Working memory

C H D T G P L J N U E

How many letters do you remember?

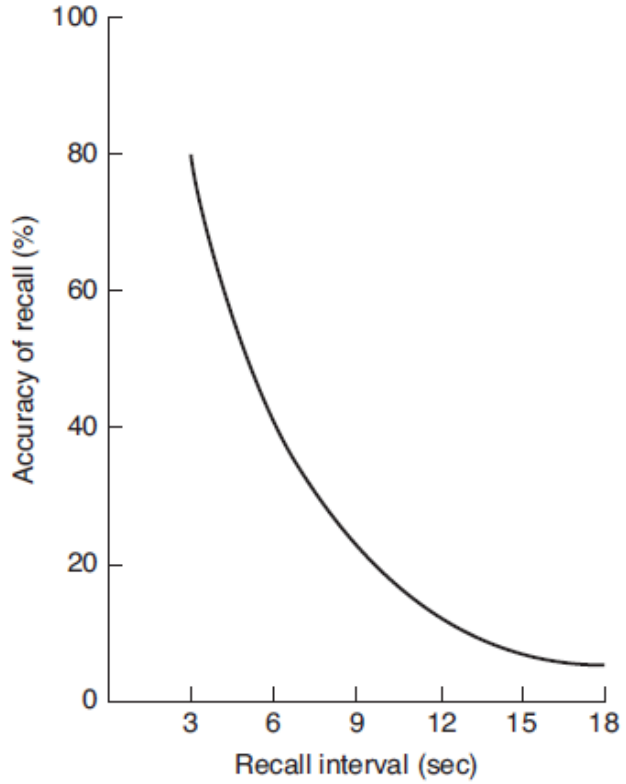
Listen to a list of words

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

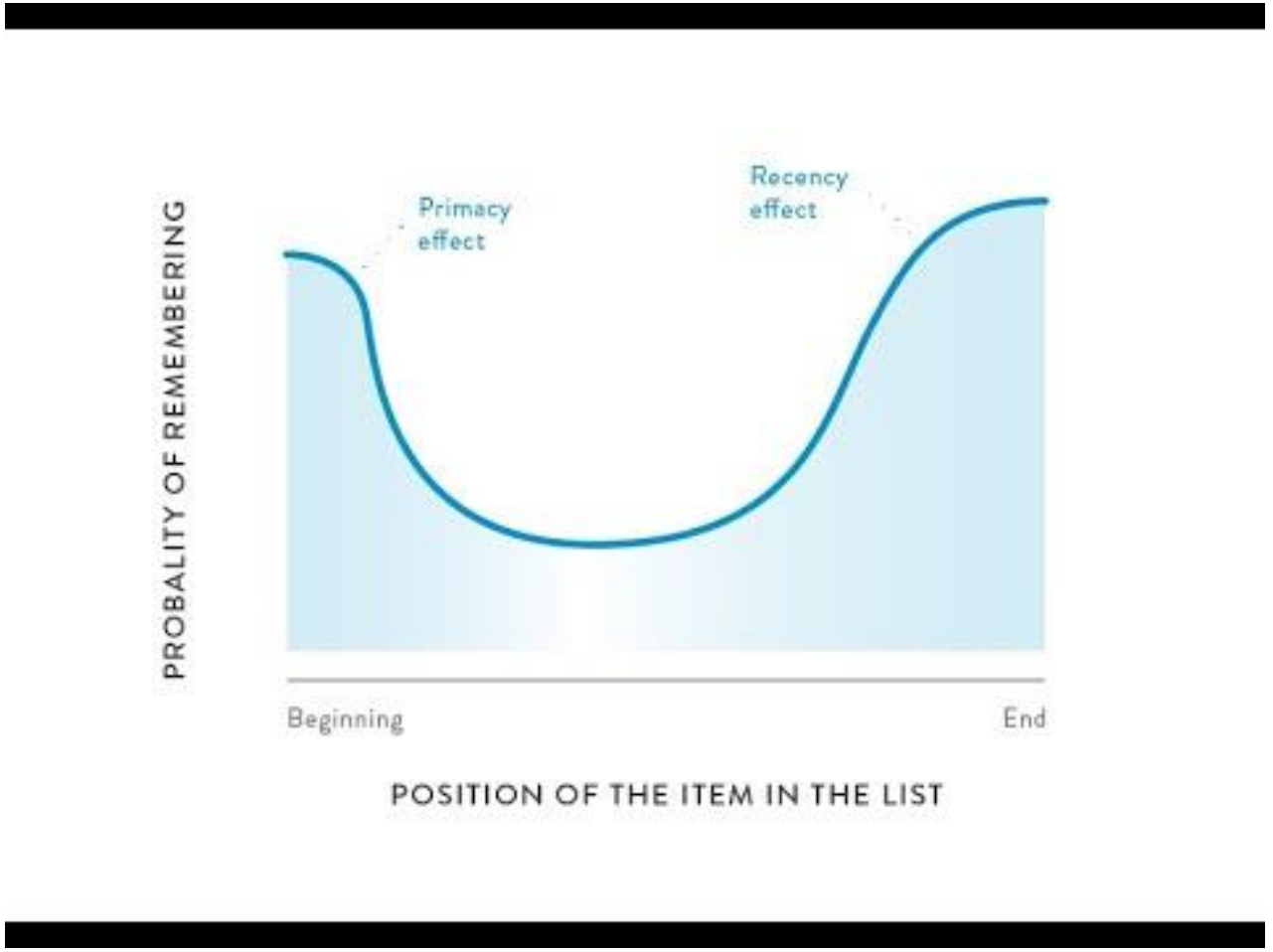
Sensory memory

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

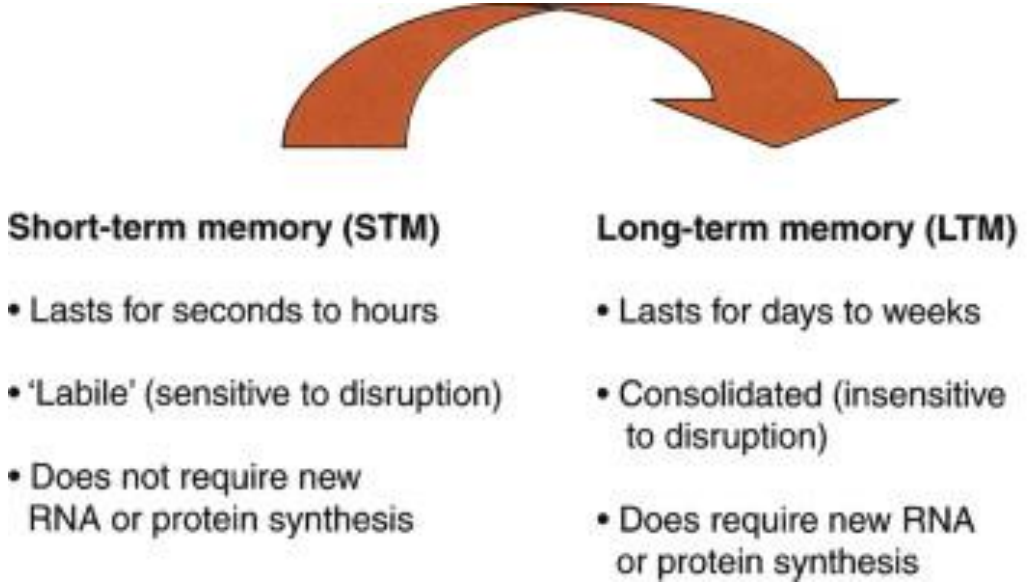
1^2 3^2 5^2 7^2 9^2 11^2

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

Information → **Sensory Memory**
Iconic (Sight)
Echoic (Sound)
and other senses
Store Capacity - large
Duration - less than one second

Attention →

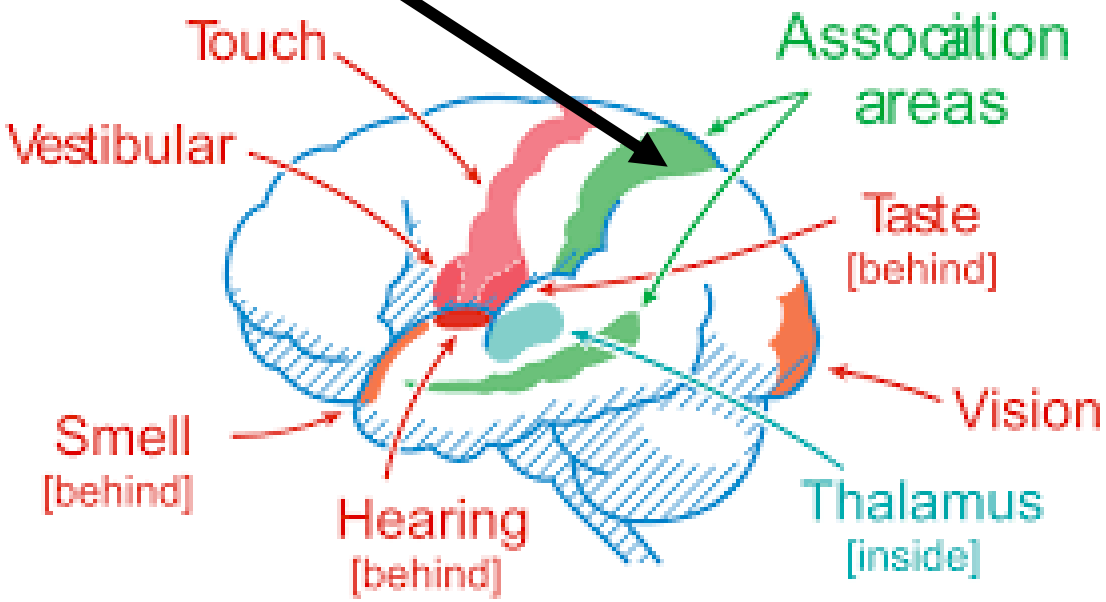
Short-term Memory
Store Capacity - small
Duration - less than 30 seconds

Elaborative Rehearsals →

Long-term Memory
Permanent
Store Capacity - unlimited
Duration - upto a lifetime

Outdated concept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?

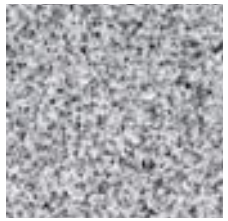
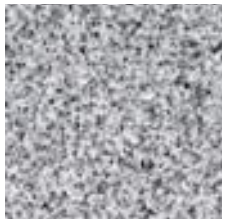
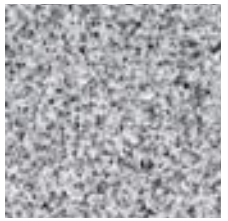
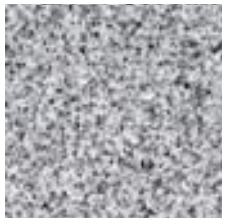
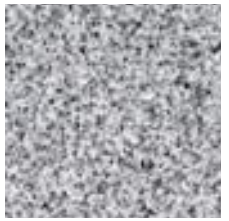
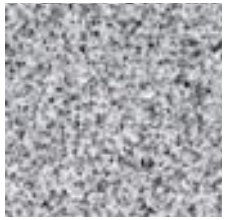
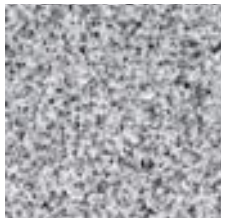
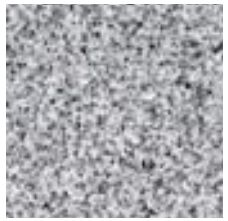
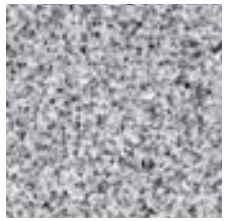
1 5 8 4 6

9 7

2 3

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

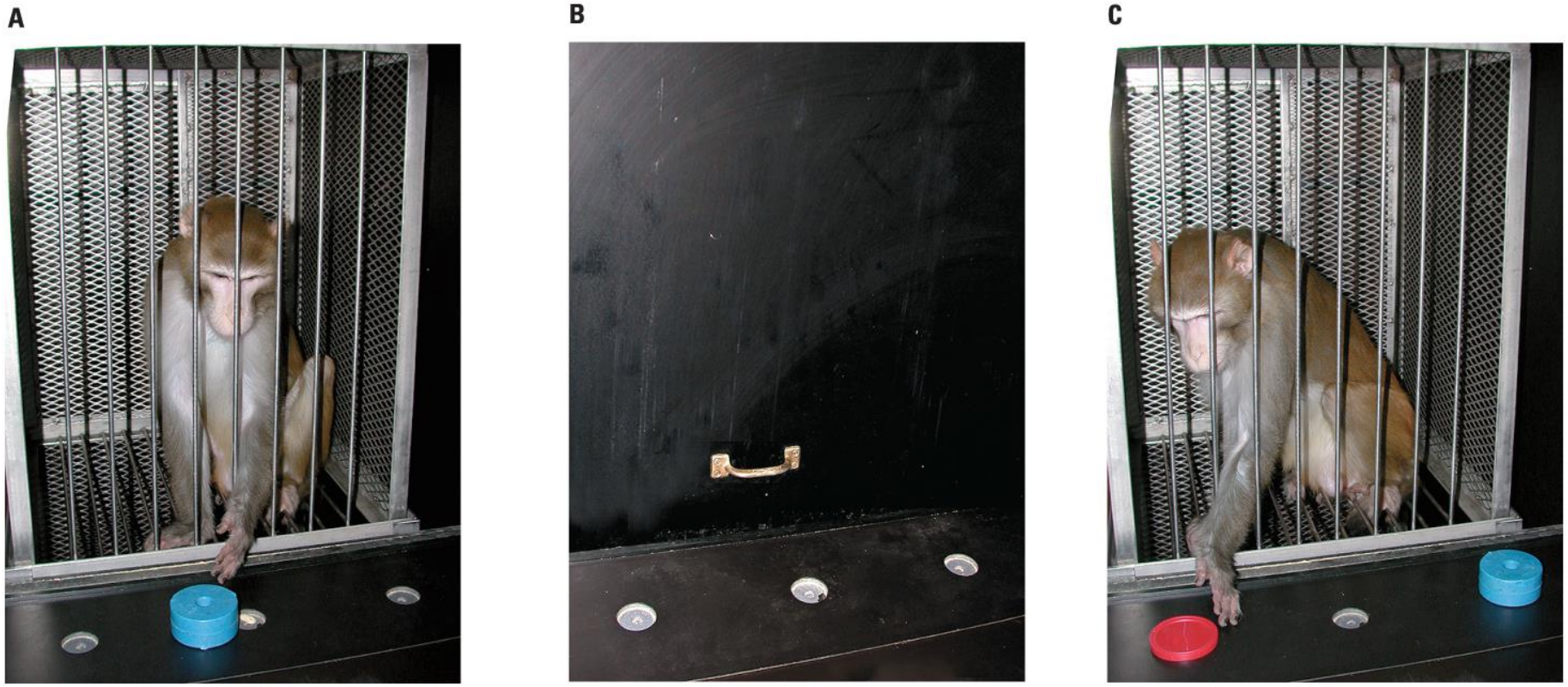
https://www.youtube.com/watch?v=nTgeLEWr614

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

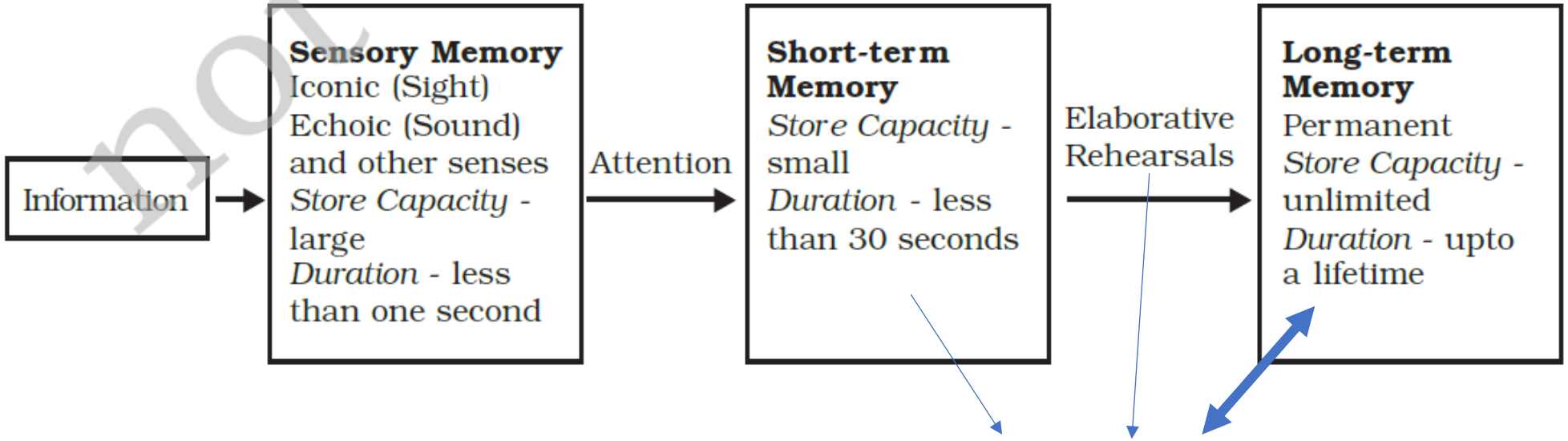
Where does that fit in?

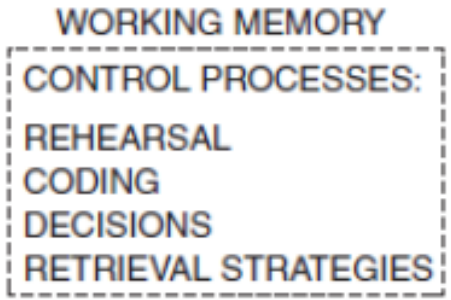
Delayed Nonmatch-to-Sample Task



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

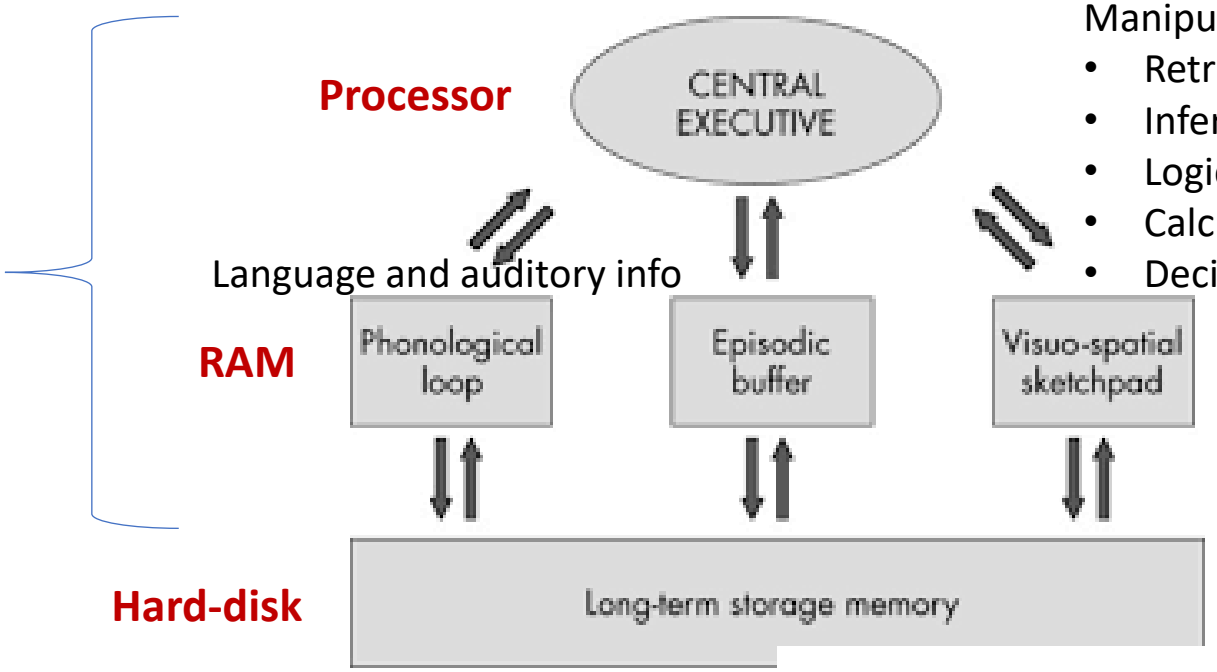




Working memory: the active and temporary representation of information that is maintained for manipulation, solving problems, making decisions

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

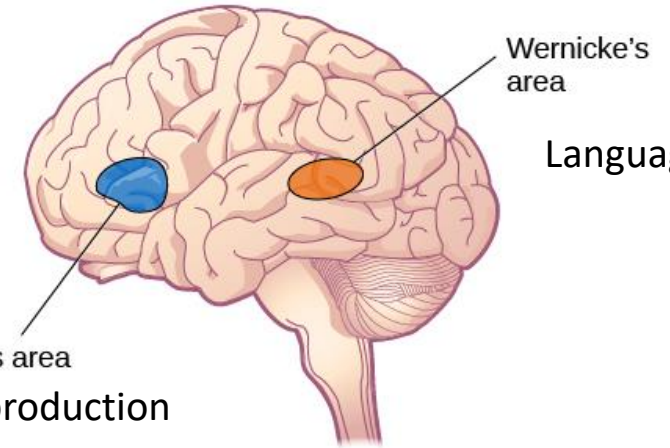
Working memory



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

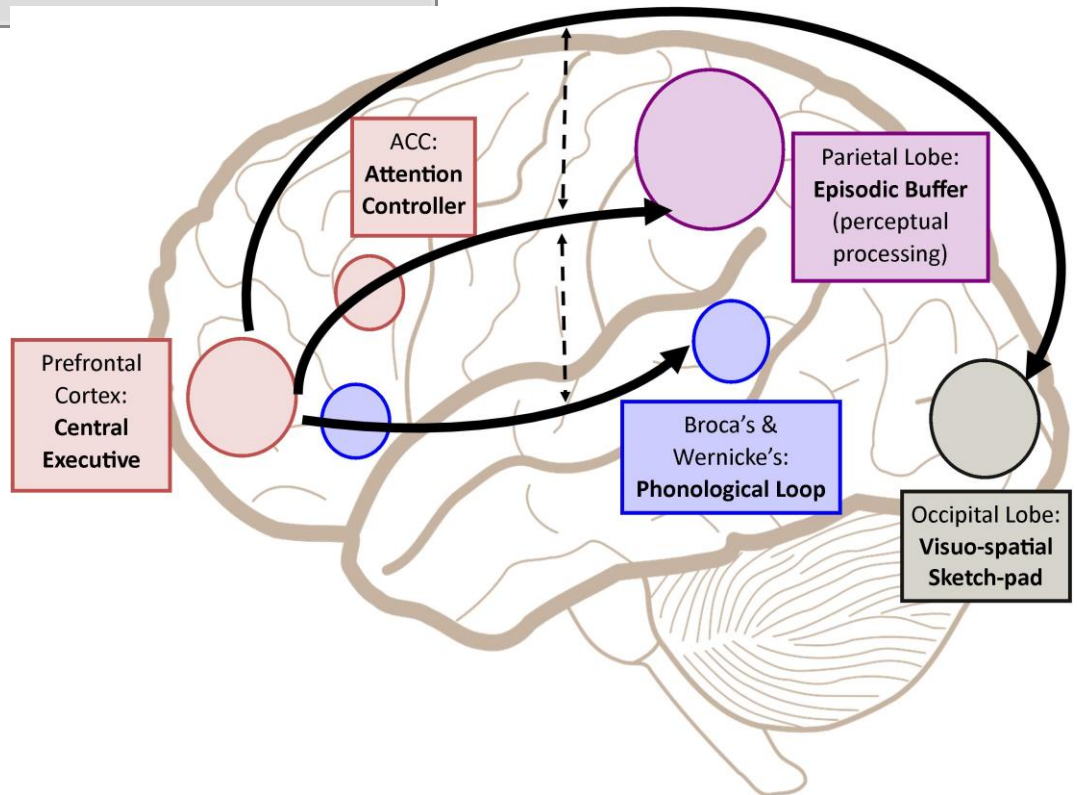
Maintaining information active

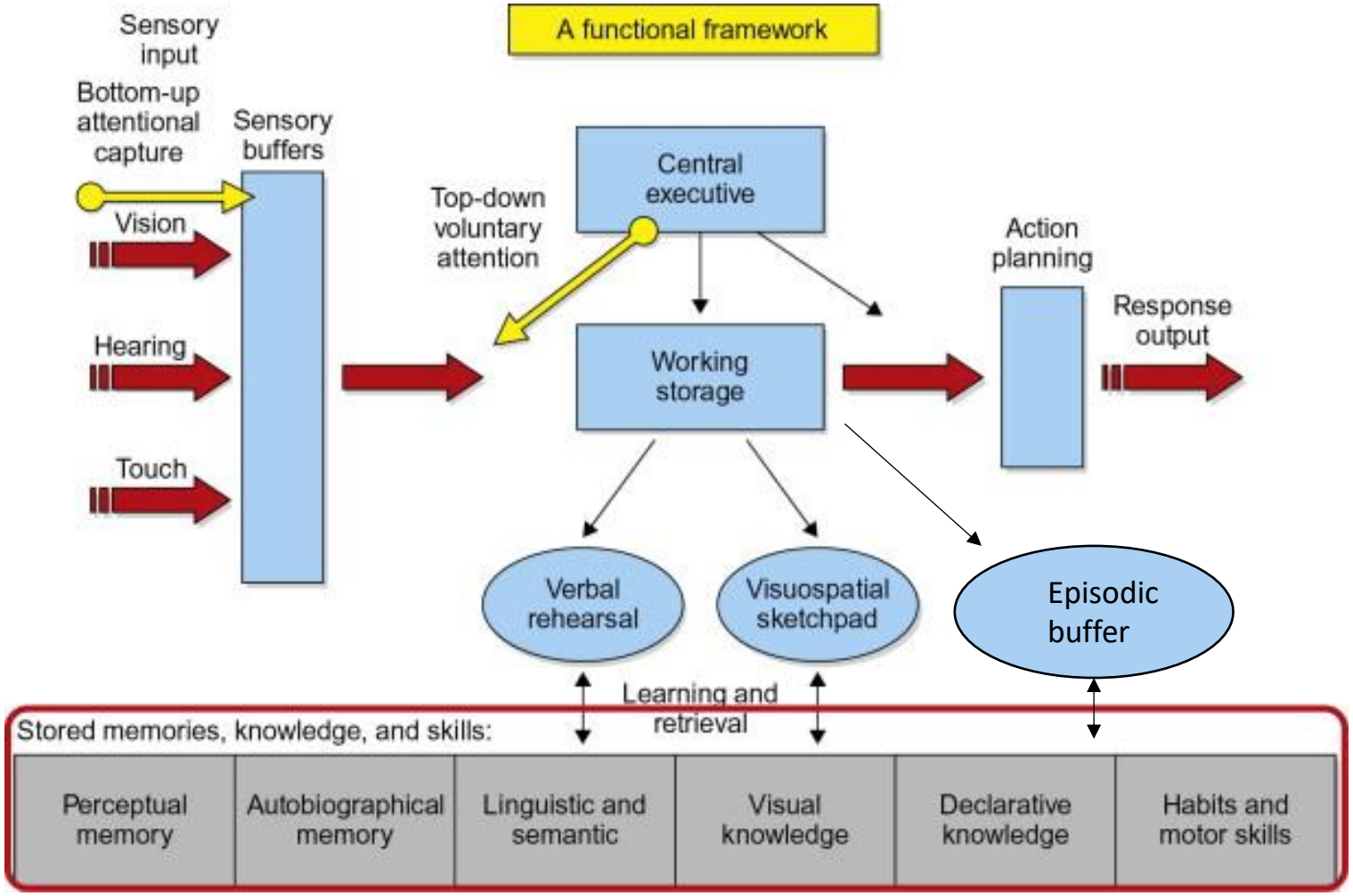
Allan Baddeley's working memory model



Language comprehension

Language production

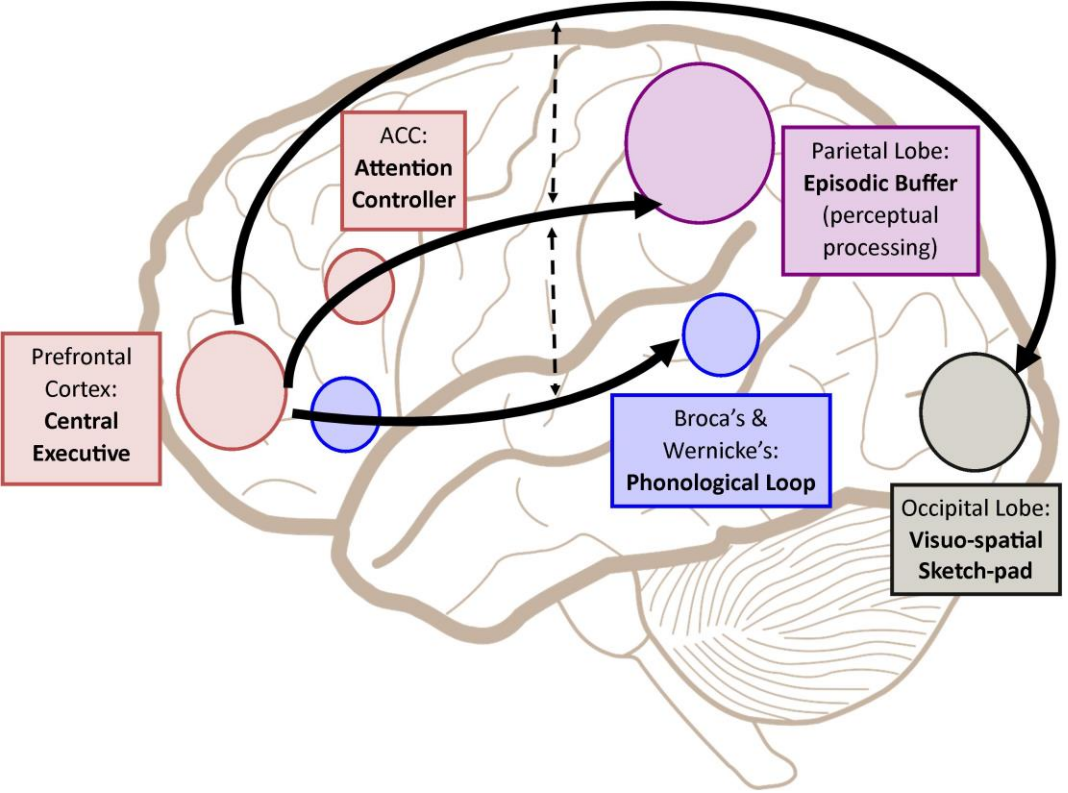


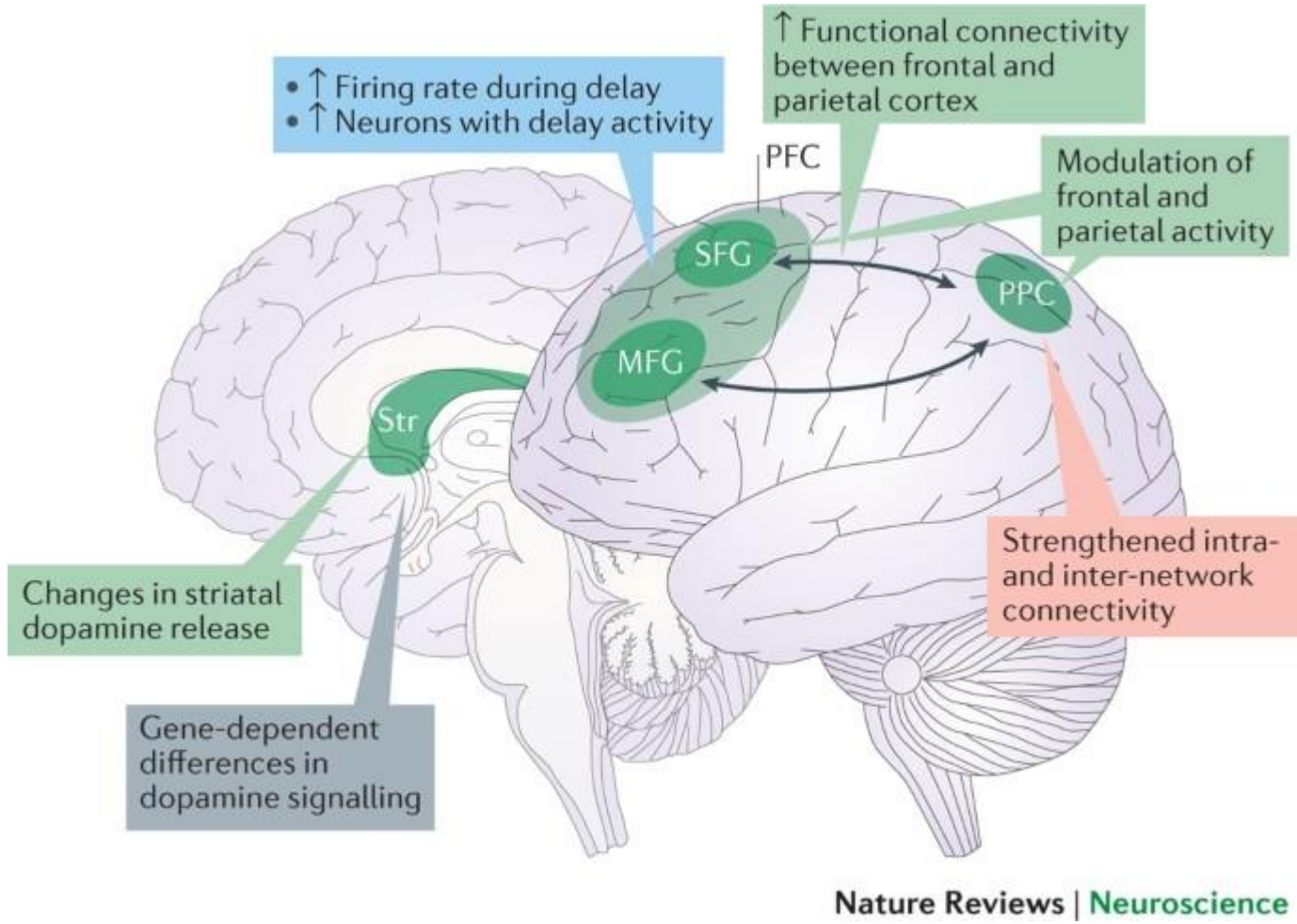

A functional framework
Sensory input
Bottom-up attentional capture
Sensory buffers
Vision
Hearing
Touch
Top-down voluntary attention
Central executive
Working storage
Action planning
Response output
Verbal rehearsal
Visuospatial sketchpad
Episodic buffer
Learning and retrieval
Stored memories, knowledge, 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

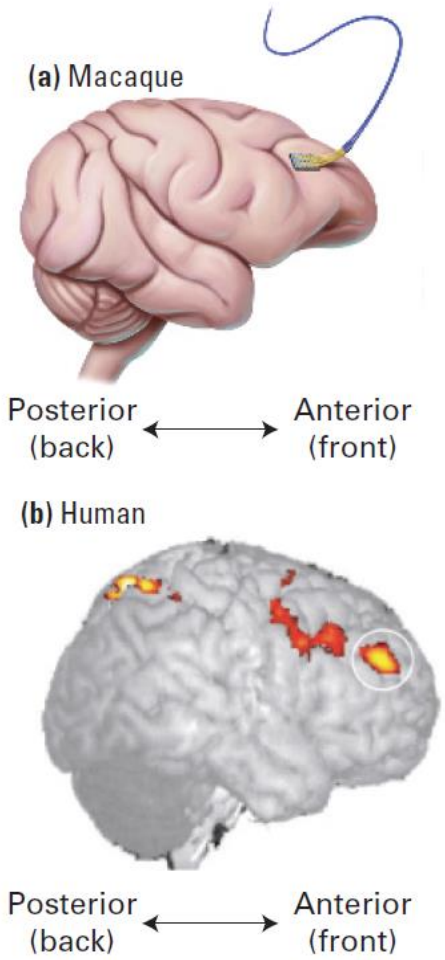


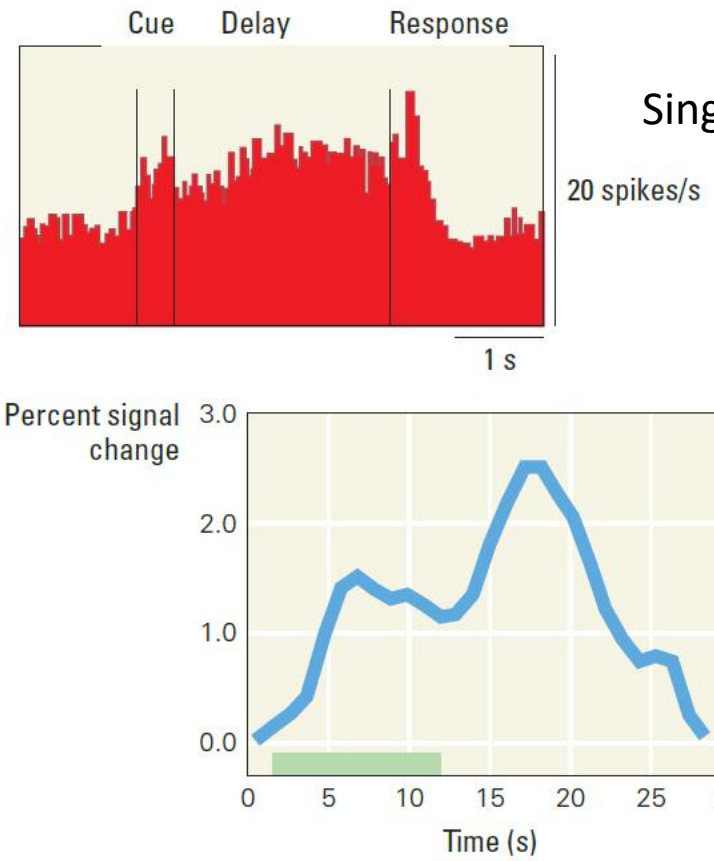


https://www.nature.com/articles/nrn.2016.43

How does the brain maintain information active over time?

(like rehearsing a phone number in your head)

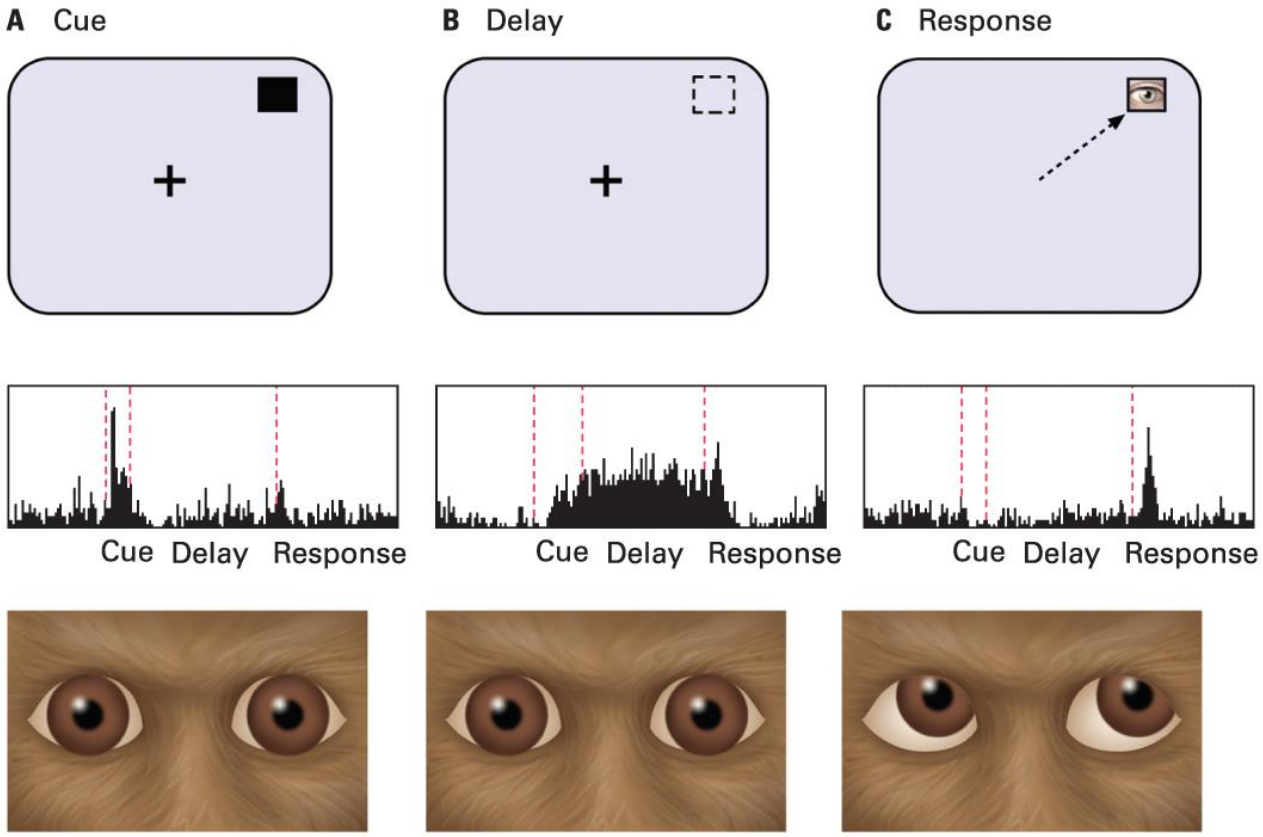




Single electrode recording

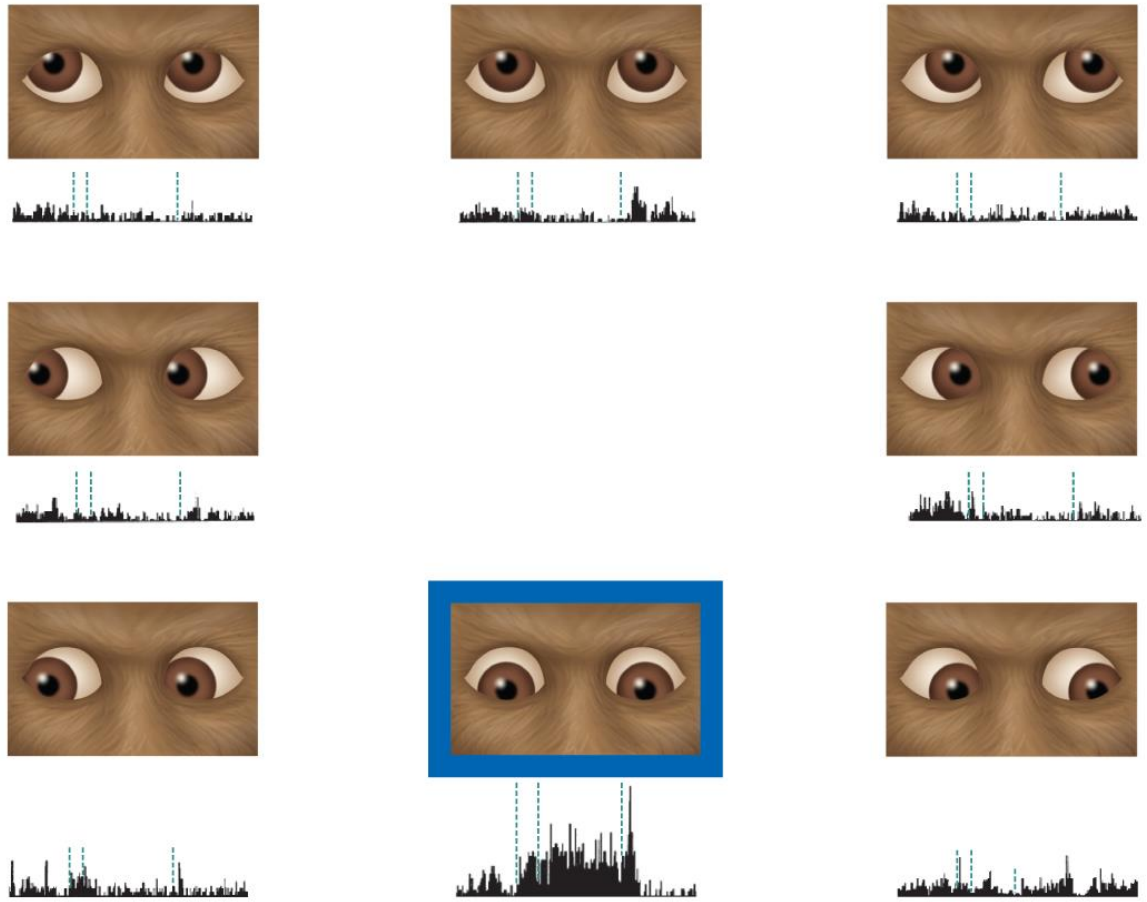
Frontal Brain Activity During Working-Memory Tasks

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



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

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



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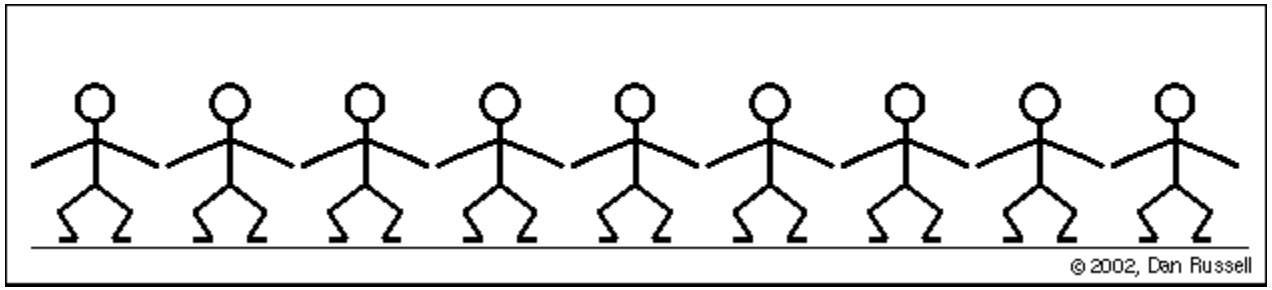
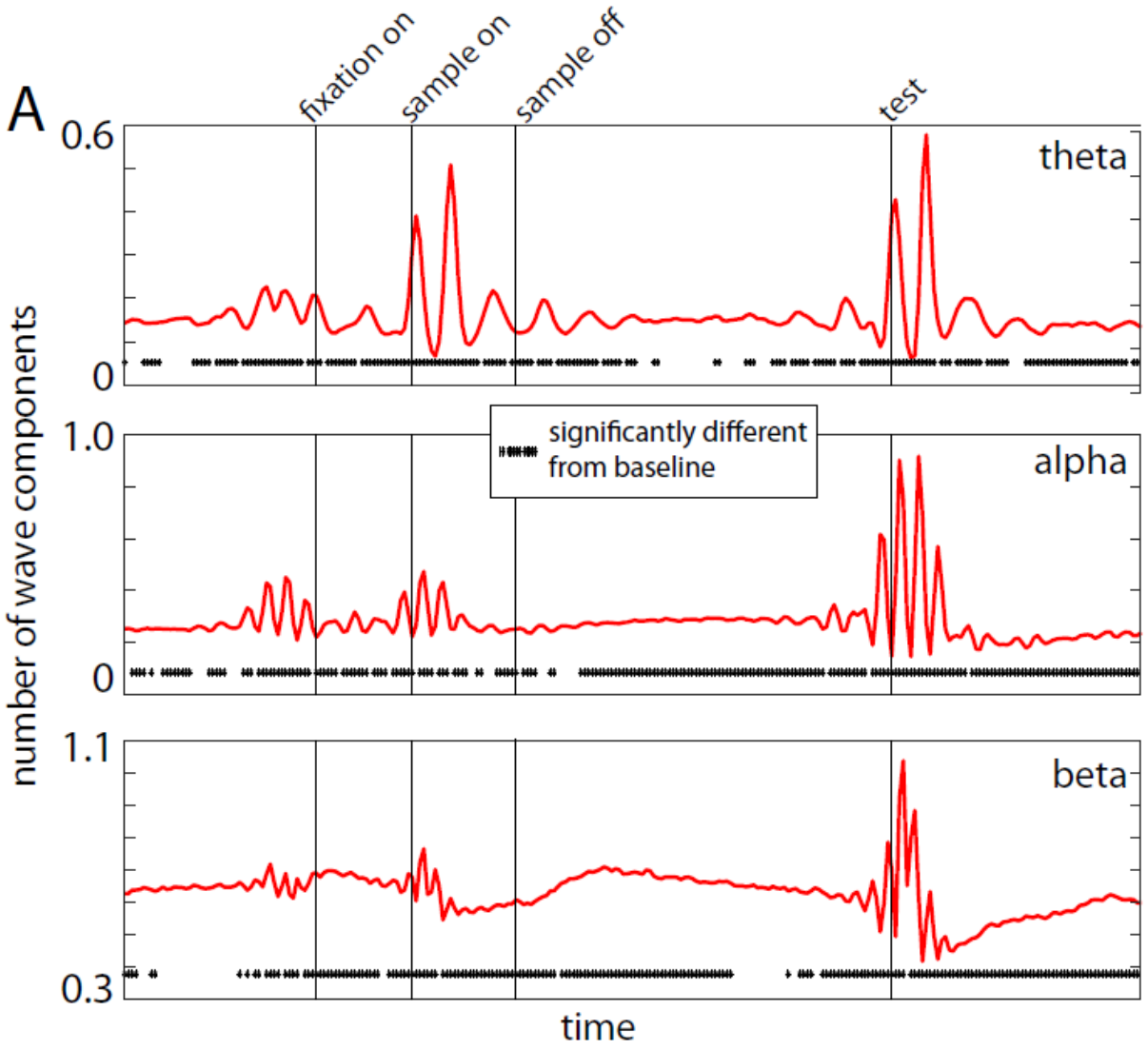
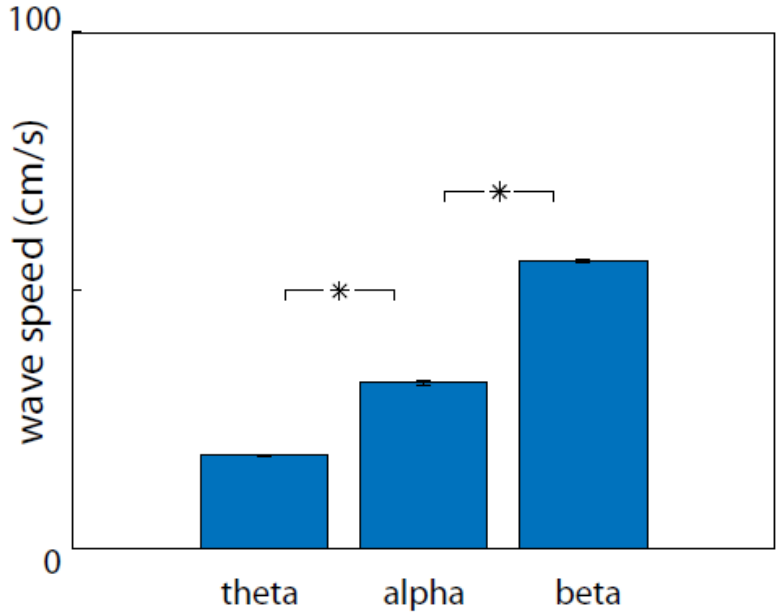

© 2002, Dan Russell

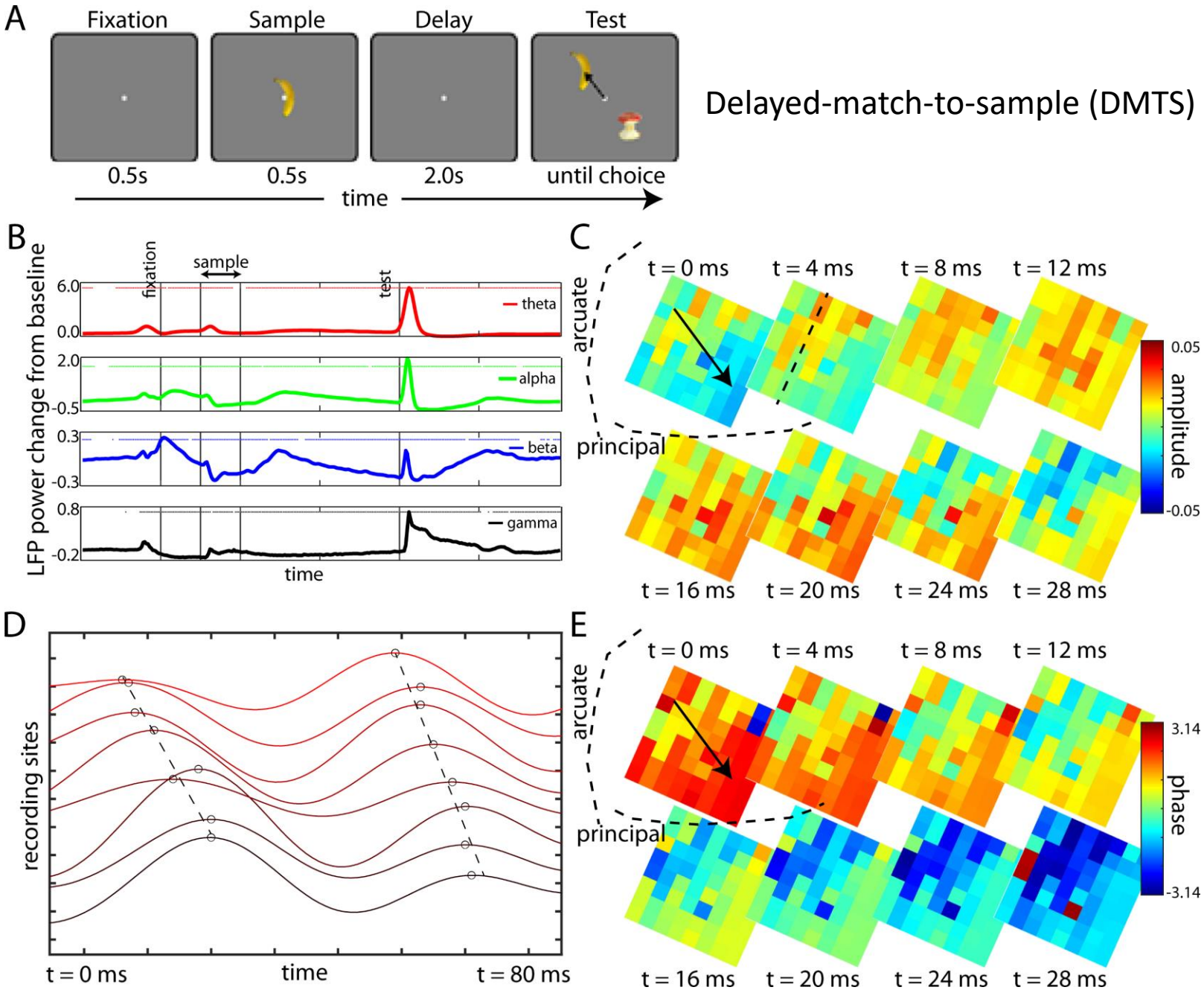

MakeAGIF.com

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





Traveling waves in the prefrontal cortex during working memory

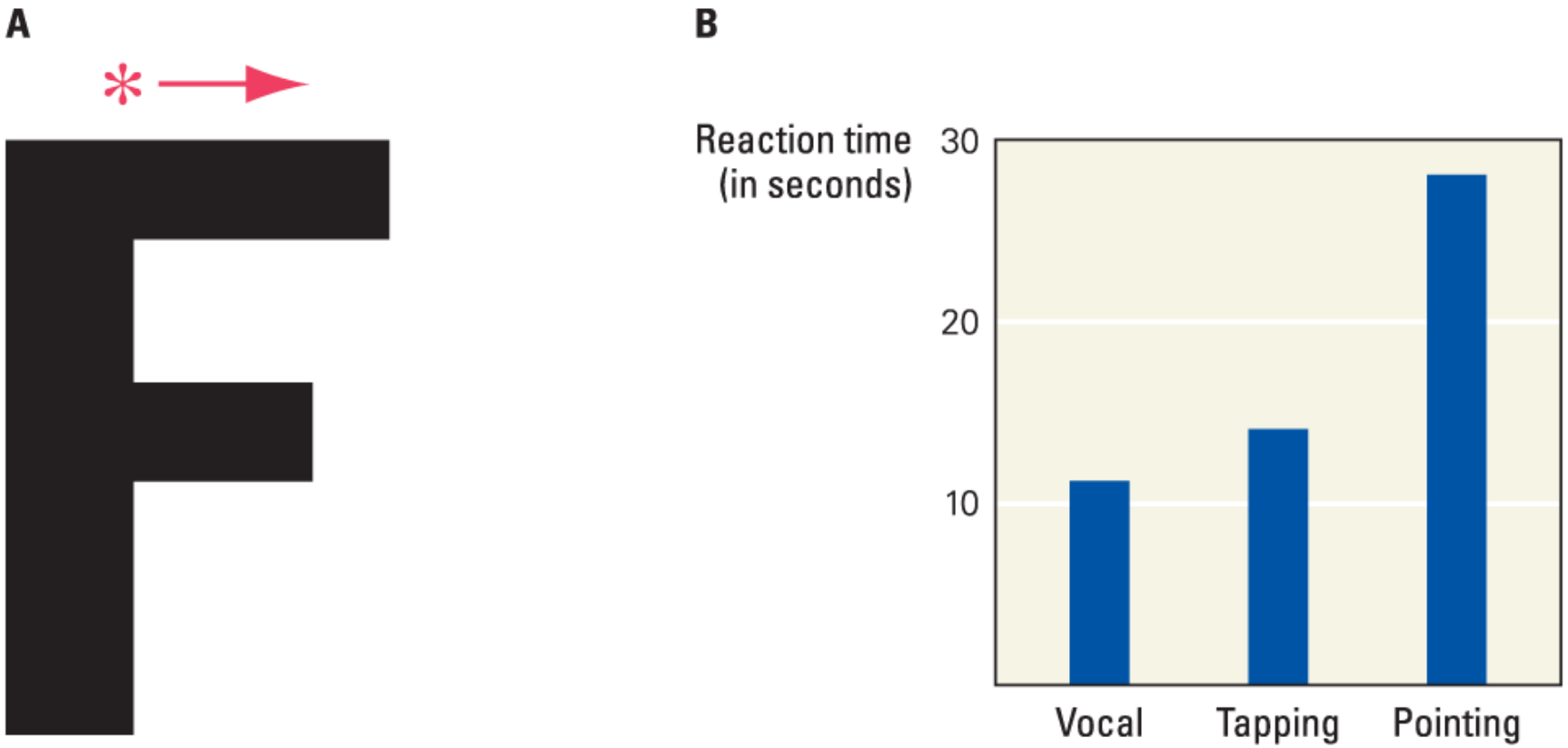


Delayed-match-to-sample (DMTS) working memory task

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

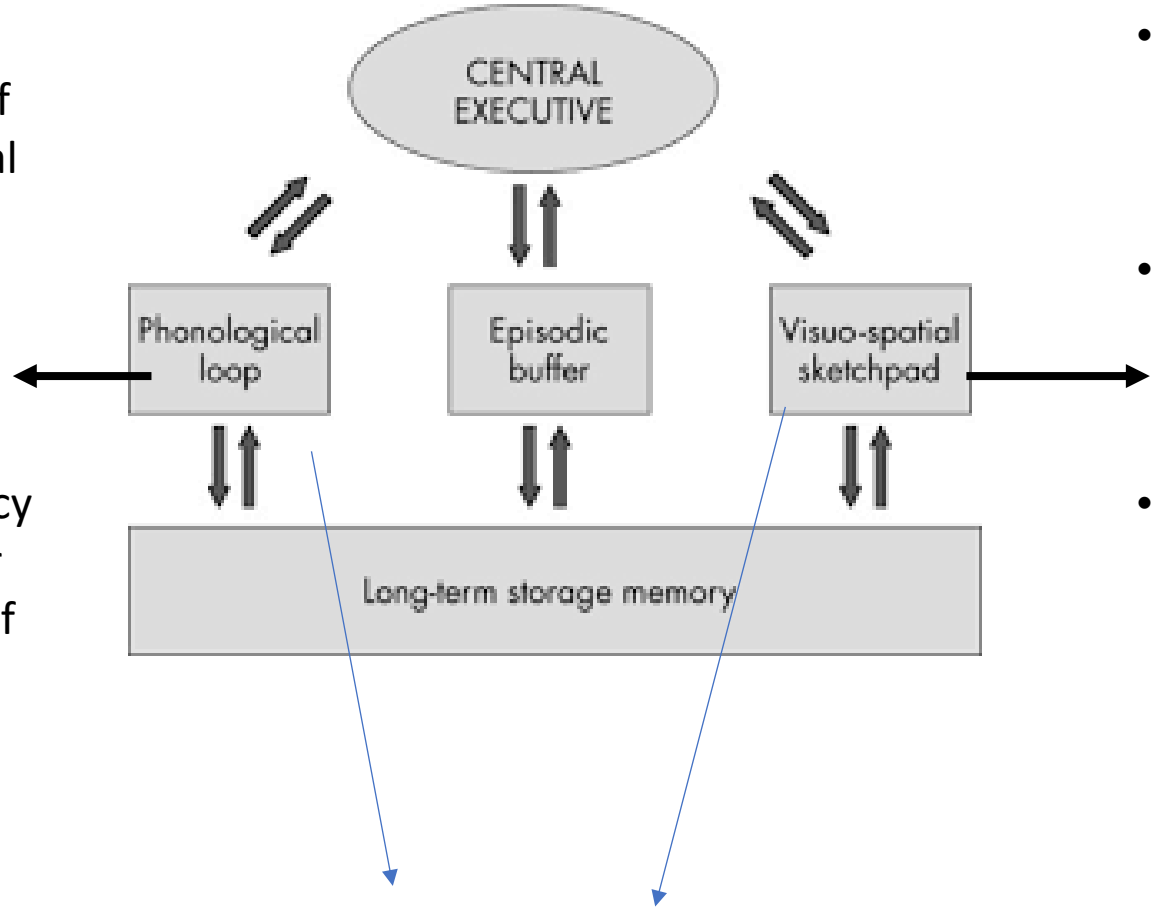


Gluck et al., *Learning and Memory*, 4e, © 2020 Worth Publishers

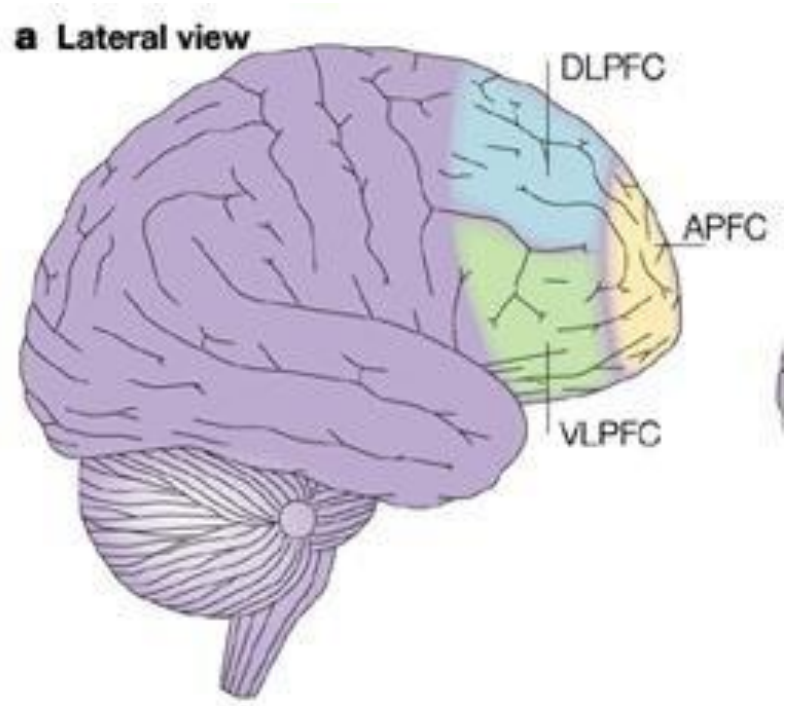
Attention competing

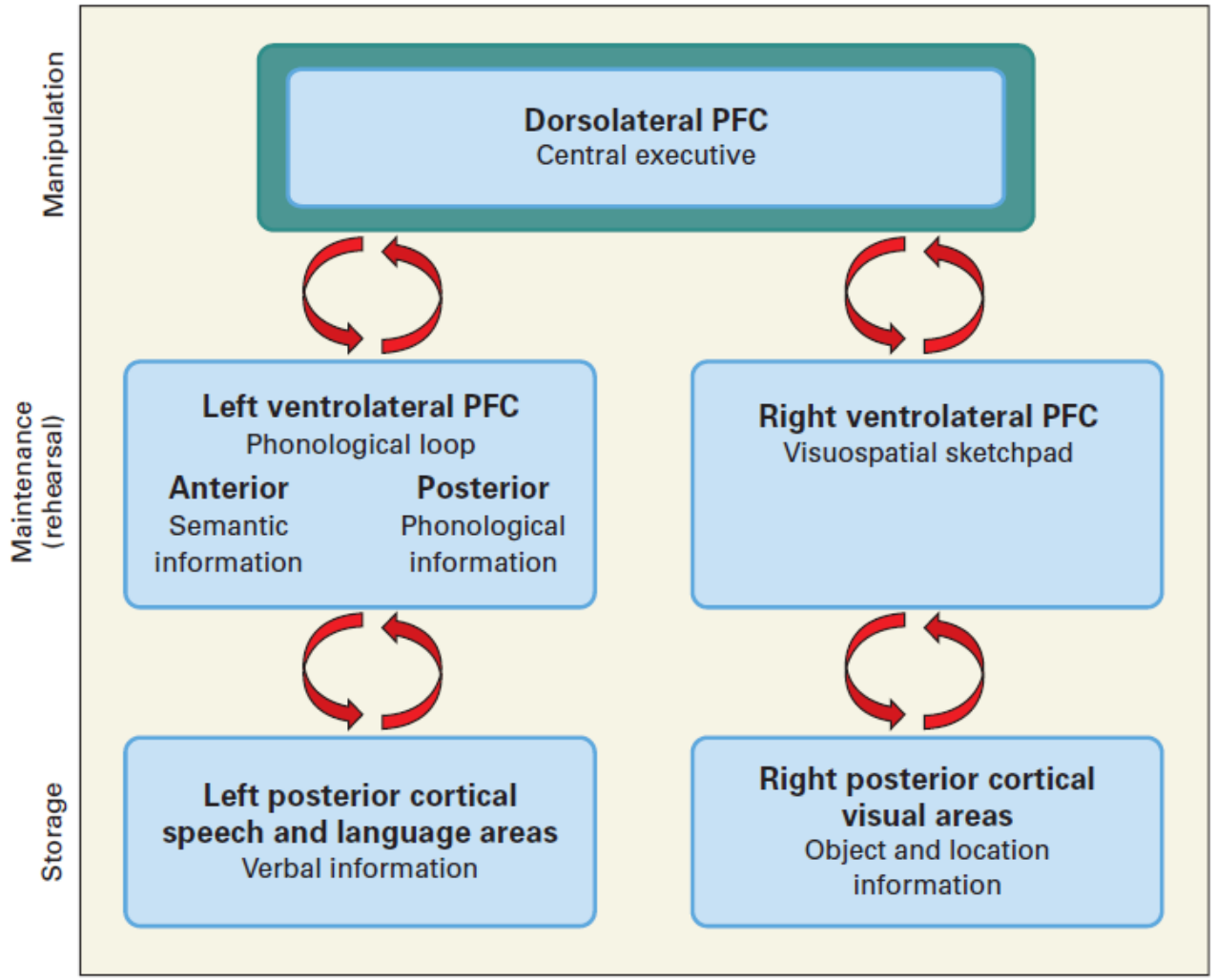
- Scanning for a friend in a large crowd and trying to speak on the phone to another friend with lots of background noise.

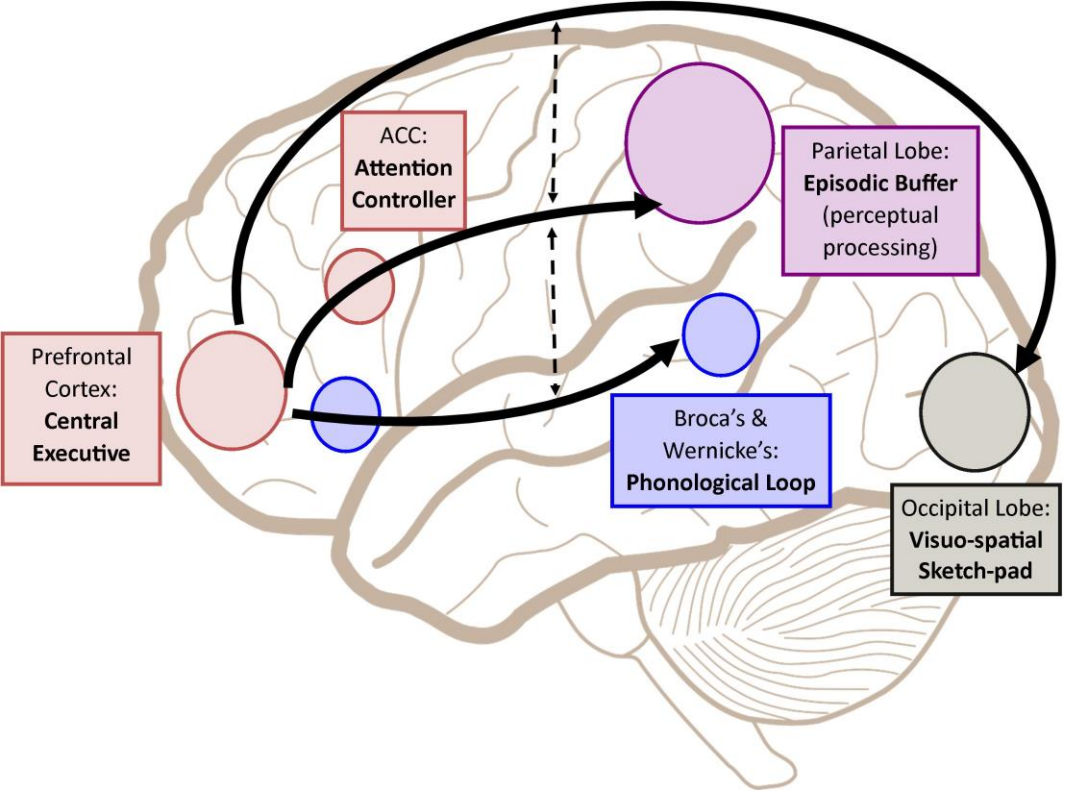
- Without rehearsal, most people retain about 2 seconds' worth of information in their phonological memory
- Internal, unspoken speech used during rehearsal is vital to the phonological loop and verbal working memory
- **Word-length effect:** the tendency for a person to remember fewer words from a list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



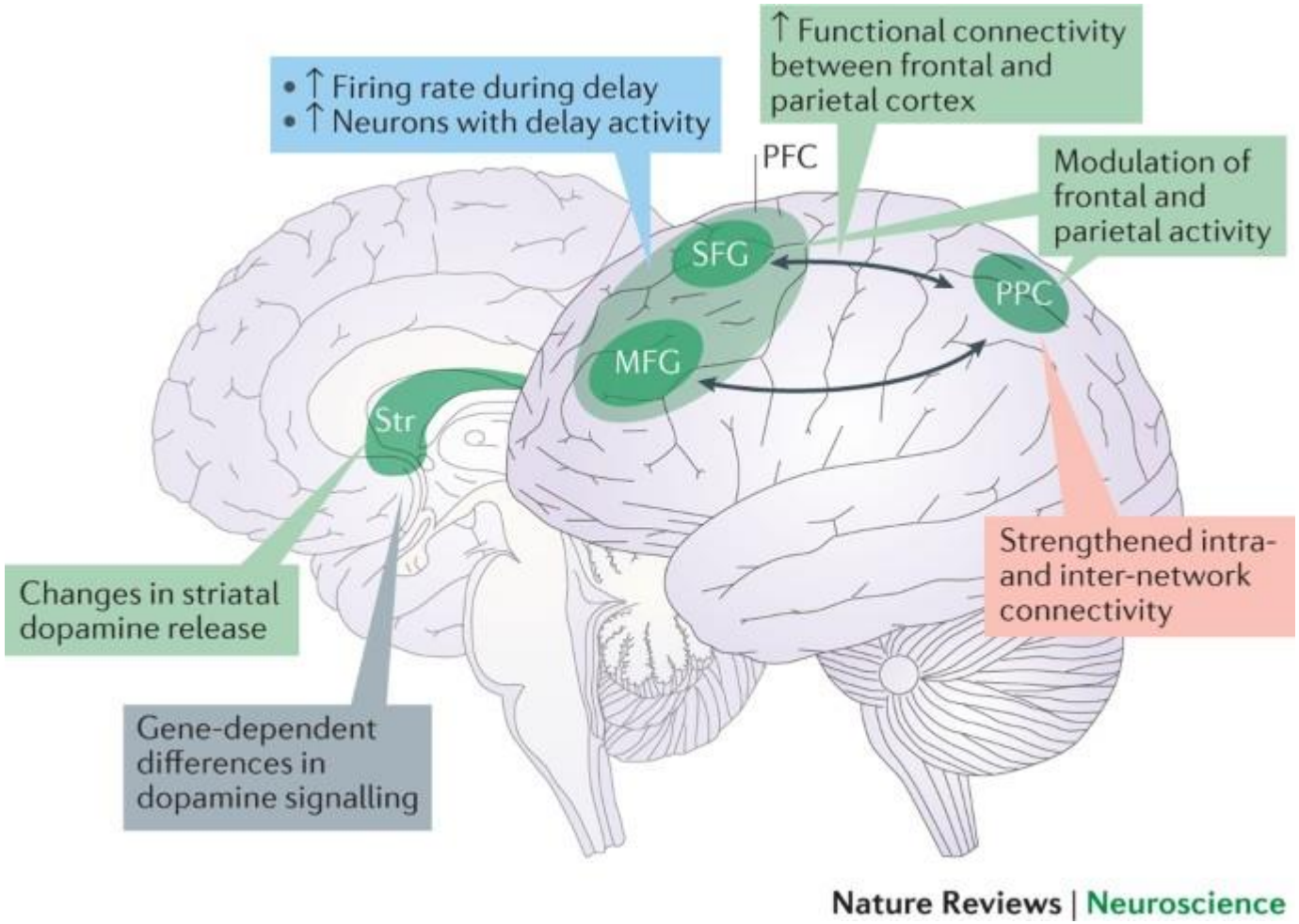
- The visuospatial sketchpad is a mental workspace for storing and manipulating visual and spatial information
- Limited capacity similar to the phonological loop, but these capacities are independent of one another
- Dual-task experiments provide evidence for the independence of these two memory buffers


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