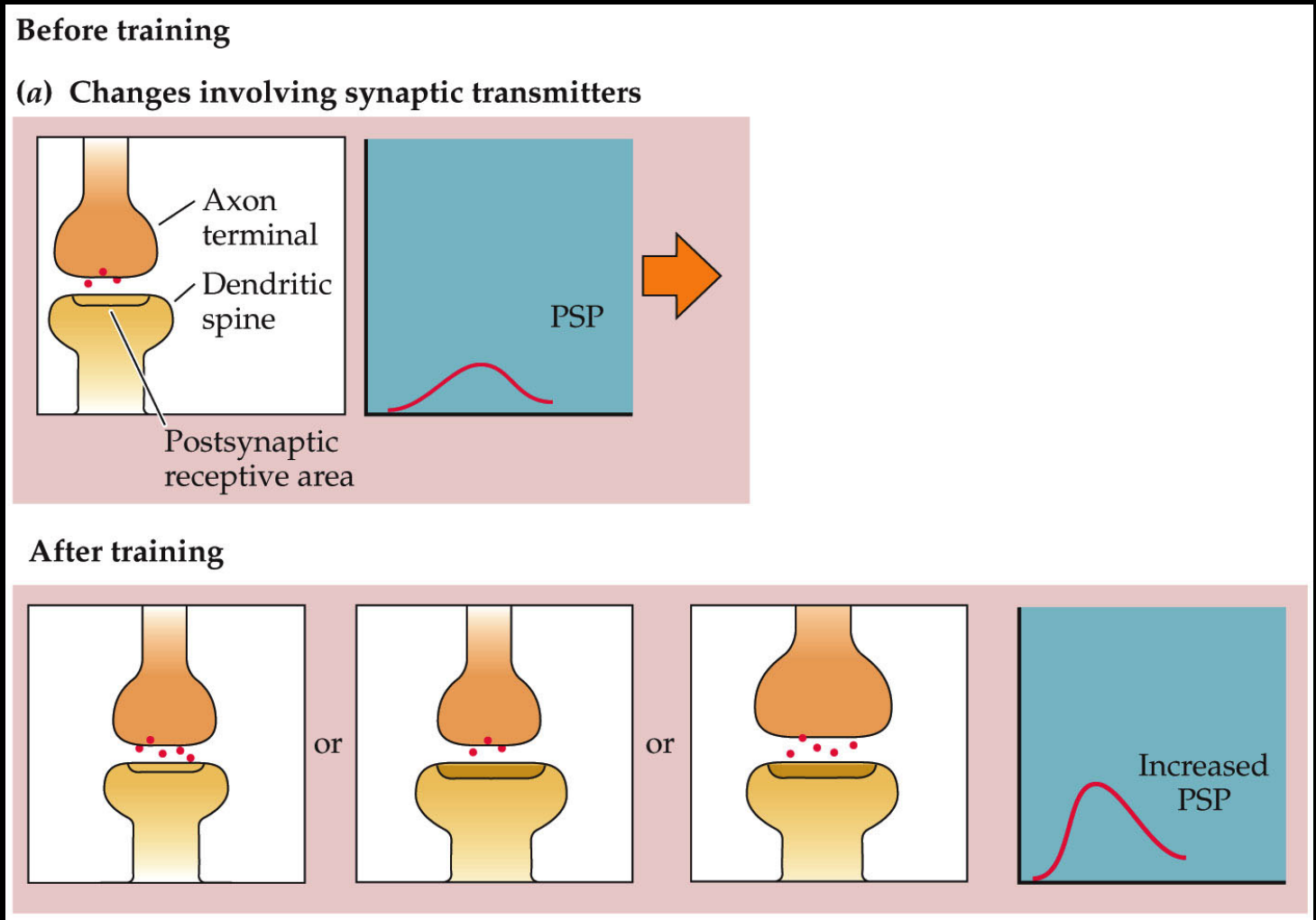




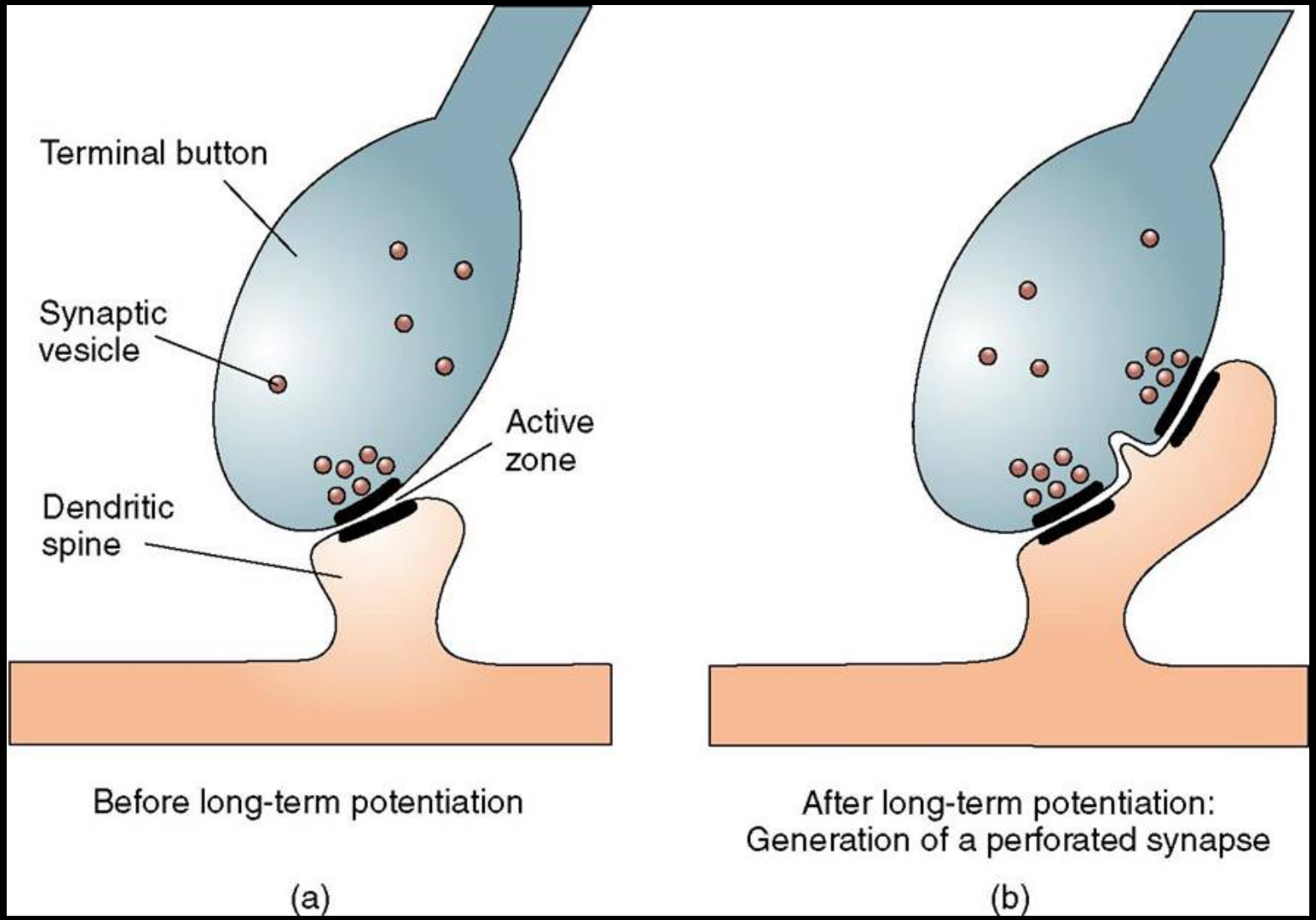
HOW?

Increased neurotransmitter release
Increase receptors
Structural changes

Figure 18.2 Synaptic Changes That May Store Memories (Part 1)



***Biological Psychology 5e,* Figure 18.2 (Part 1)**


Terminal button
Synaptic vesicle
Active zone
Dendritic spine
Before long-term potentiation
(a)
After long-term potentiation:
Generation of a perforated synapse
(b)

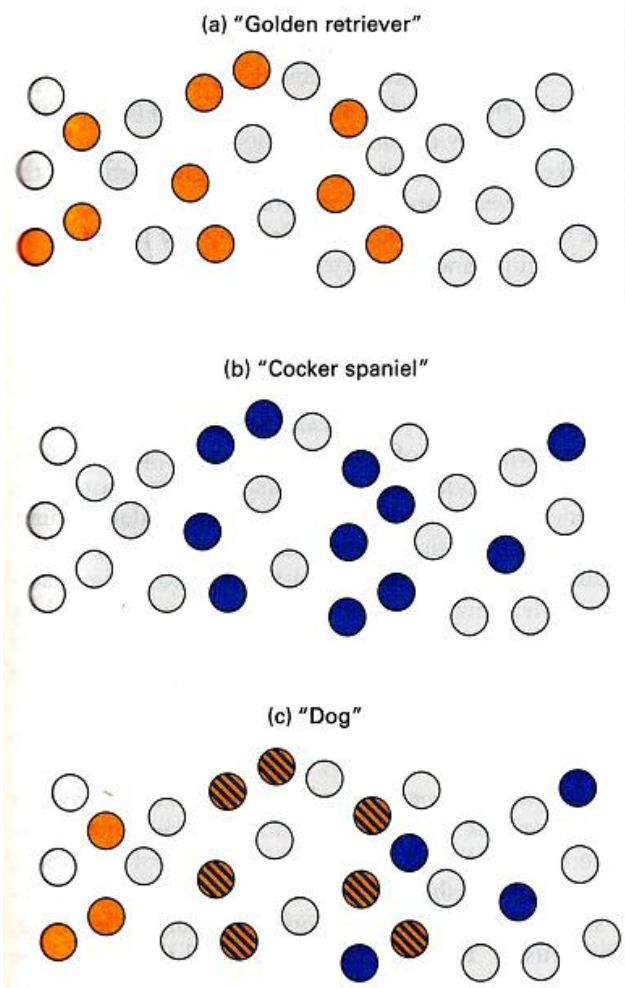
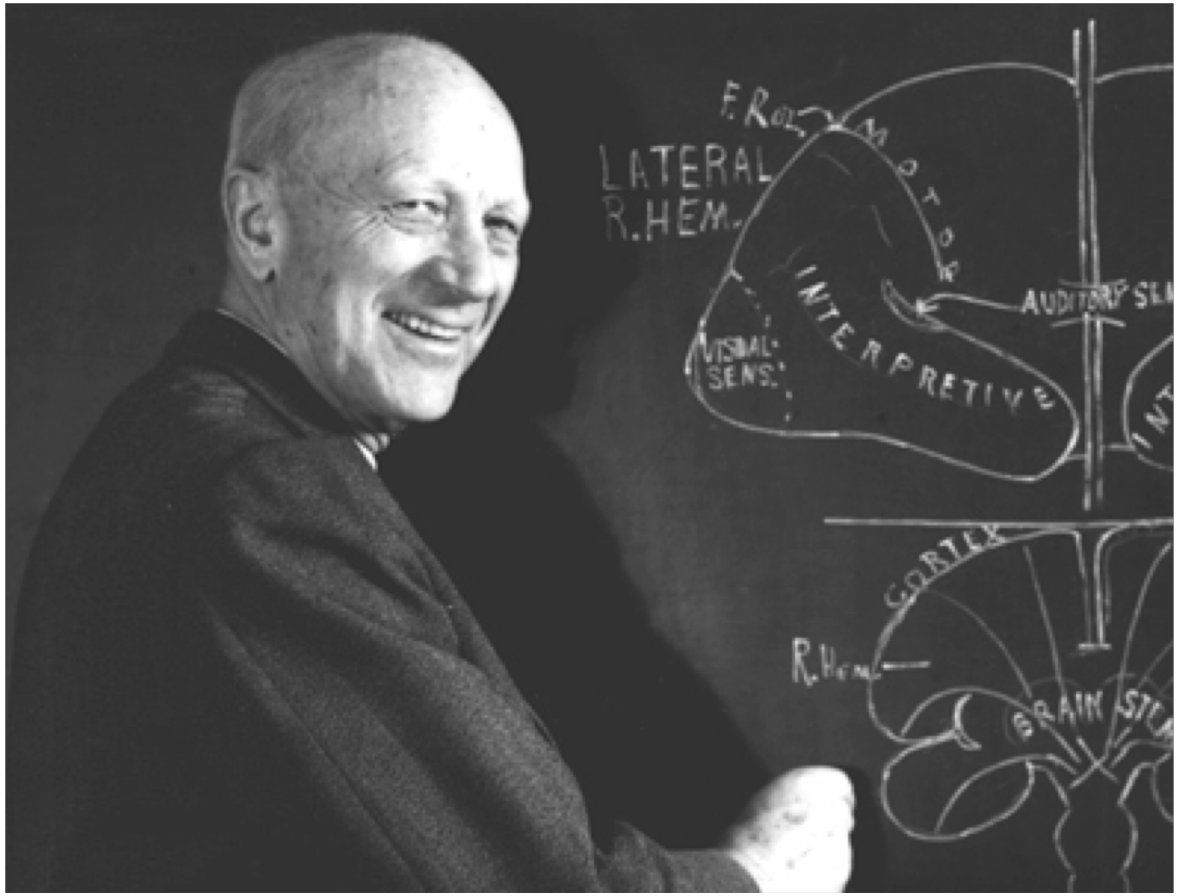


Figure 1.11 Distributed representations (a) The representation of "golden retriever" activates one subset of nodes, shown in yellow. (b) "Cocker spaniel" activates a different subset, shown in blue. (c) The similarity between them—both are dogs—emerges naturally as a function of the overlap between representations, shown by the yellow-and-blue nodes.

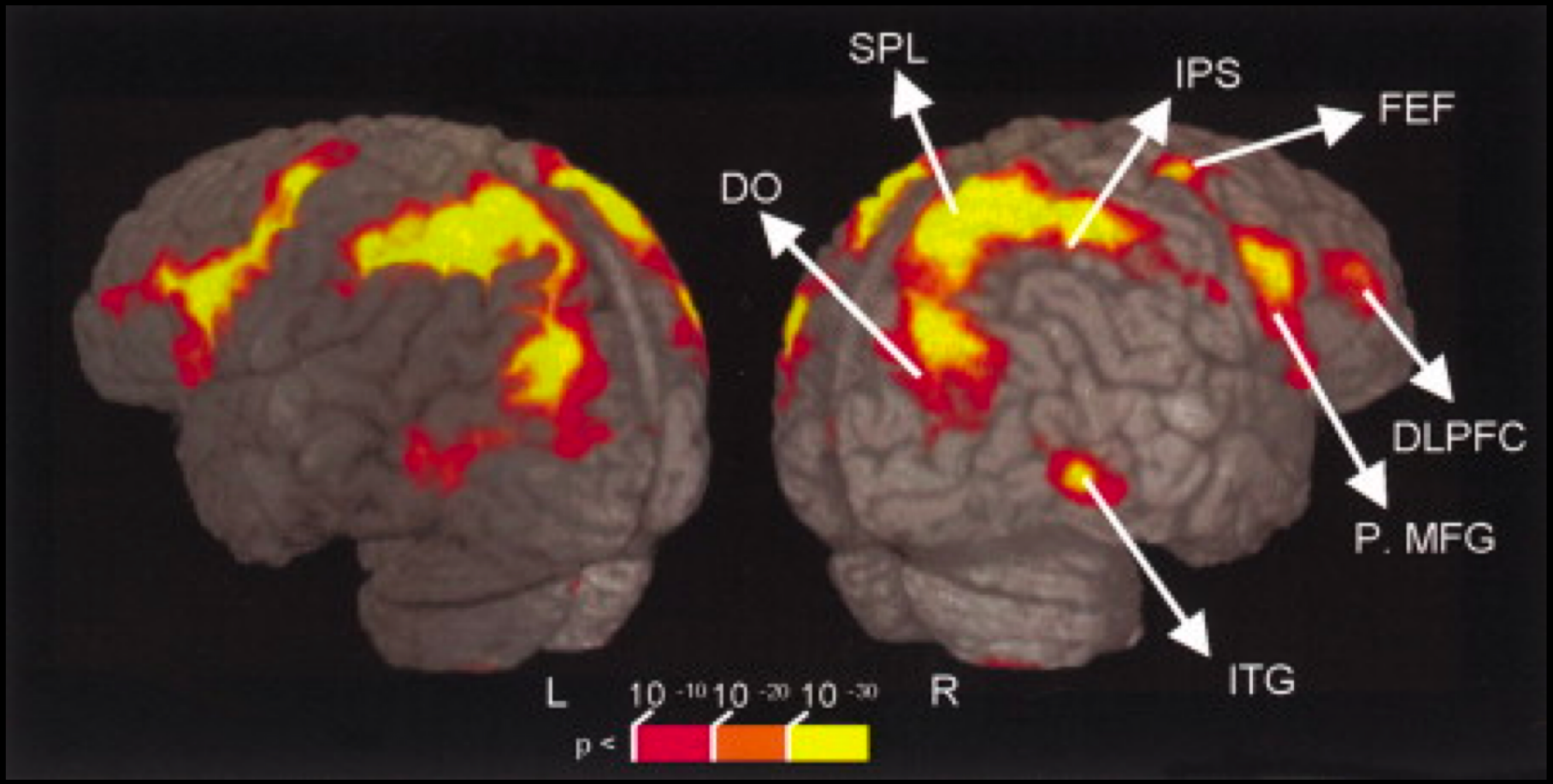
So what matters is the pattern of the neurons – the sum total of neuronal activity is the memory.

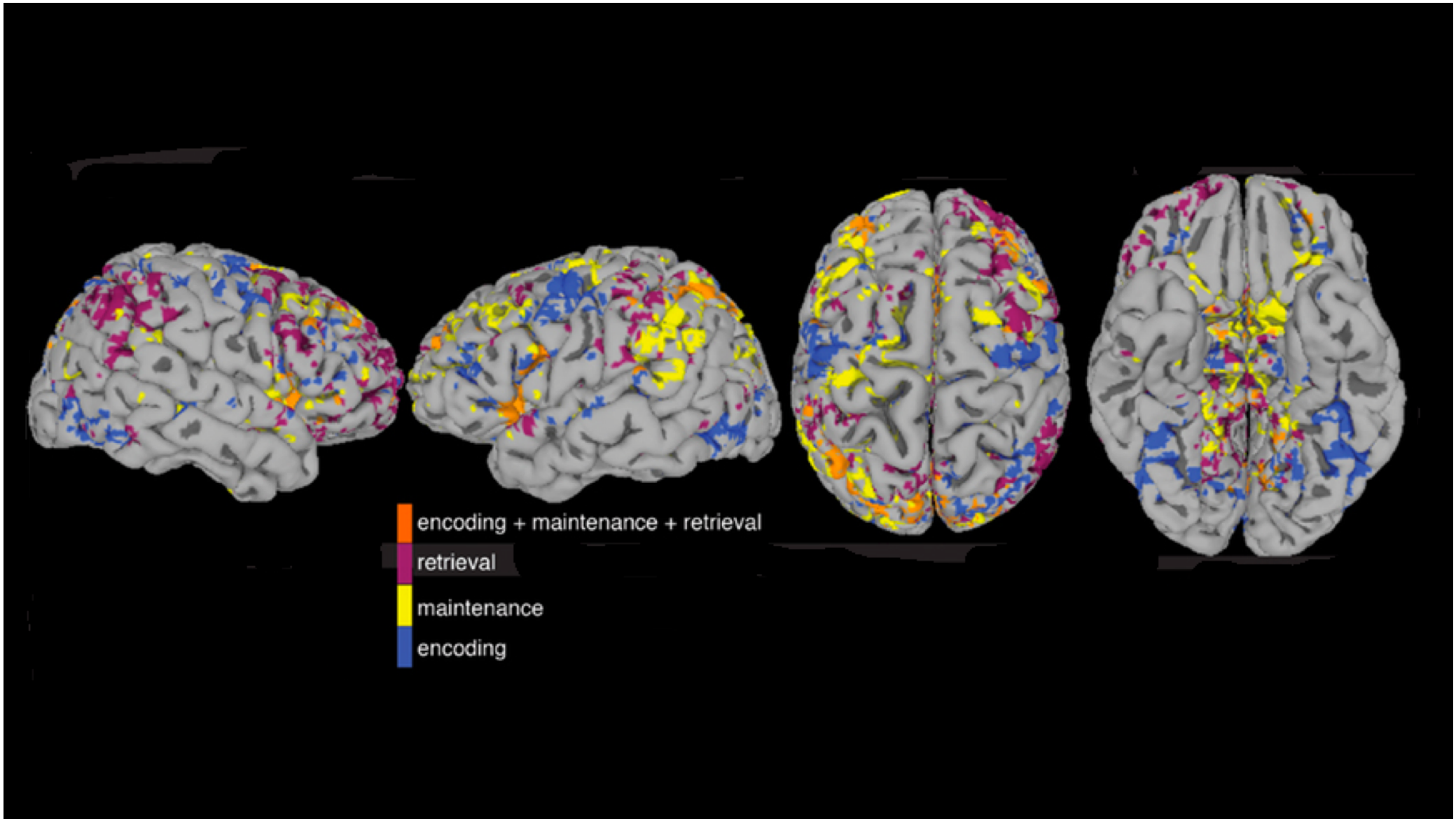


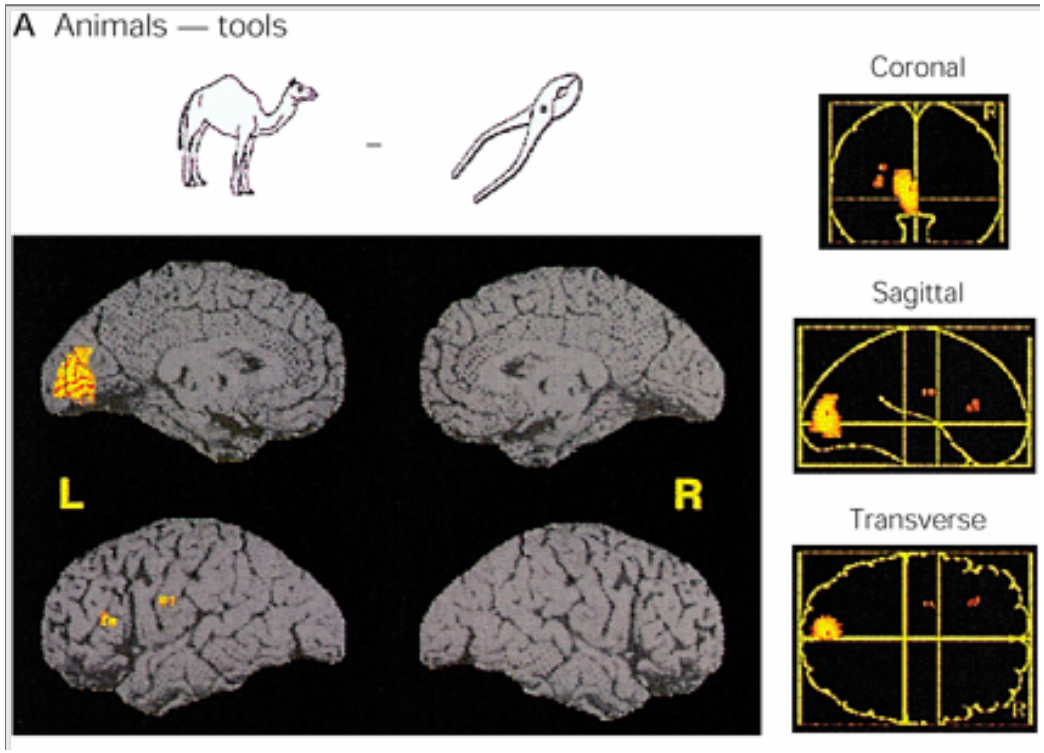
Wilder Penfield

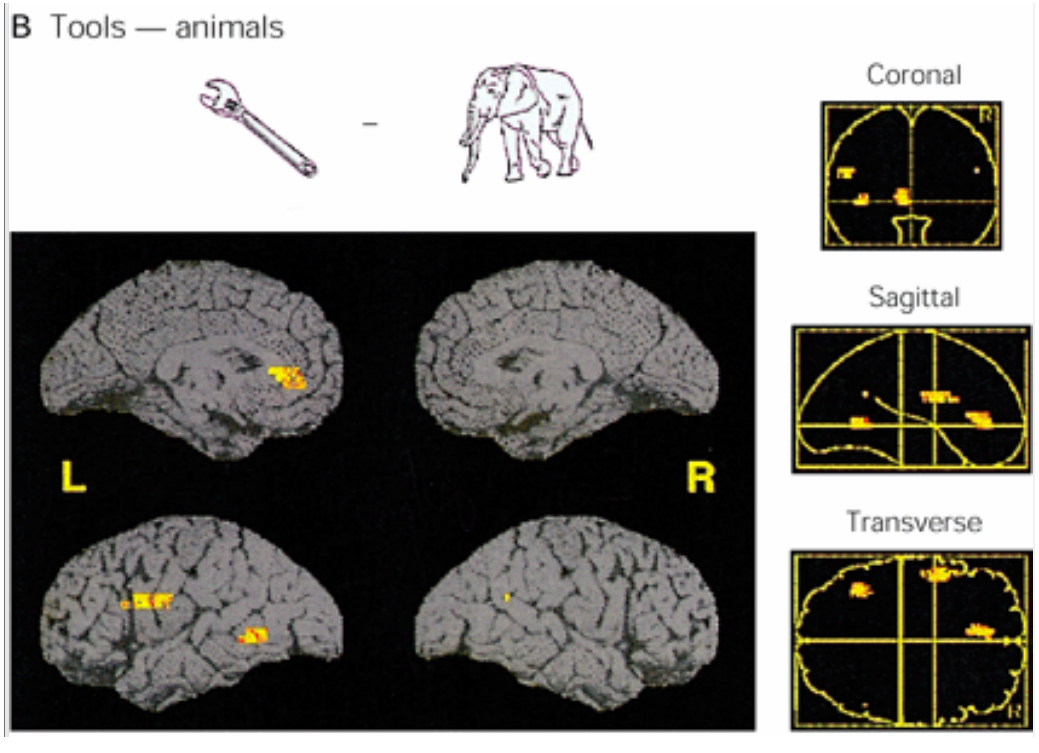
stimulation of regions of cortex led to an "experiential response" – a coherent recollection of a previous event

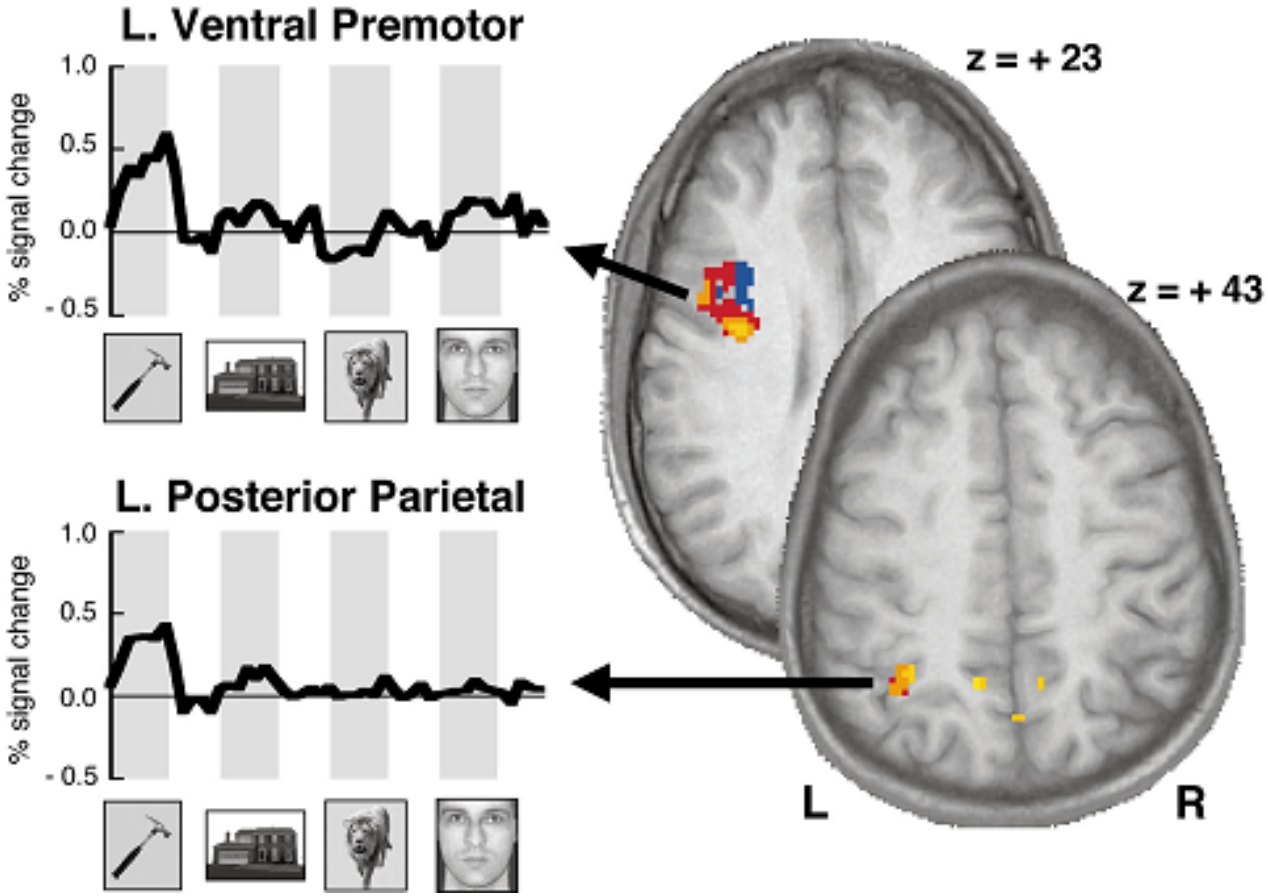
note, while interesting, Penfield's success rate was about 8%


SPL
IPS
FEF
DO
DLPFC
P. MFG
ITG
L
R
p <
10 -10
10 -20
10 -30


encoding + maintenance + retrieval
retrieval
maintenance
encoding


A Animals — tools
Coronal
Sagittal
Transverse
L
R

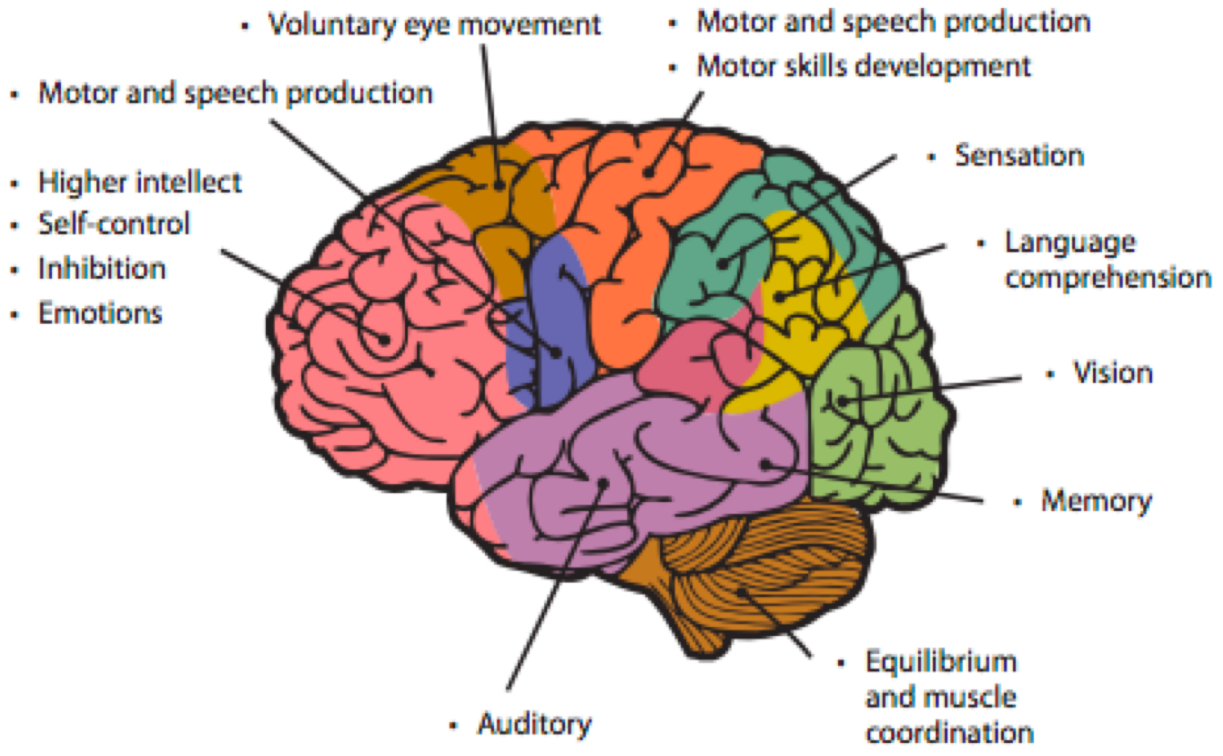

B Tools — animals
Coronal
Sagittal
Transverse
L
R

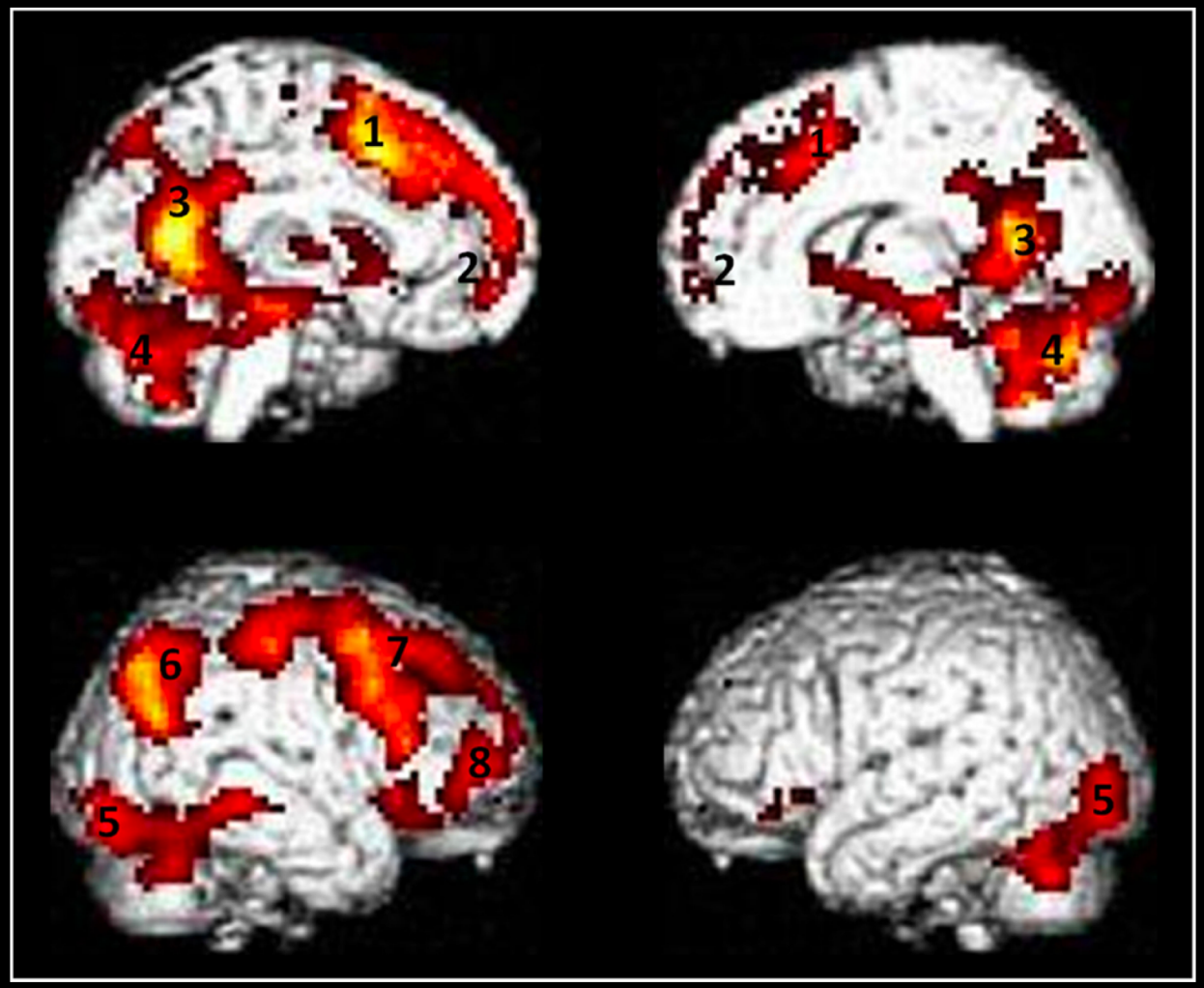

L. Ventral Premotor
% signal change
1.0
0.5
0.0
- 0.5
L. Posterior Parietal
% signal change
1.0
0.5
0.0
- 0.5
z = + 23
z = + 43
L
R

Memories are distributed

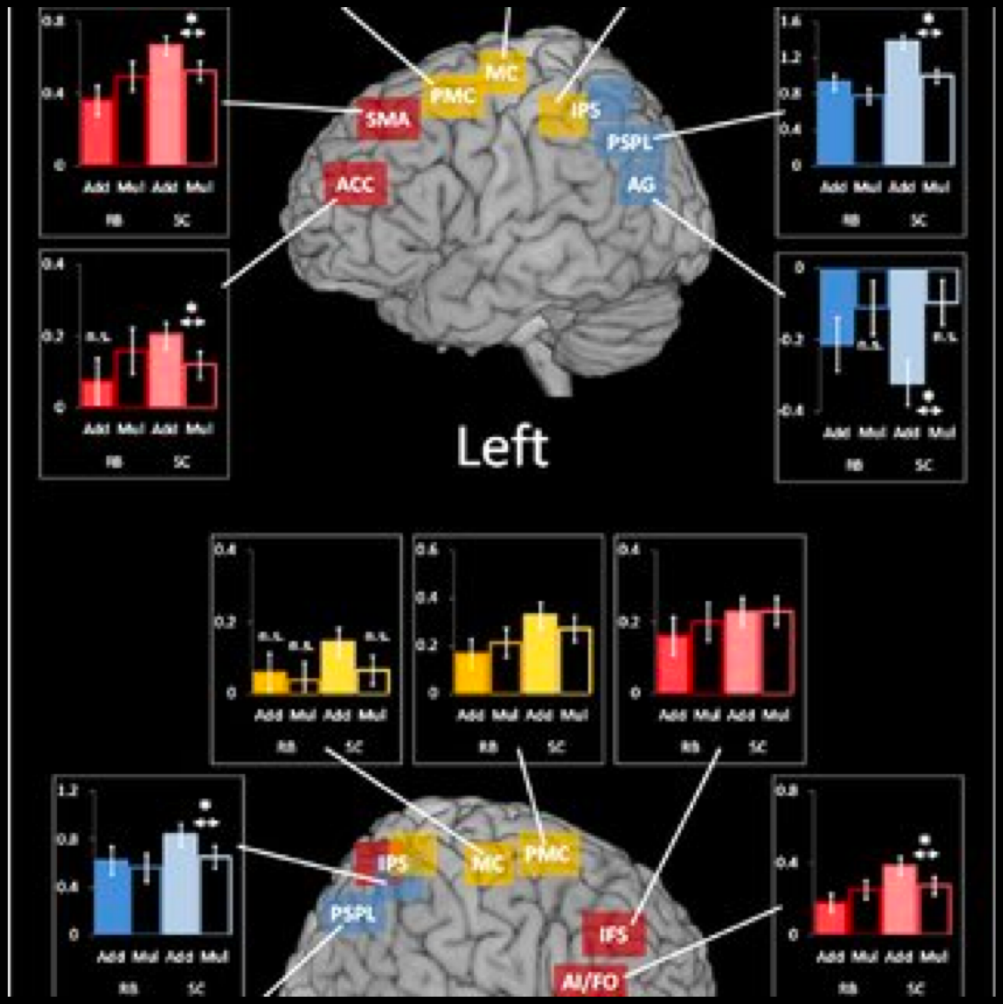
Functional areas of the brain

This illustration shows the brain's functional areas. After a stroke, deficits in function depend on which cerebral artery is affected.



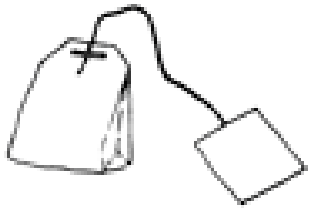
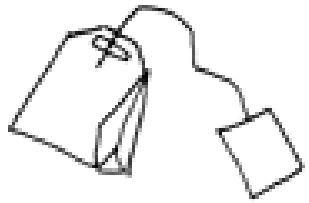


Episodic Memory

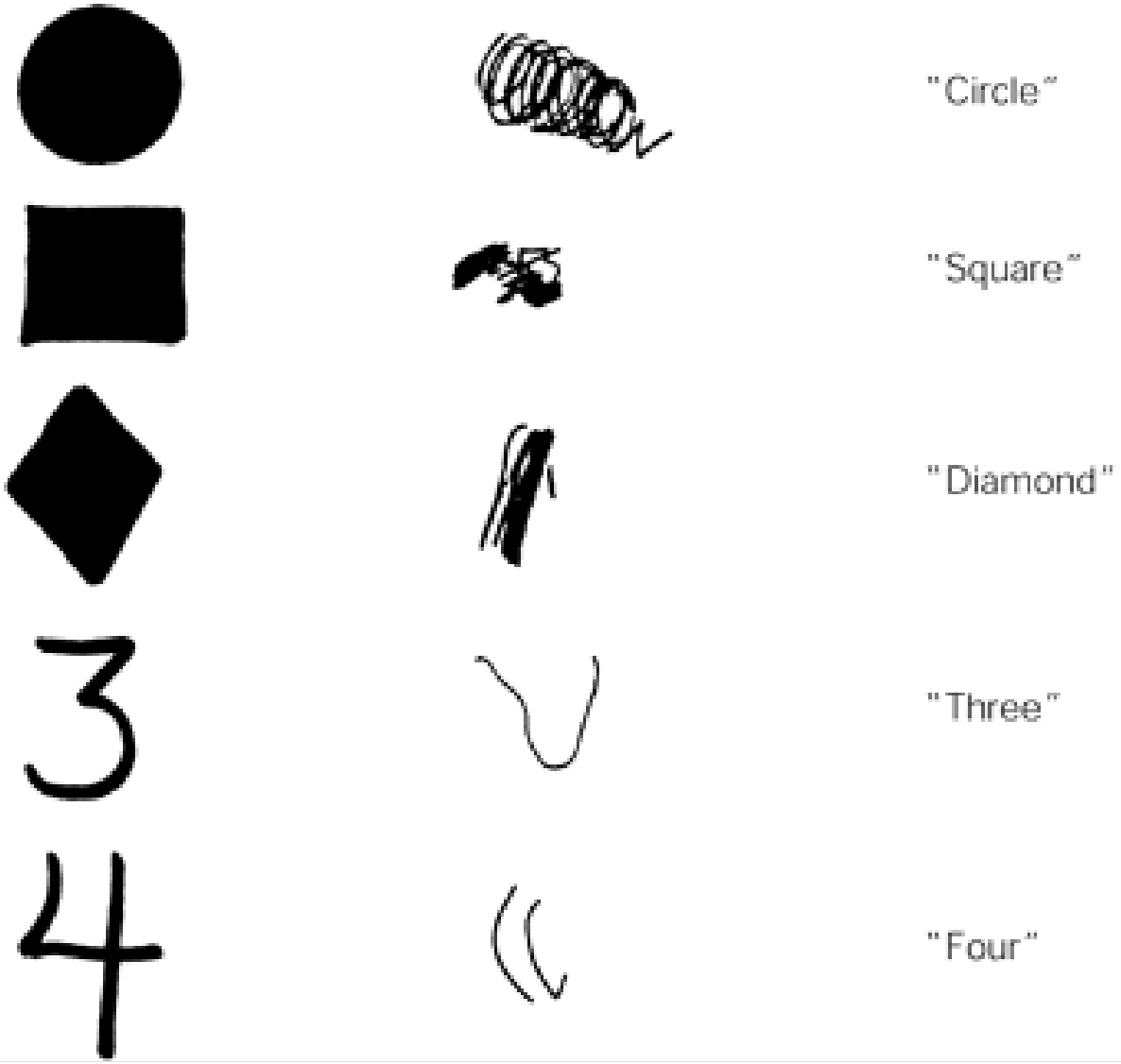


Procedural Memory

A Associative agnosia

	Model drawing	Patient´s drawing	Verbal identification of object
			—
			—
			—

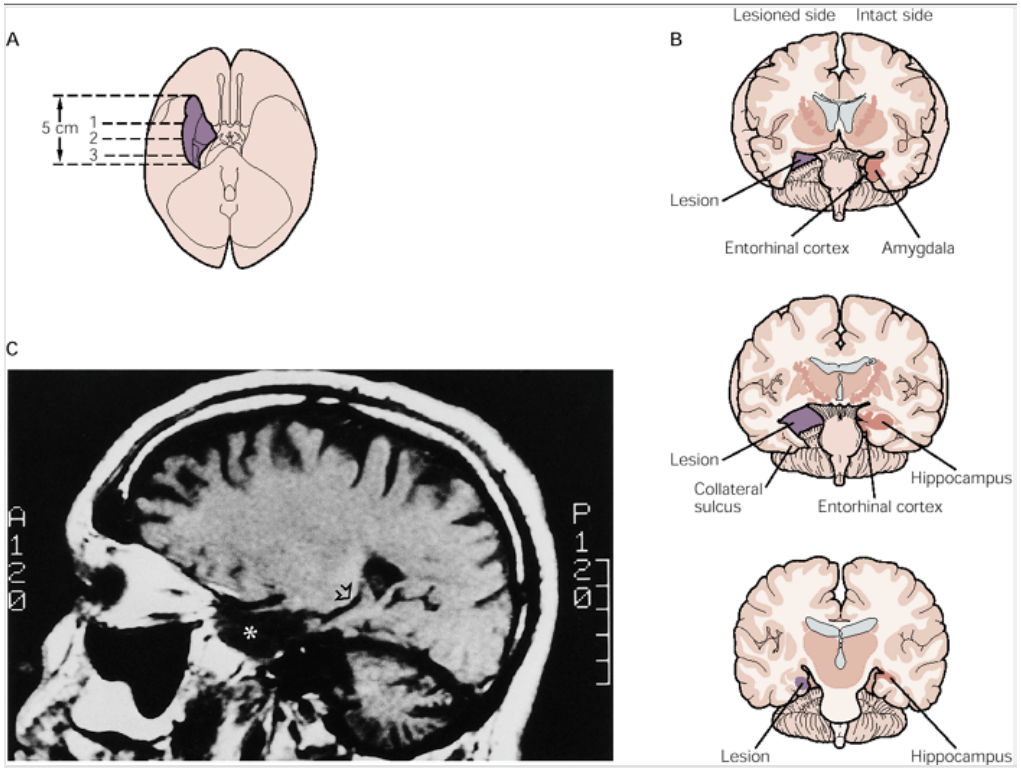
B Apperceptive agnosia



The Hippocampus

HM

surgery to remove portions of the hippocampus, amygdala, and multimodal association area (bilaterally) to treat seizure



HM

surgery to remove portions of the hippocampus, amygdala, and multimodal association area (bilaterally) to treat seizure

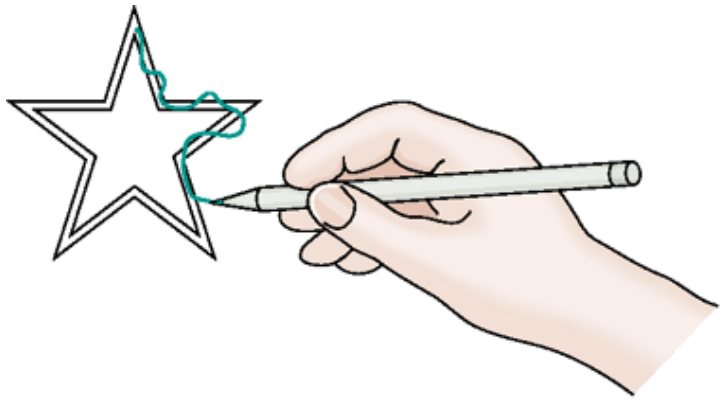
HM

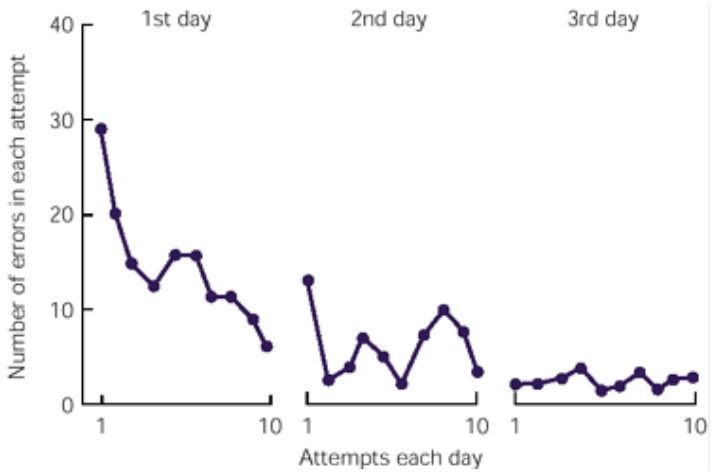
If you told HM to repeat the number 765382 over and over, he could do it.

But, if you distracted him for a minute then asked him the number? He could not.

HM also did not recall people who had visited his house on a regular basis.

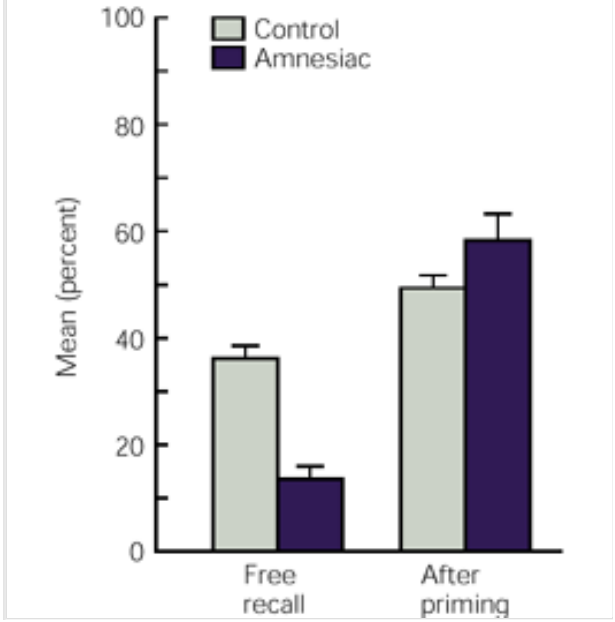
But…



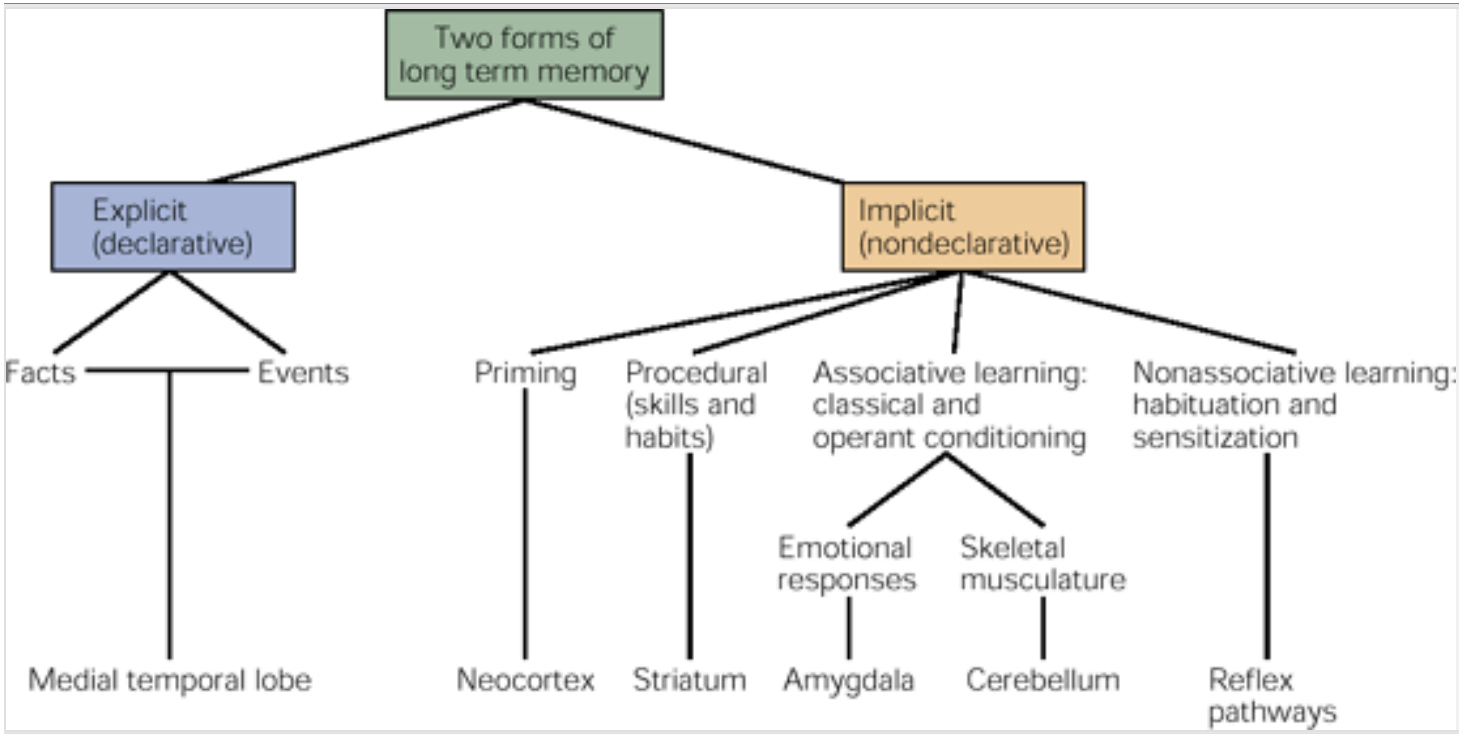


What does this mean?

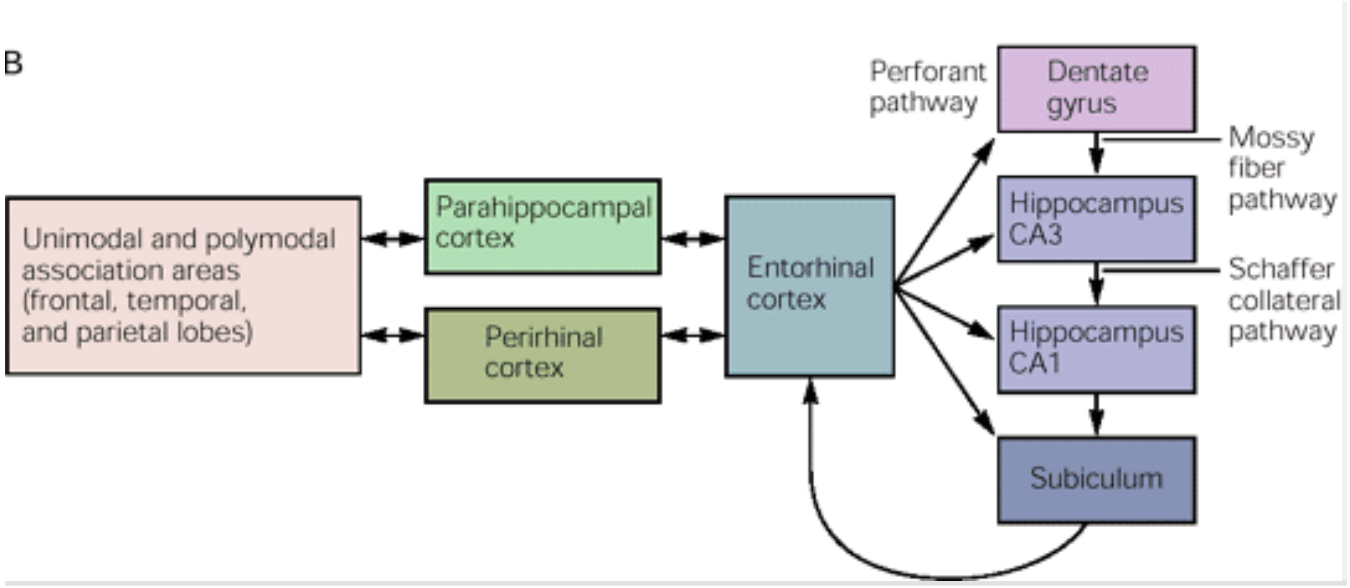
ABSENT	ABS _____
INCOME	INC _____
FILLY	FIL _____
DISCUSS	DIS _____
CHEESE	CHE _____
ELEMENT	ELE _____

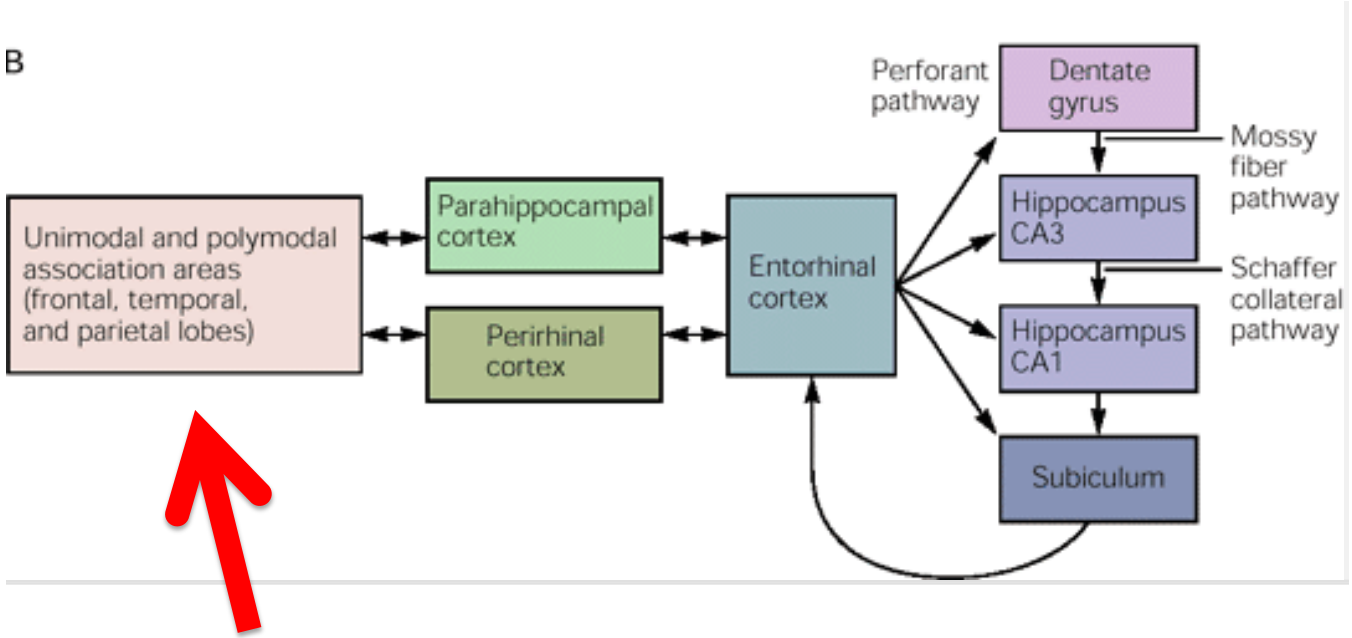


And what about this?


Two forms of long term memory
Explicit (declarative)
Implicit (nondeclarative)
Facts
Events
Priming
Procedural (skills and habits)
Associative learning: classical and operant conditioning
Nonassociative learning: habituation and sensitization
Emotional responses
Skeletal musculature
Medial temporal lobe
Neocortex
Striatum
Amygdala
Cerebellum
Reflex pathways

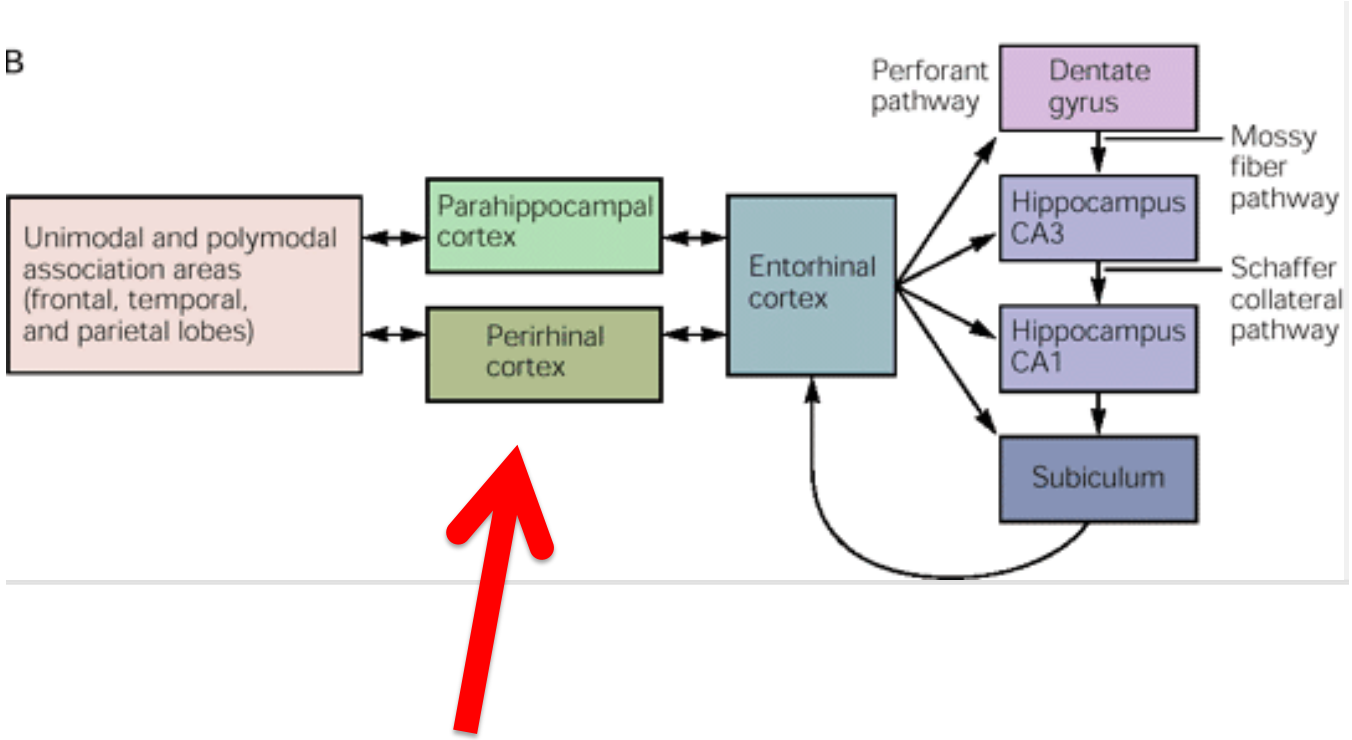
We know from HM and studies in monkey that the hippocampus plays a key role in explicit memory formation





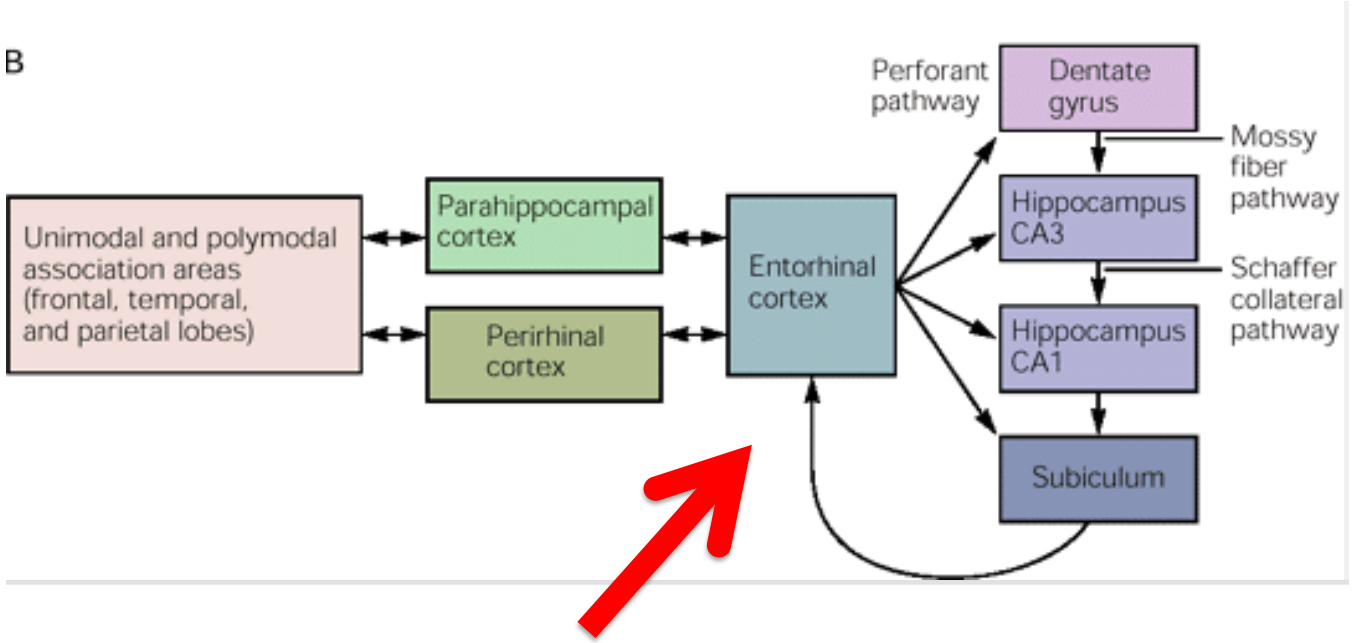
Stage 1. Processing

Synthesis of visual, auditory, and somatosensory information



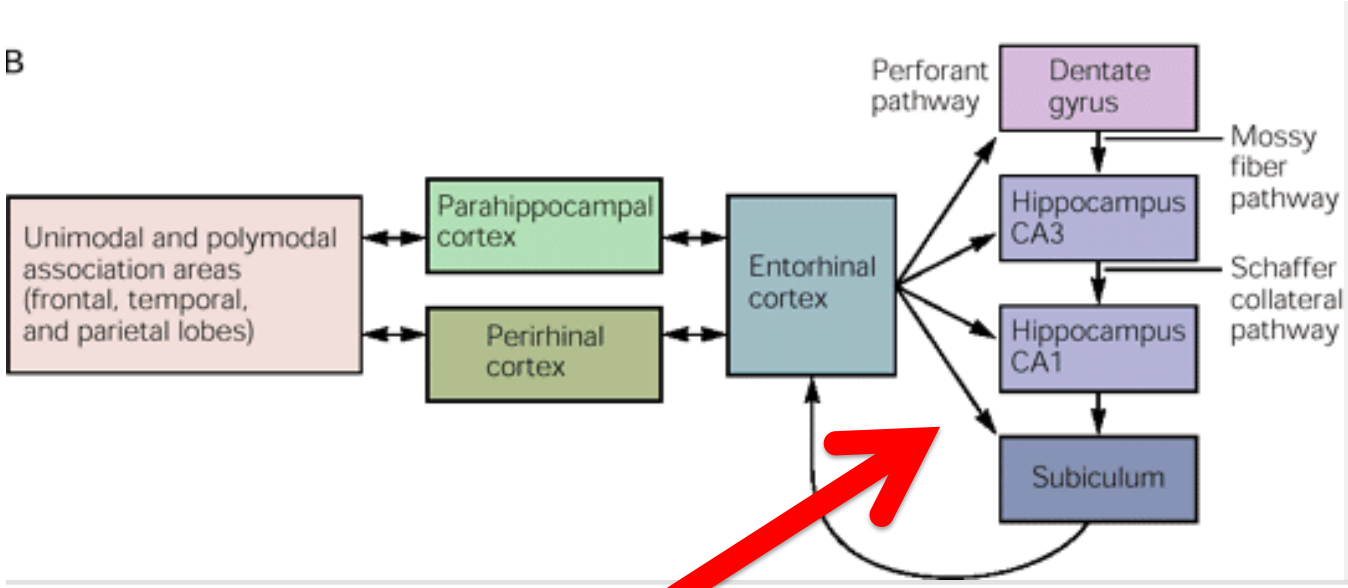
Stage 2. Transfer

But damage here can impair memory storage



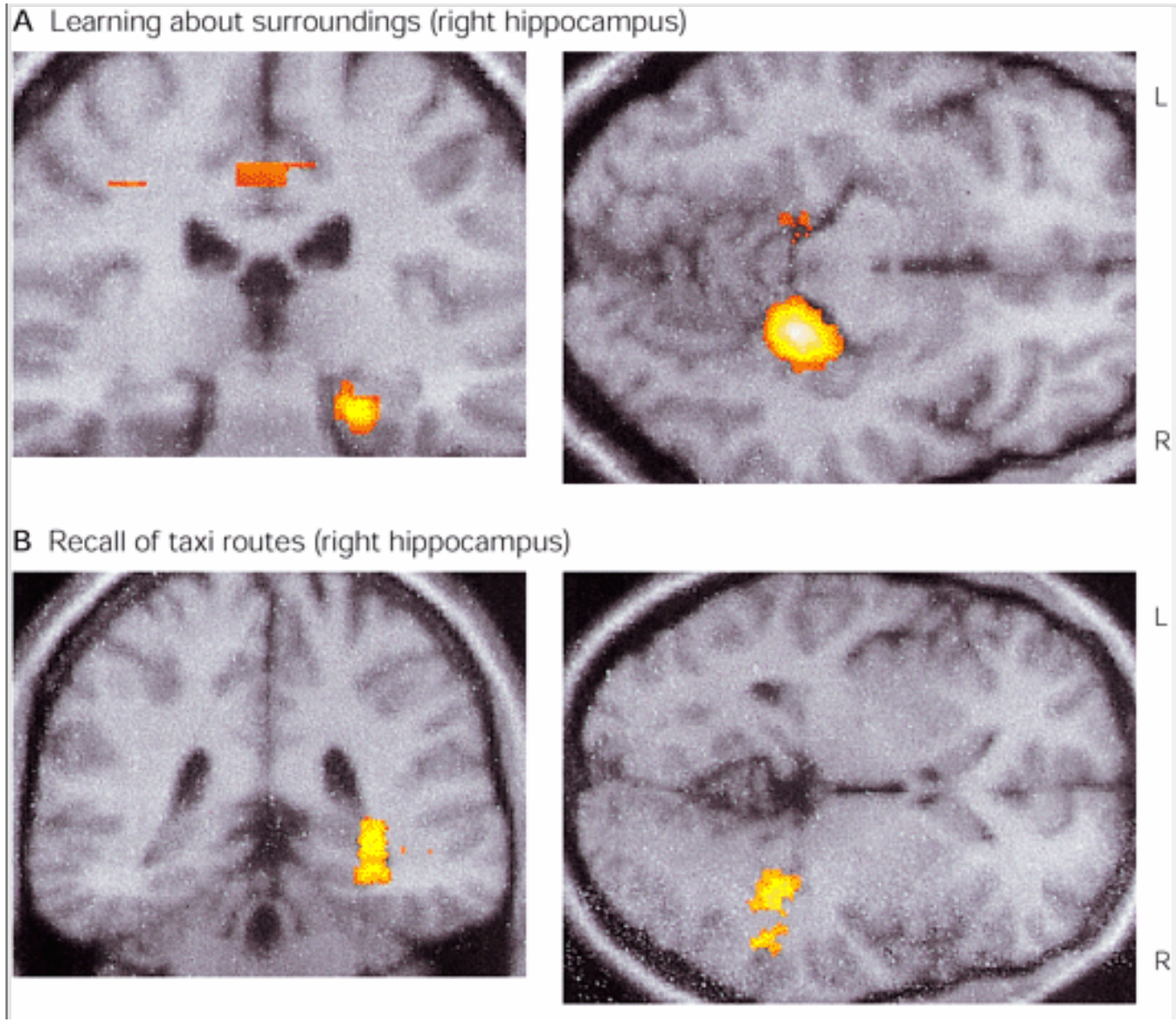
Stage 3.
Gateway

Input to the Hippocampus
(Alzheimer's targets this region)

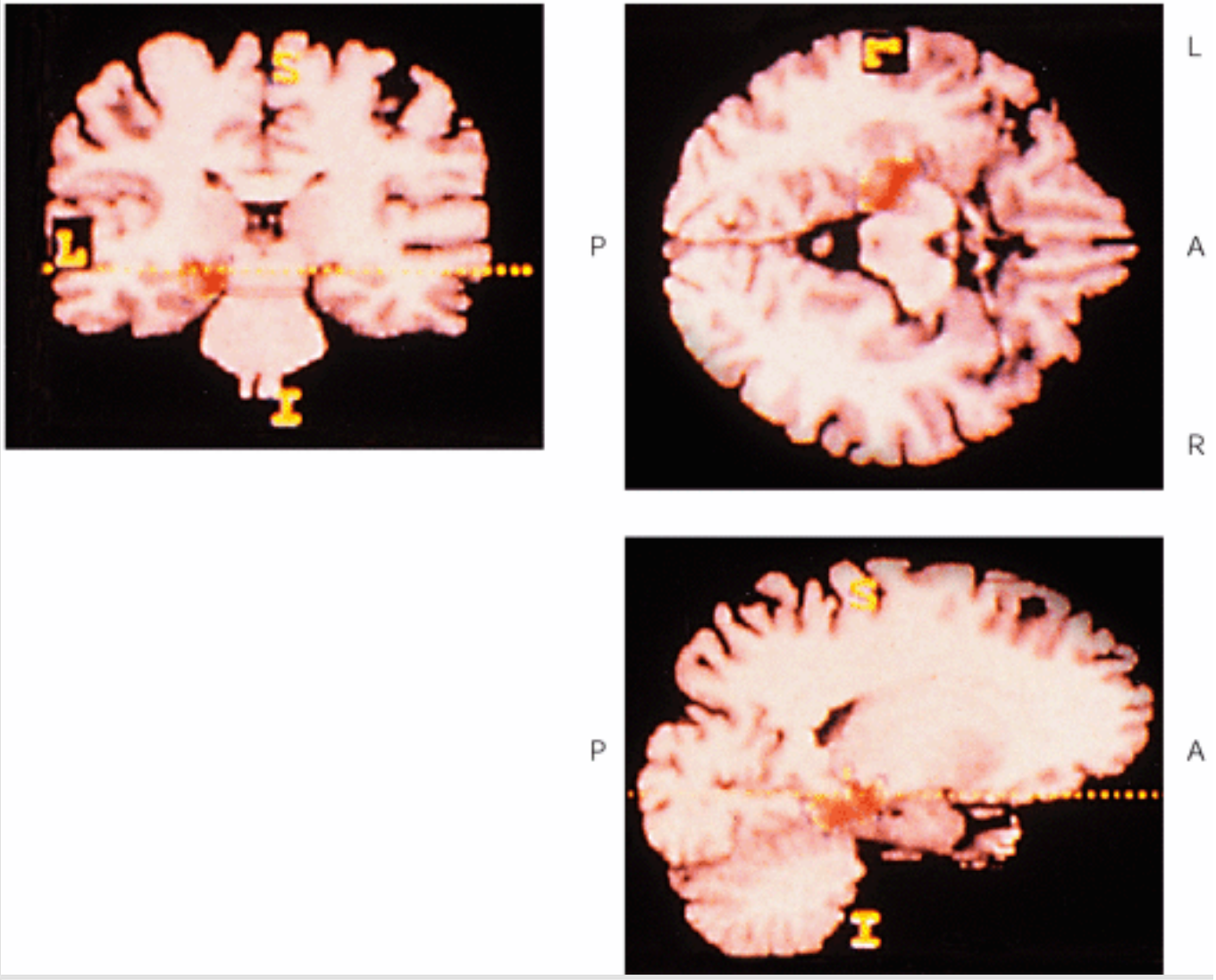


Stage 4. Hippocampus

- right hippocampus = spatial
- left hippocampus = verbal
- RB, damage to CA1 brought about similar symptoms to HM


A Learning about surroundings (right hippocampus)
L
R
B Recall of taxi routes (right hippocampus)
L
R

C Word recall (left hippocampus)



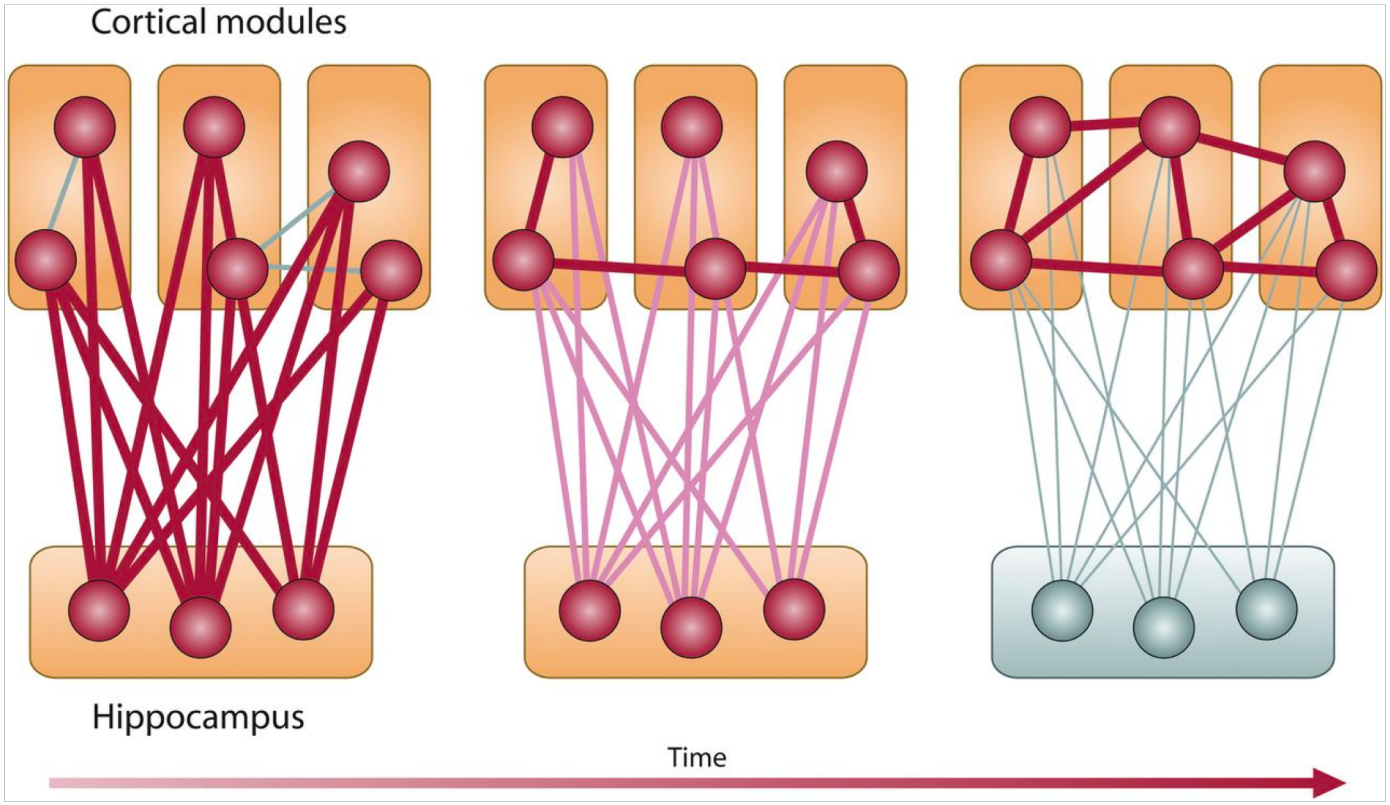
Explicit Information is Stored in the Association Cortices (Distribution!)

HM and RB for instance had no trouble in recalling childhood memories in great detail

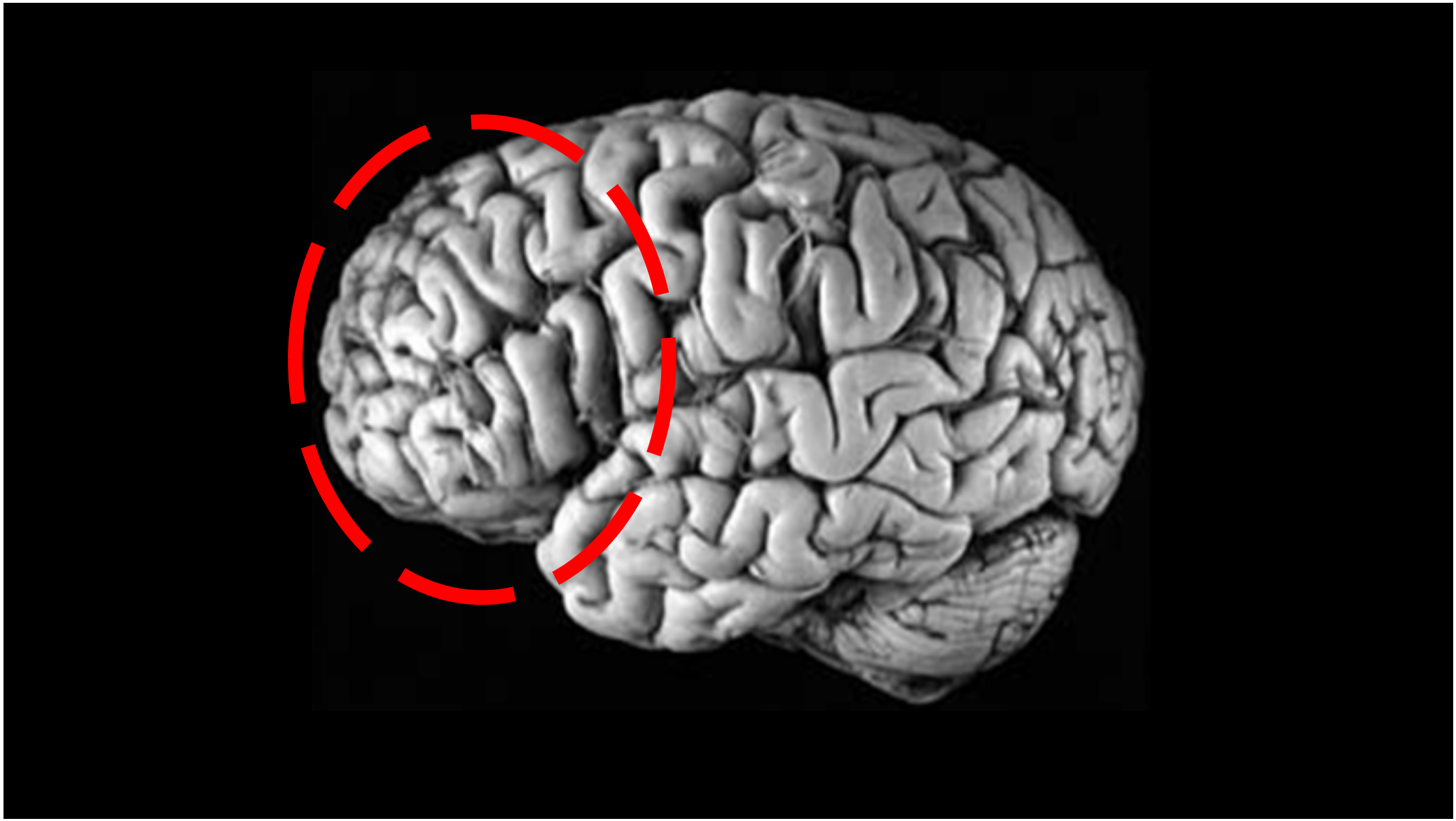
So what is actually happening when we see a face…

1) initial processing
2) hippocampus helps to begin long term formation
3) over time, the transfer is completely to the association areas
4) thus, damage to an association area should impair long term memories

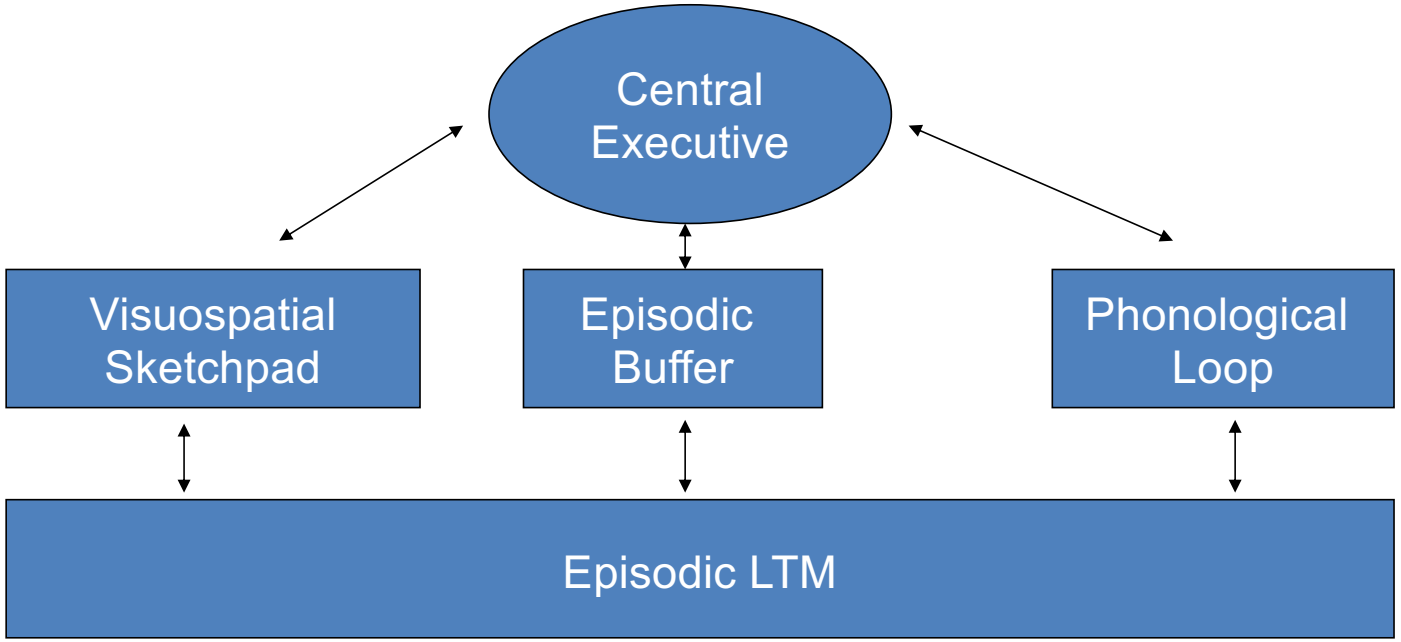
Consolidation



Prefrontal Cortex



4-Component Model of Working Memory



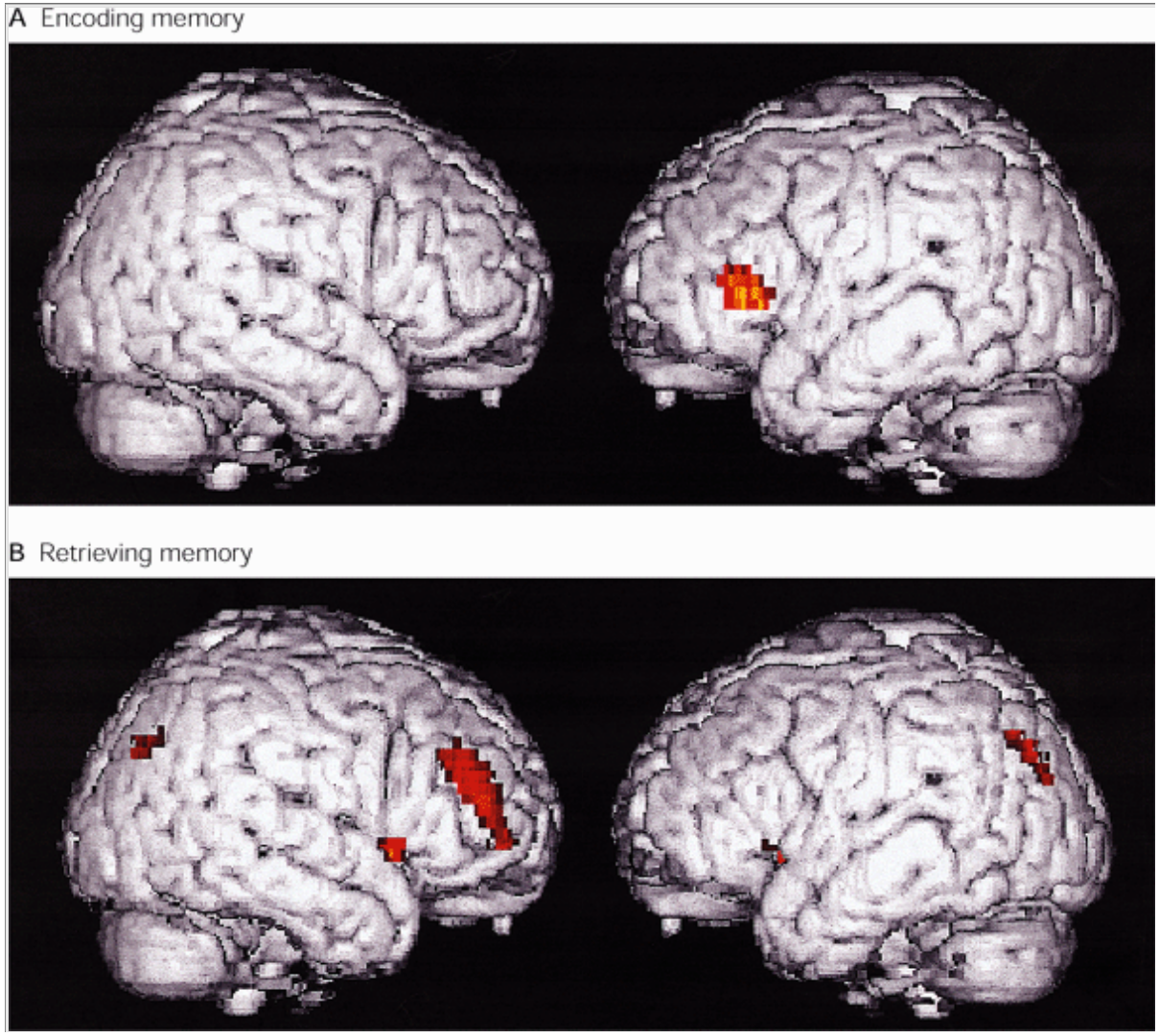
Explicit Memory Formation

Encoding

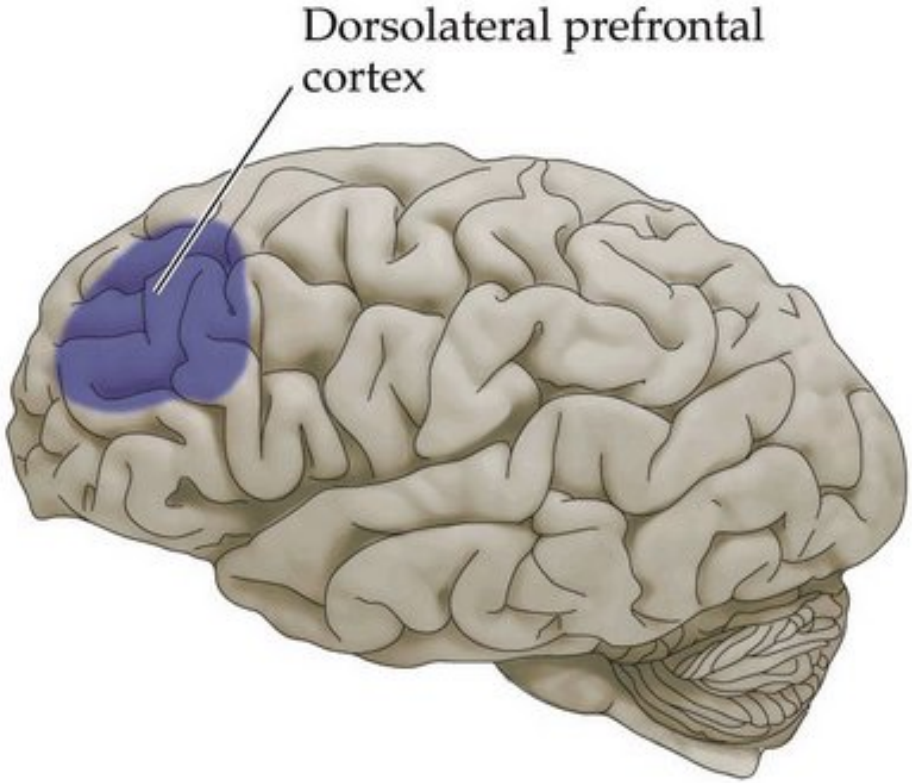
Consolidation

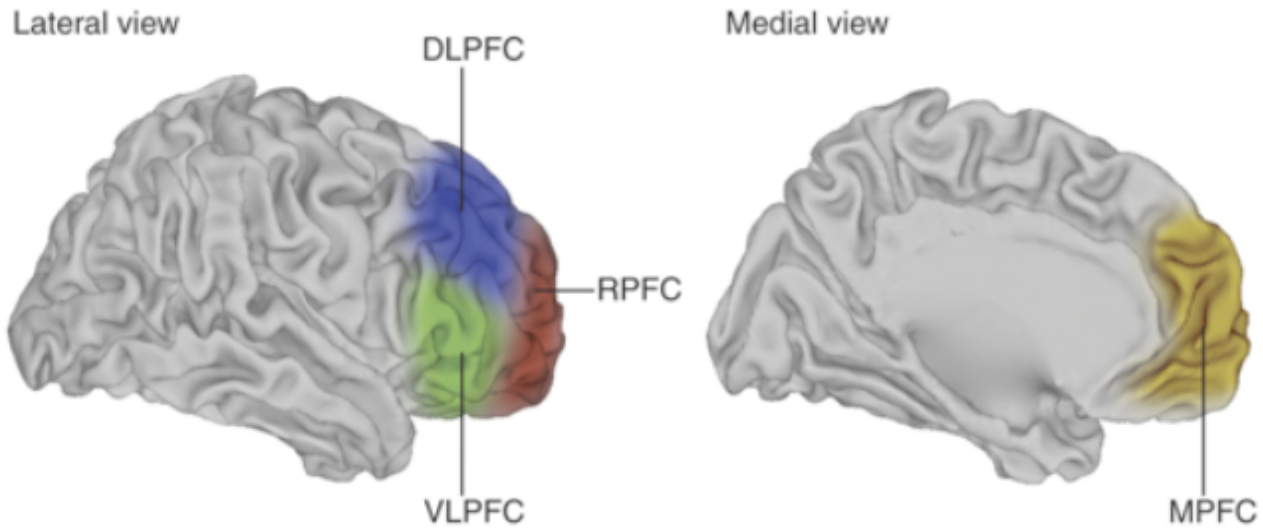
Storage

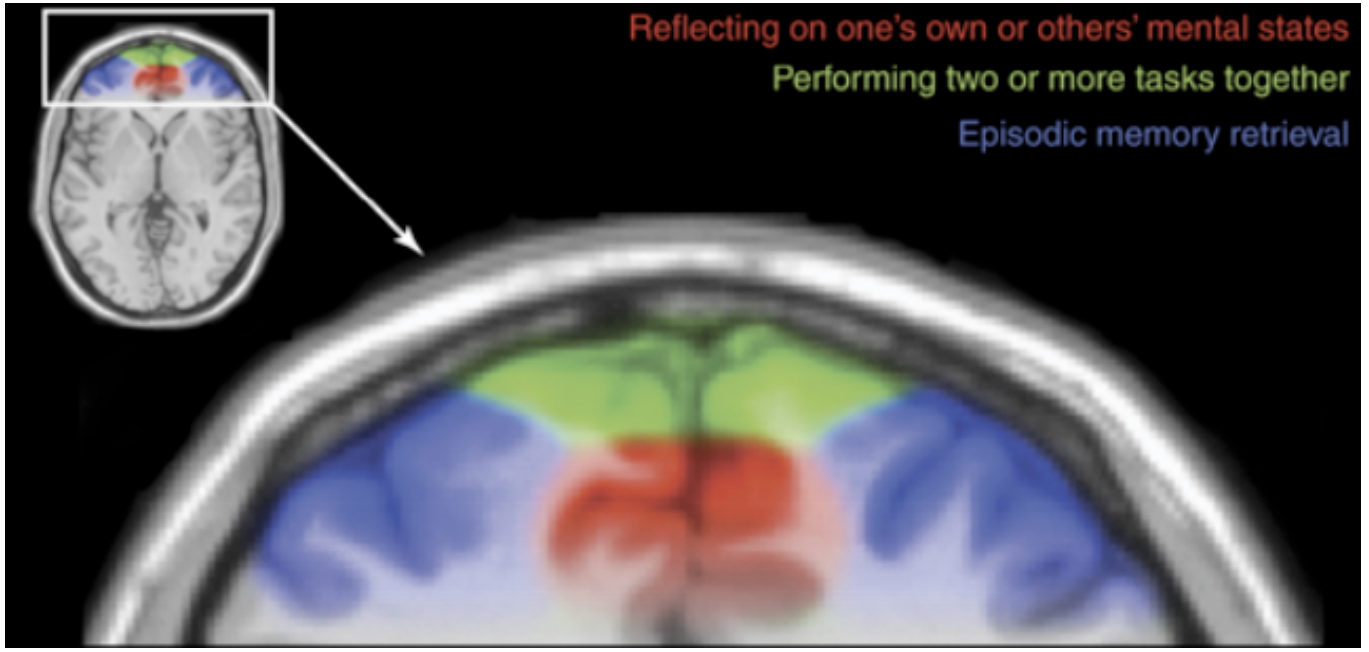
Retrieval


A Encoding memory
B Retrieving memory

Orbitofrontal Cortex


Dorsolateral prefrontal
cortex


Lateral view
DLPFC
RPFC
VLPFC
Medial view
MPFC


Reflecting on one's own or others' mental states
Performing two or more tasks together
Episodic memory retrieval

Phineas Gage

Dr. P. was a successful middle-aged surgeon who used the financial rewards of his practice to pursue his passion for traveling and playing sports. Tragically, while he was undergoing minor facial surgery, complications caused his brain to be deprived of oxygen for a short period. The ensuing brain damage had profound negative consequences on his mental functioning, compromising his ability to plan, to adapt to change, and to act independently.

After the surgery, standard IQ tests revealed Dr. P.'s intelligence to be, for the most part, in the superior range. Yet, he could not handle many simple day-to-day activities and was unable to appreciate the *nature of his deficits*. His dysfunction was so severe that not only was returning to work as a surgeon impossible for him, but in addition his brother had to be appointed his legal guardian. As a surgeon, Dr. P. had skillfully juggled many competing demands and had flexibly adjusted to changing situations. Now, however, he was unable to carry out all but the most basic routines and then only in a rigid, routinized manner. Furthermore, he had lost his ability to initiate actions and to plan for the future. For example, his sister-in-law had to tell him to change his clothes, and only after years of explicit rule-setting did he learn to do so on his own. He managed to work as a delivery truck driver for his brother's business, but only because his brother could structure the deliveries so that they involved minimal planning. Dr. P. could not be provided with an itinerary for the deliveries of the day because he was incapable of advance planning. Rather, his brother would give him information about one delivery at a time. After each delivery, Dr. P. would call in for directions to the next stop.

Dr. P. also was totally unaware of his situation. He seemed unconcerned and uninterested in how he was provided with the basic necessities of life, such as clothes, food, and lodging, and was totally complacent about being a ward of his brother and sister-in-law. Formerly an outgoing man, he now spoke in a monotone and expressed little emotion. He did not initiate any activities or ask questions about his existence, being content to spend his free time watching television. ■

Tower of London Task

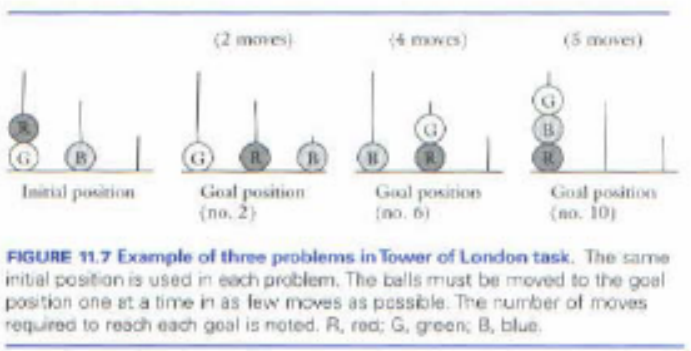


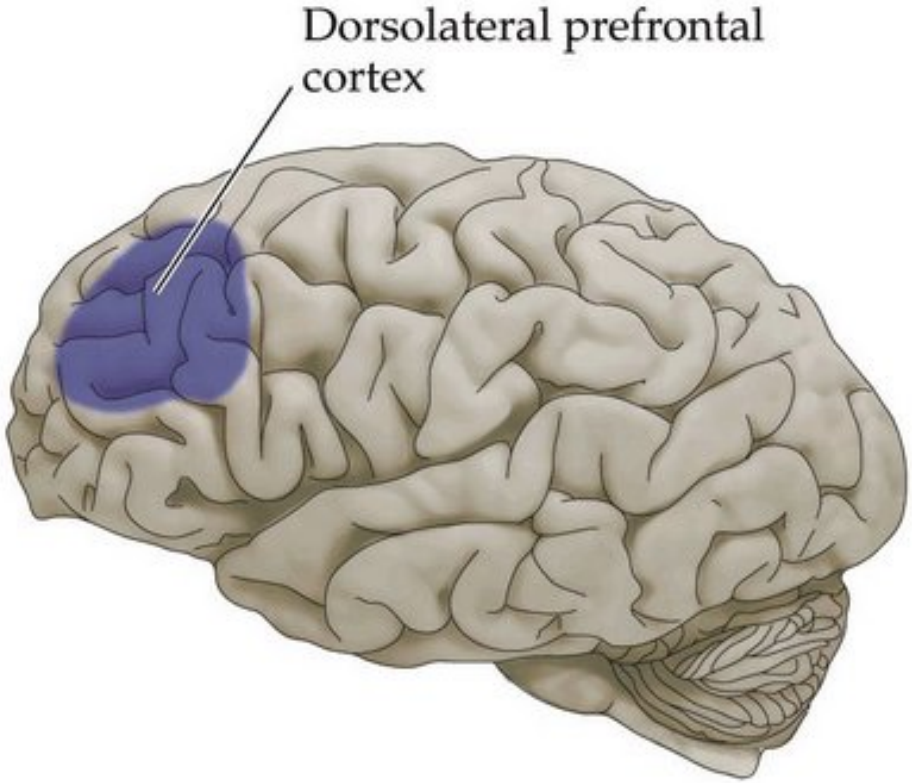
FIGURE 11.7 Example of three problems in Tower of London task. The same initial position is used in each problem. The balls must be moved to the goal position one at a time in as few moves as possible. The number of moves required to reach each goal is noted. R, red; G, green; B, blue.

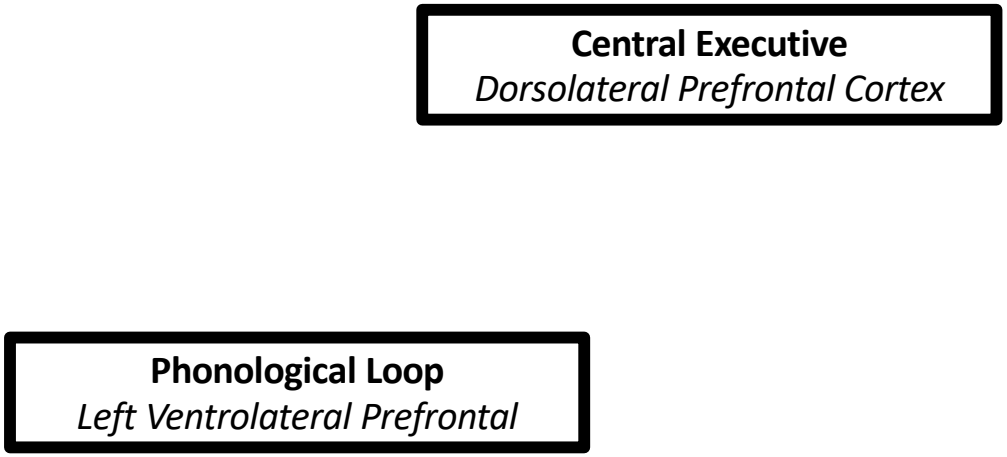
- **Tower of London** task requires planning to reach a goal
- People with dorsolateral prefrontal cortex damage do poorly at the task, because they make aimless moves that are not directed toward the goal
- Functional neuroimaging studies show that DLPFC is activated in this task, and that this area is most activated in those individuals who solve the task in the fewest number of moves

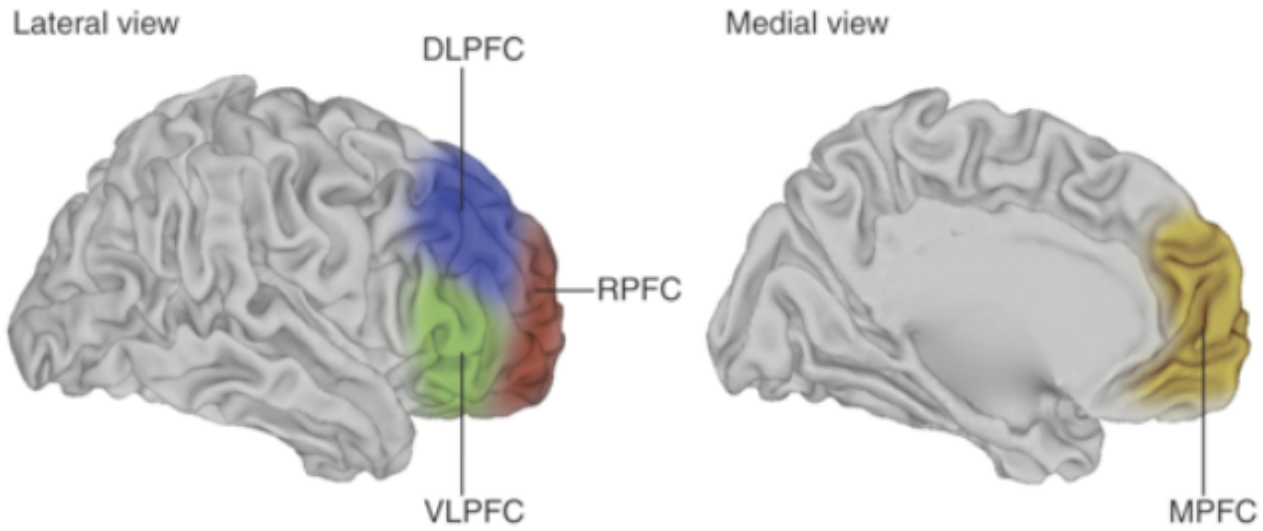
Working Memory

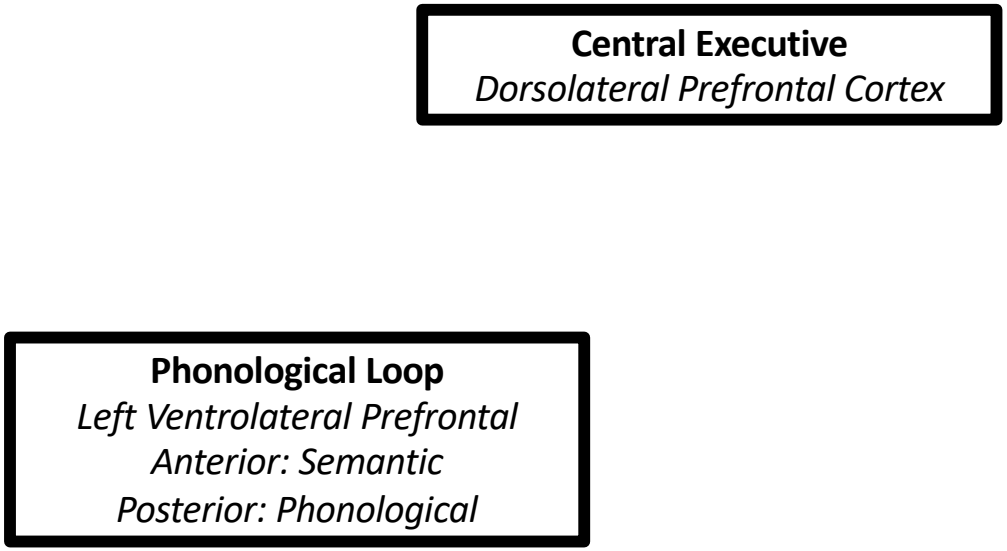
- DLPFC is implicated in working memory in both monkeys and humans
- Sensory areas are also implicated in working memory in both monkeys and humans
- Working memory is an ACTIVE process
- Domain-specificity of responses

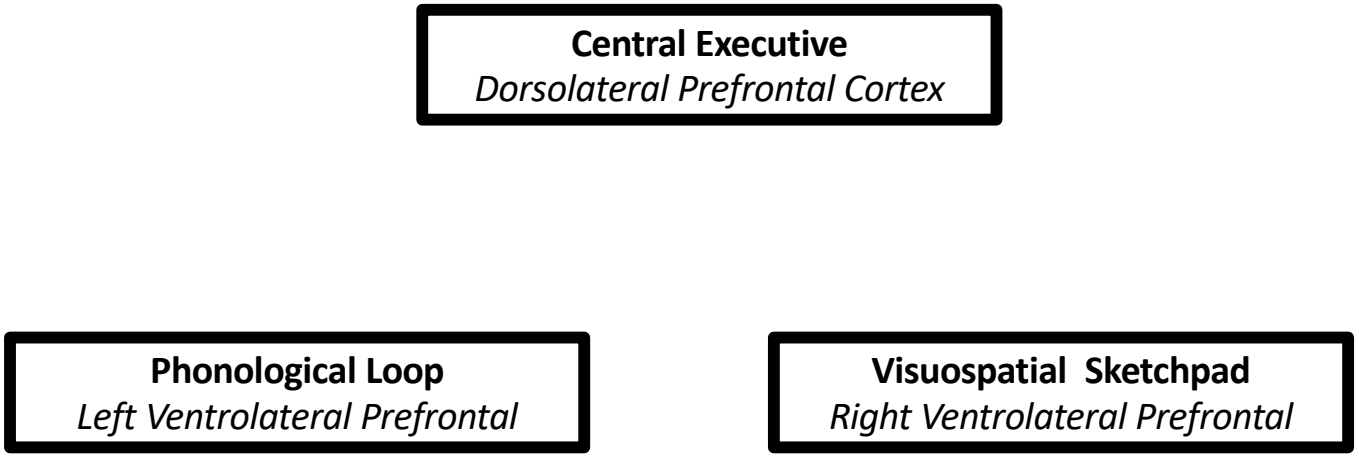
Central Executive
Dorsolateral Prefrontal Cortex


Dorsolateral prefrontal
cortex


Central Executive
Dorsolateral Prefrontal Cortex
Phonological Loop
Left Ventrolateral Prefrontal

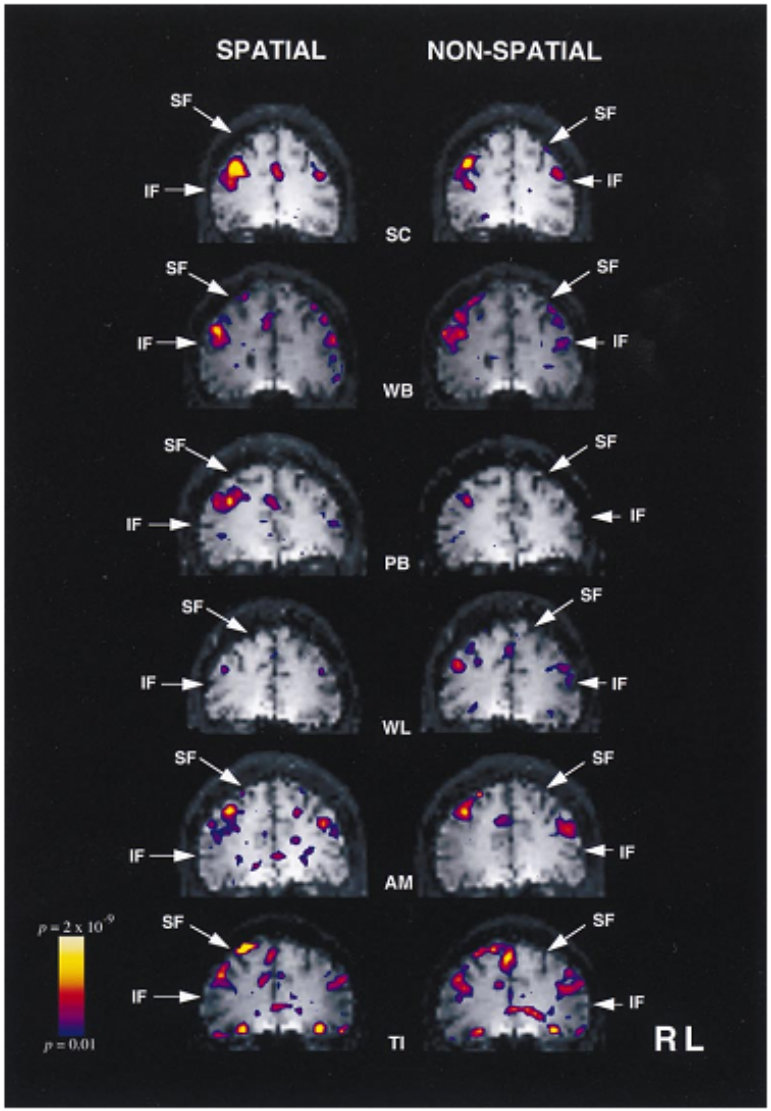

Lateral view
DLPFC
RPFC
VLPFC
Medial view
MPFC


Central Executive
Dorsolateral Prefrontal Cortex
Phonological Loop
Left Ventrolateral Prefrontal
Anterior: Semantic
Posterior: Phonological


Central Executive
Dorsolateral Prefrontal Cortex
Phonological Loop
Left Ventrolateral Prefrontal
Visuospatial Sketchpad
Right Ventrolateral Prefrontal

Functional organization of spatial and nonspatial working memory processing within the human lateral frontal cortex

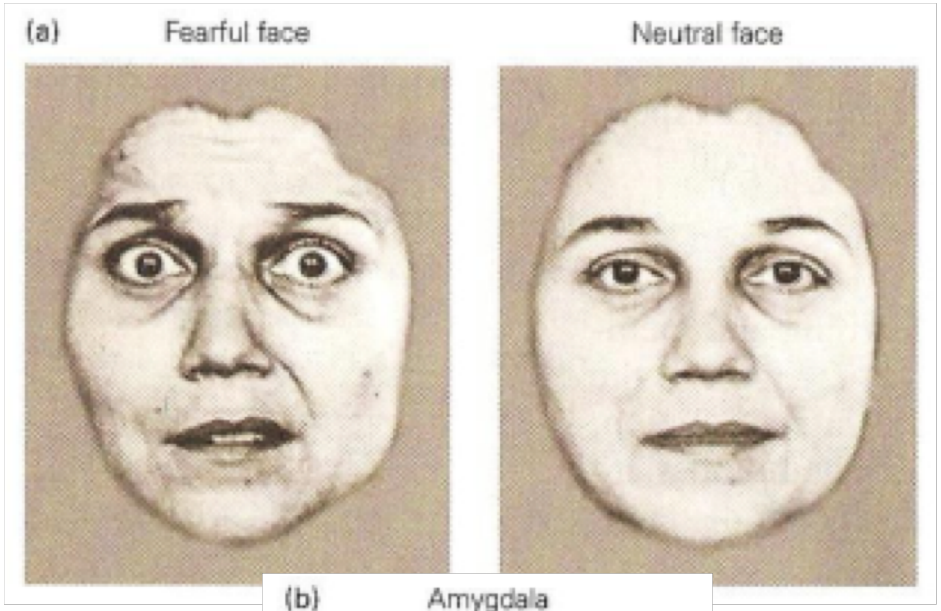
Adrian M. Owen*†‡, Chantal E. Stern§, Rodney B. Look§, Irene Tracey§, Bruce R. Rosen§, and Michael Petrides†

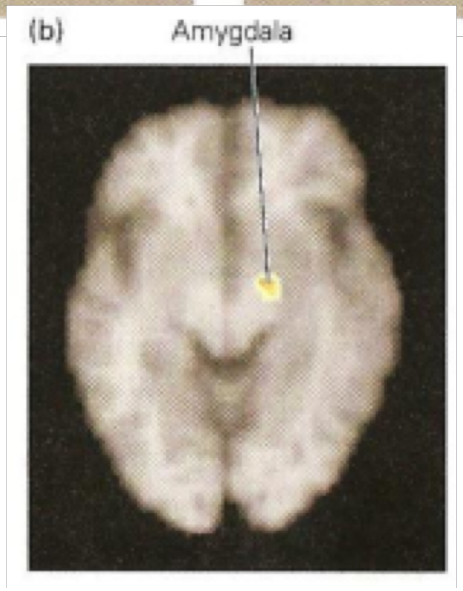

SPATIAL
NON-SPATIAL
SF
IF
SC
WB
PB
WL
AM
TI
p = 2 x 10^-9
p = 0.01
R L

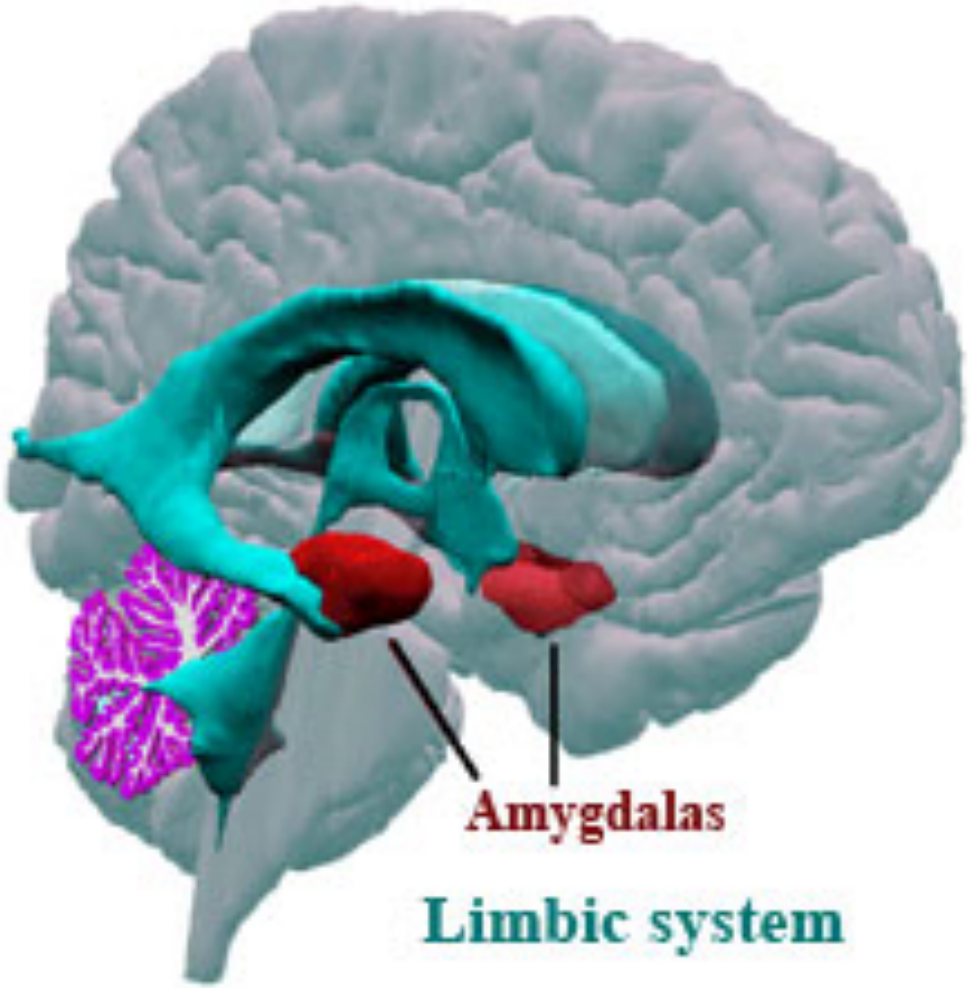
How is Information in WM Anatomically Organized?

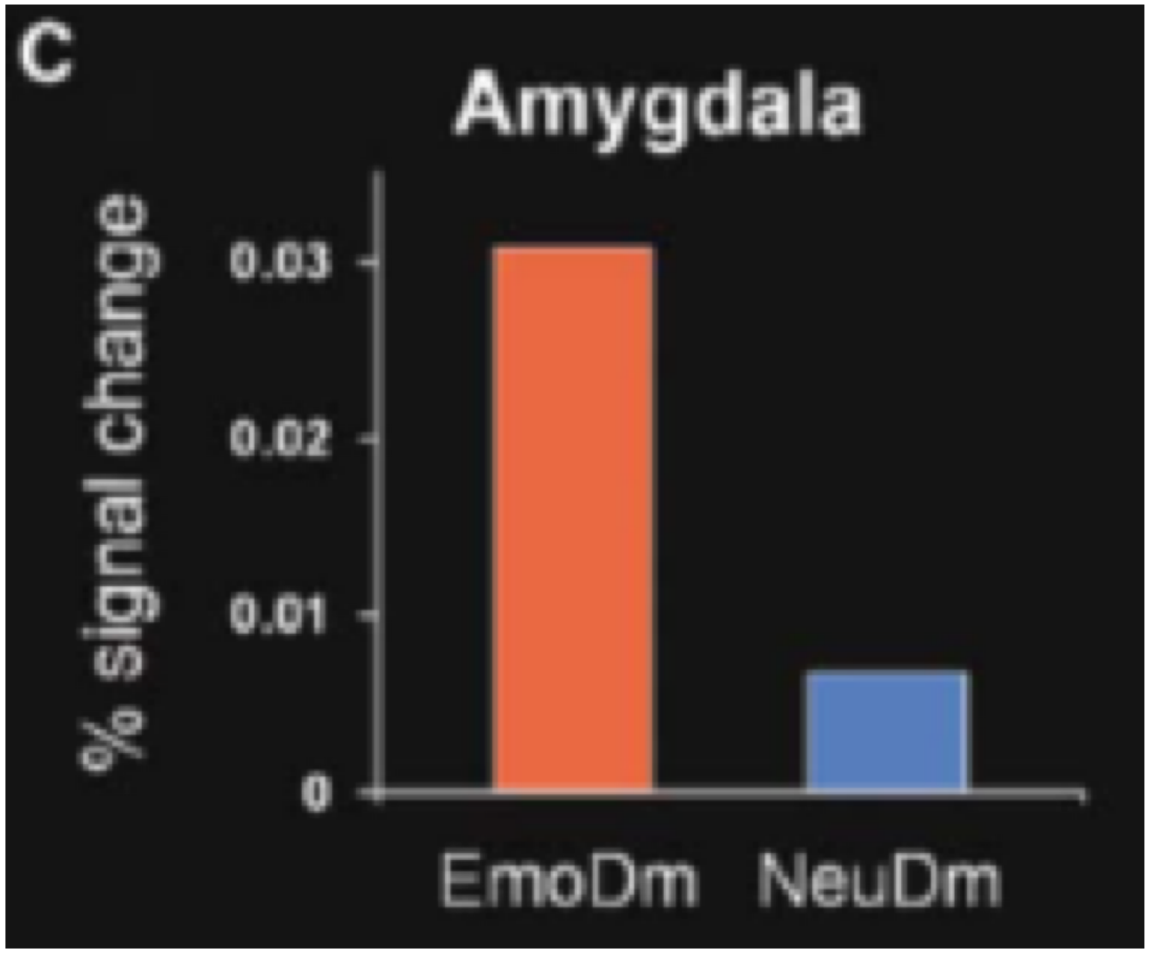
- Agreement that ventral and dorsal PFC are involved in different aspects of WM.
  - Theory(1) WM in PFC is organized according to the type of information being stored or rehearsed
  - Theory(2) WM in PFC is organized according to the operations being performed

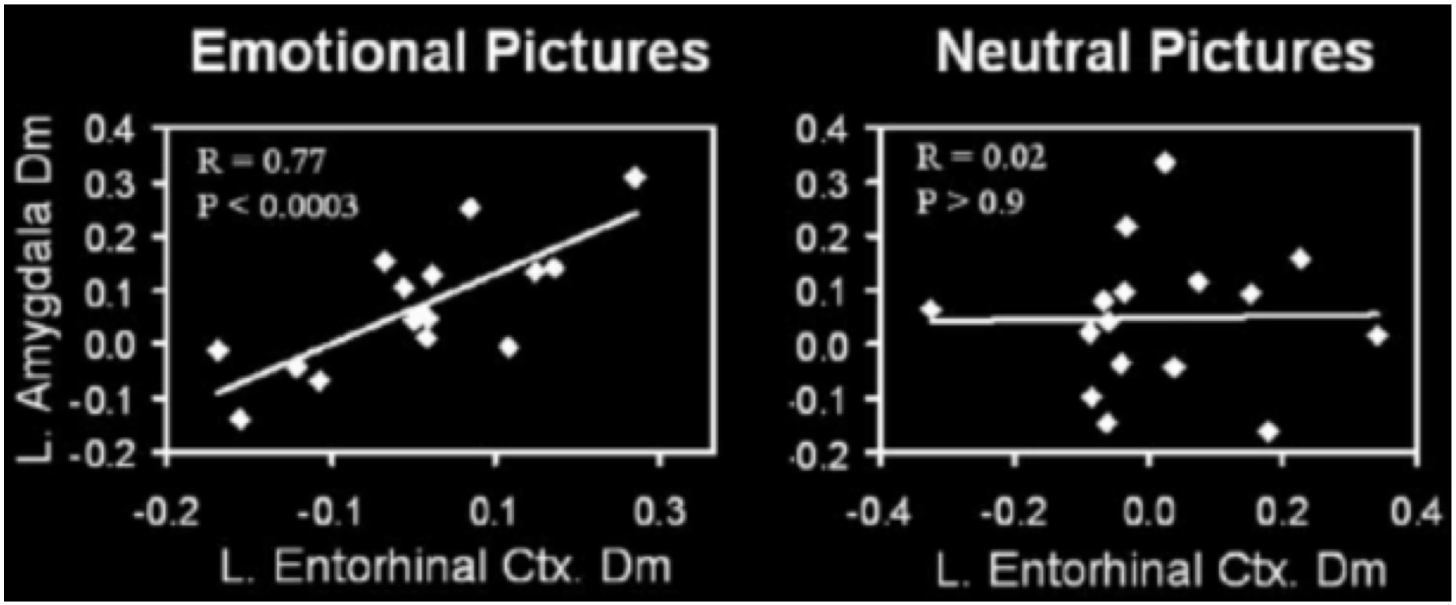
The Amygdala


(a)
Fearful face
Neutral face


(b)
Amygdala


Amygdalas
Limbic system


C
Amygdala
% signal change
0.03
0.02
0.01
0
EmoDm
NeuDm


Emotional Pictures
Neutral Pictures
L. Amygdala Dm
R = 0.77
P < 0.0003
R = 0.02
P > 0.9
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.4
-0.2
0.1
0.3
0.0
0.2
0.4
L. Entorhinal Ctx. Dm
L. Entorhinal Ctx. Dm

1. A mother and her son are leaving home in the morning.

2. She is taking him to visit his father's workplace.

3. The father is the chief laboratory technician at a nearby hospital.

4. They check before crossing a busy road.

5. While crossing the road, the boy is struck by a runaway car, which critically injures him.

5. While walking along, they pass the scene of a minor accident, which the boy finds interesting.

6. At the hospital, the staff prepares the emergency room, to which the boy is rushed.

6. At the hospital, the staff are preparing for a practice disaster drill, which the boy will watch.

7. All morning long, surgeons struggled to save the boy's life.

7. All morning long, surgeons practiced the standard disaster drill procedures.

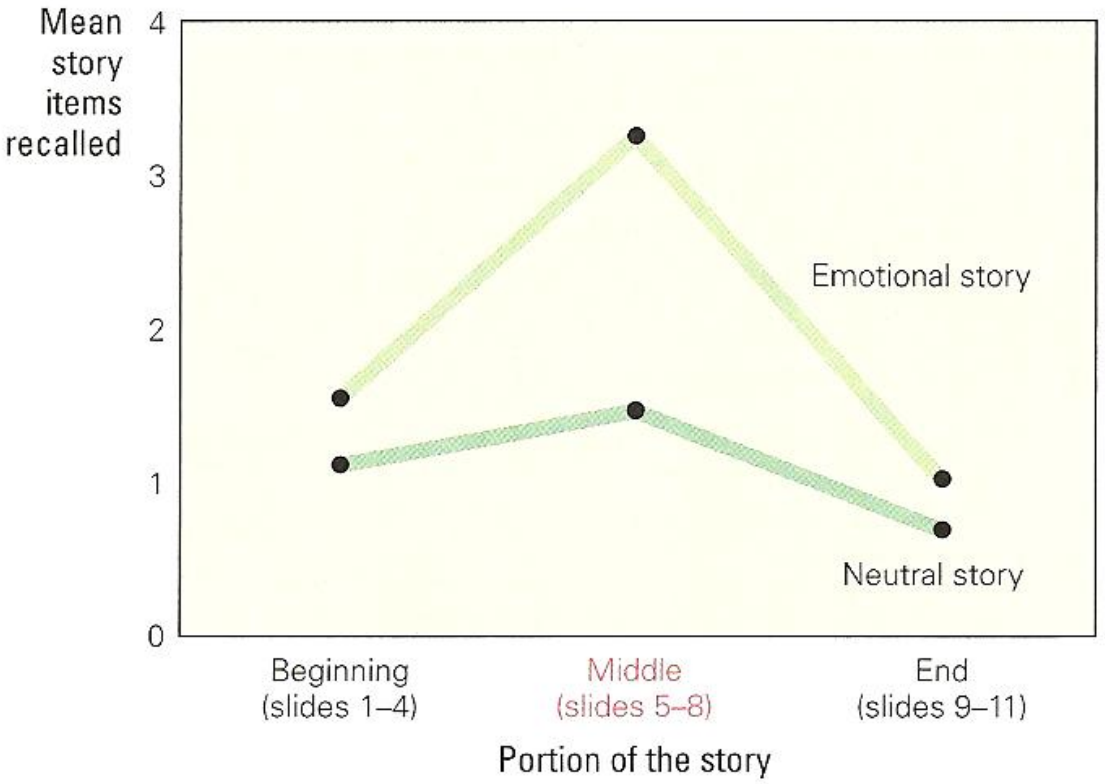
8. Specialized surgeons were able to successfully reattach the boy's severed feet.

8. Special make-up artists were able to create realistic-looking injuries on actors for the drill.

9. Afterward, while the father stayed with the boy, the mother left to phone her other child's preschool.

10. She phones the preschool to tell them she will soon pick up her child.

11. Heading to pick up her child, she hails a taxi at the number 9 bus stop.


Mean story items recalled
4
3
2
1
0
Emotional story
Neutral story
Beginning (slides 1–4)
Middle (slides 5–8)
End (slides 9–11)
Portion of the story

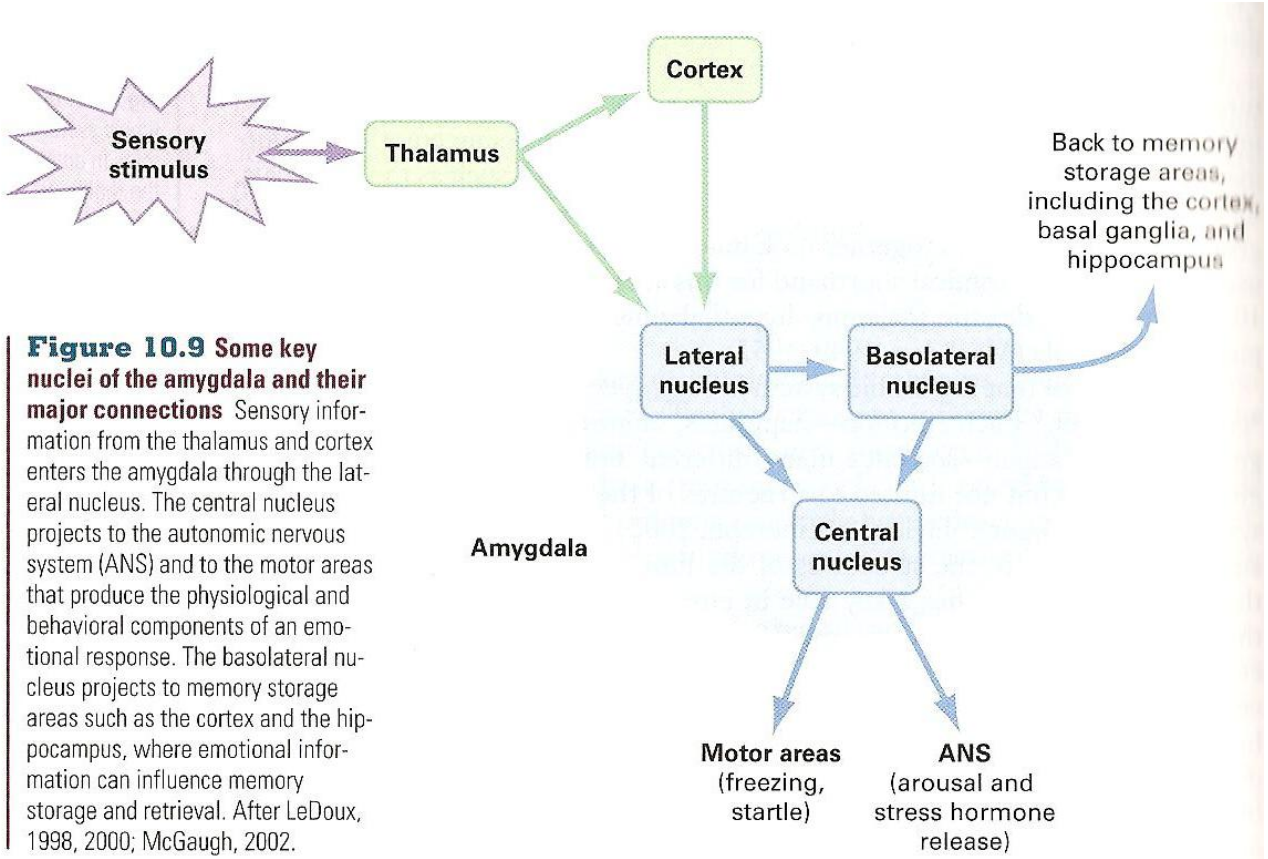


Figure 10.9 Some key nuclei of the amygdala and their major connections Sensory information from the thalamus and cortex enters the amygdala through the lateral nucleus. The central nucleus projects to the autonomic nervous system (ANS) and to the motor areas that produce the physiological and behavioral components of an emotional response. The basolateral nucleus projects to memory storage areas such as the cortex and the hippocampus, where emotional information can influence memory storage and retrieval. After LeDoux, 1998, 2000; McGaugh, 2002.

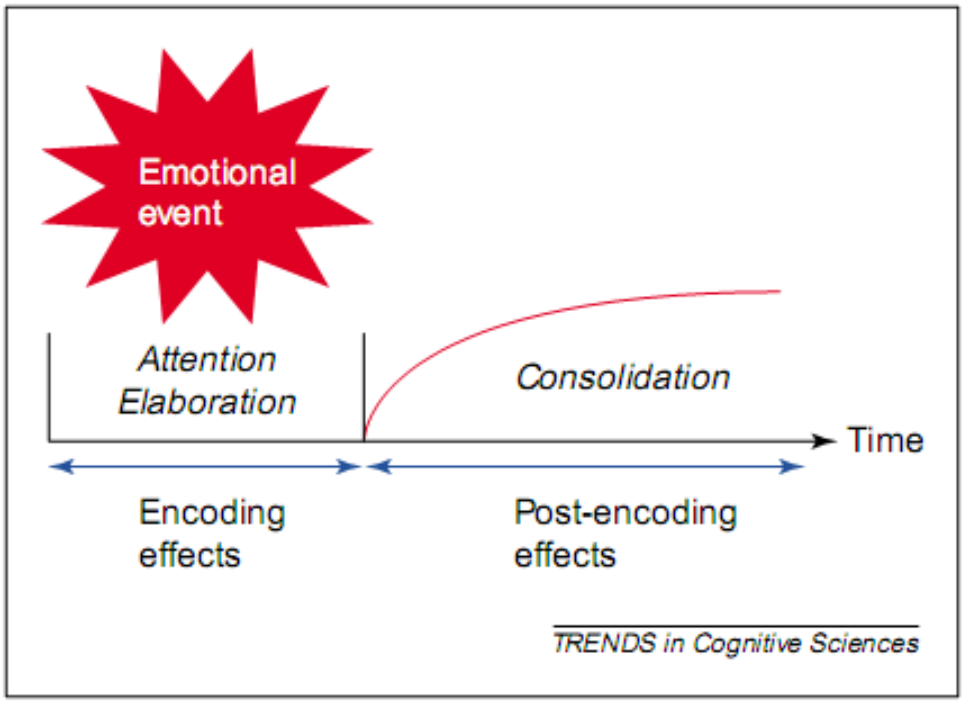


Fig. 1. Encoding and post-encoding effects of emotion. Encoding processes create the initial memory representation. After the event, post-encoding processes, primarily consolidation, continue to influence the memory representation. Consolidation is thought to continue for an extended period; therefore, the observed effects of emotion on memory should increase with time until consolidation is complete.