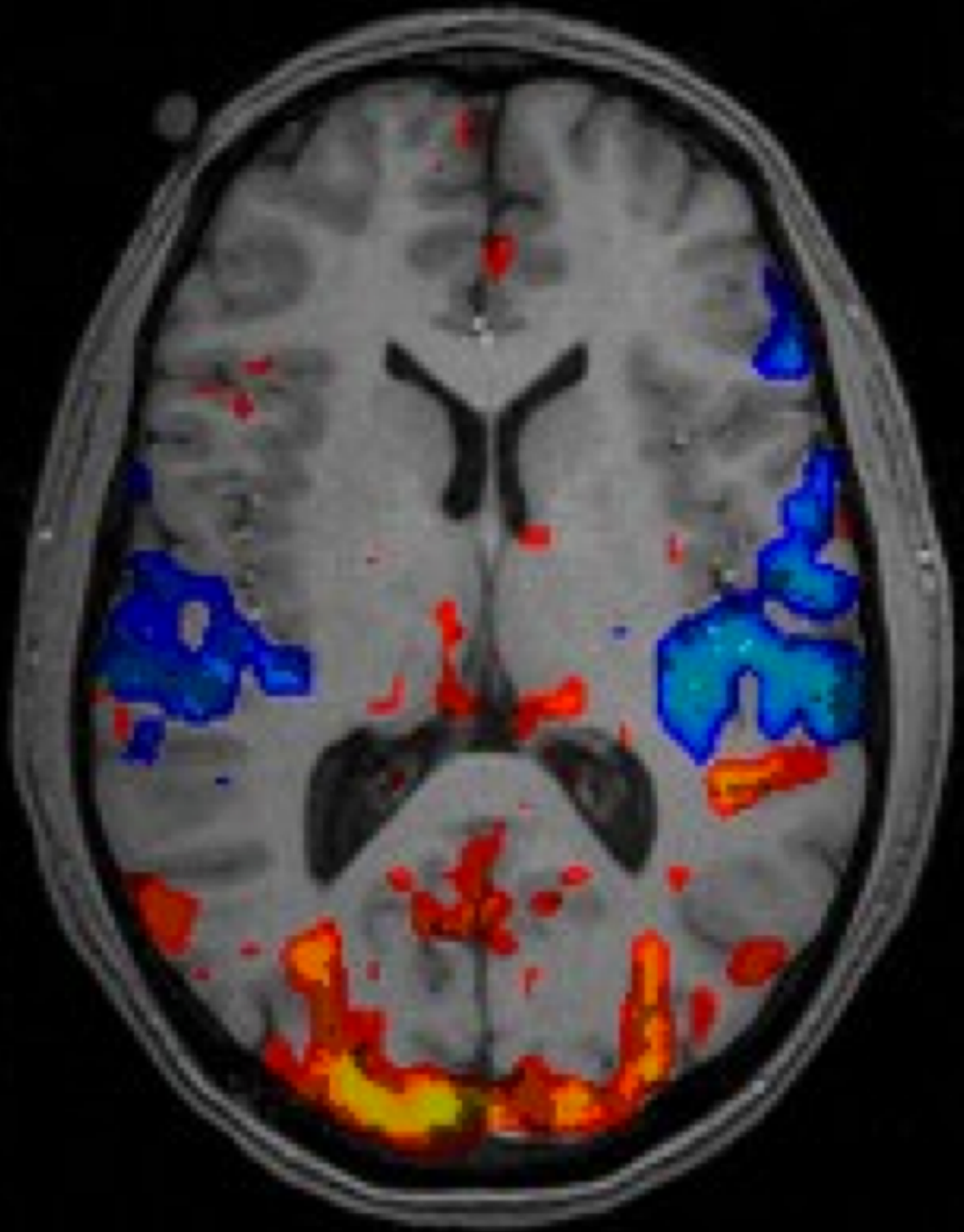
ASHI 712

The Neuroscience of Human Memory

Dr. Olave E. Krigolson
krigolson@uvic.ca

LECTURE 2:
Short Term Memory and Sleep and Memory



Working / Short Term Memory

Sunglasses
Chair
Dress
Earrings
Boots
Bed
Counter
Shower
Floor
Shoes
Desk

What is the average of the following numbers?

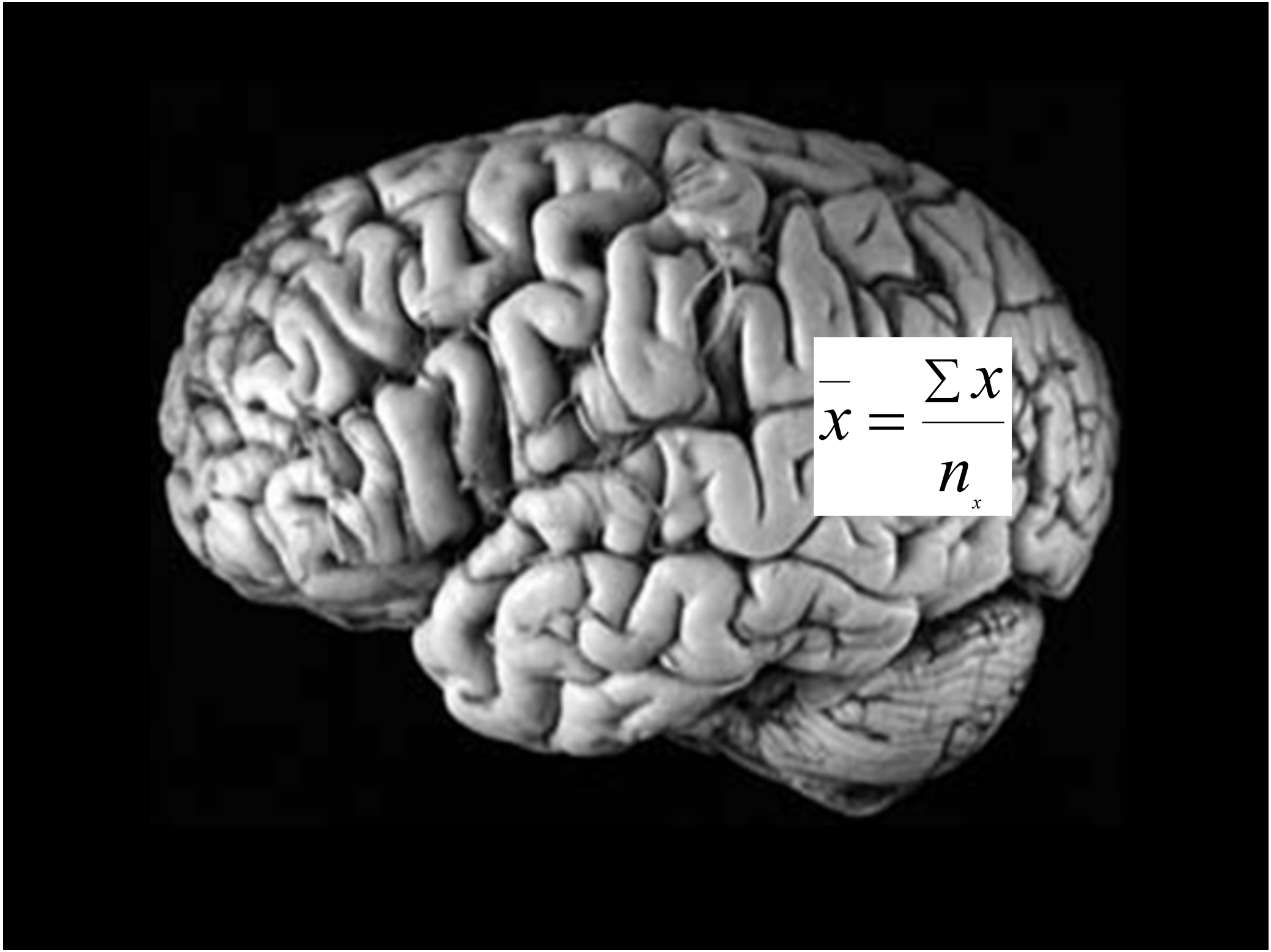
1

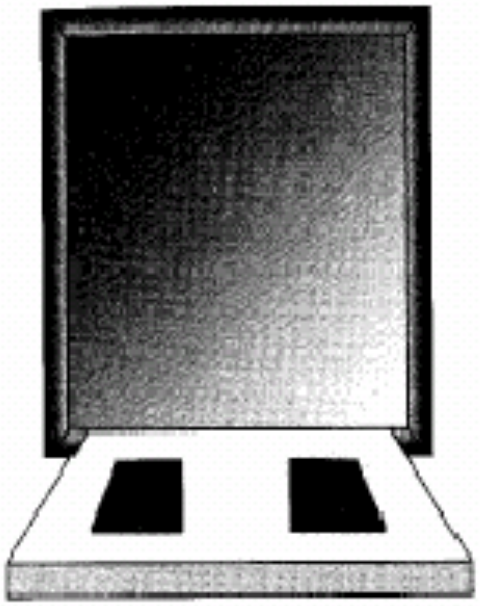
3

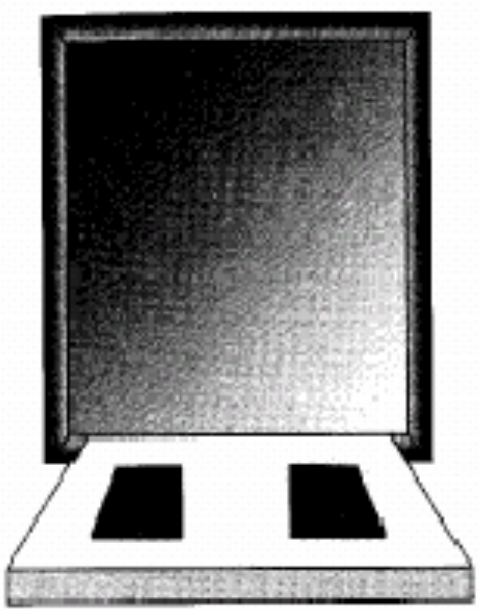
6

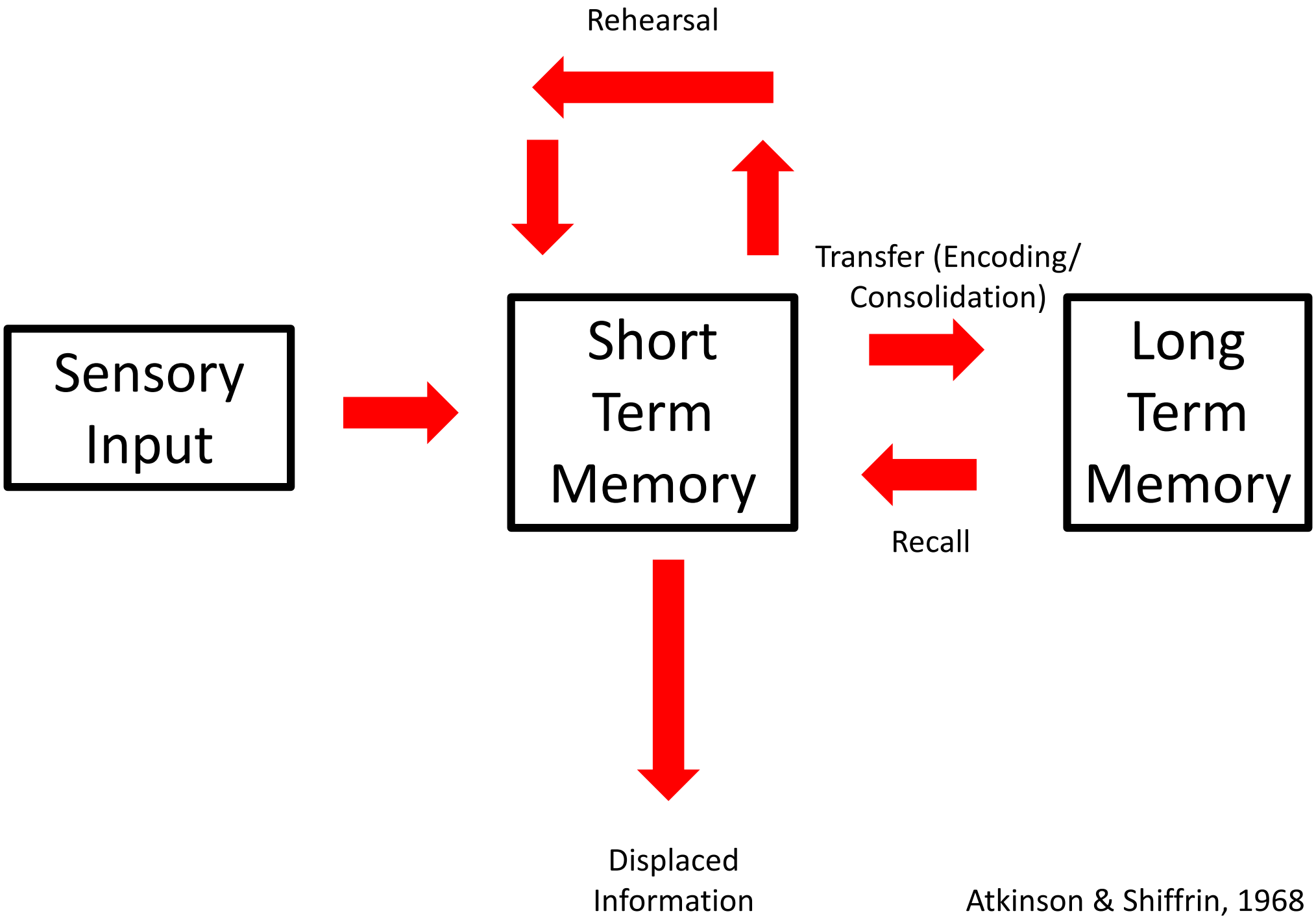
9

11


$\bar{x} = \frac{\sum x}{n_x}$







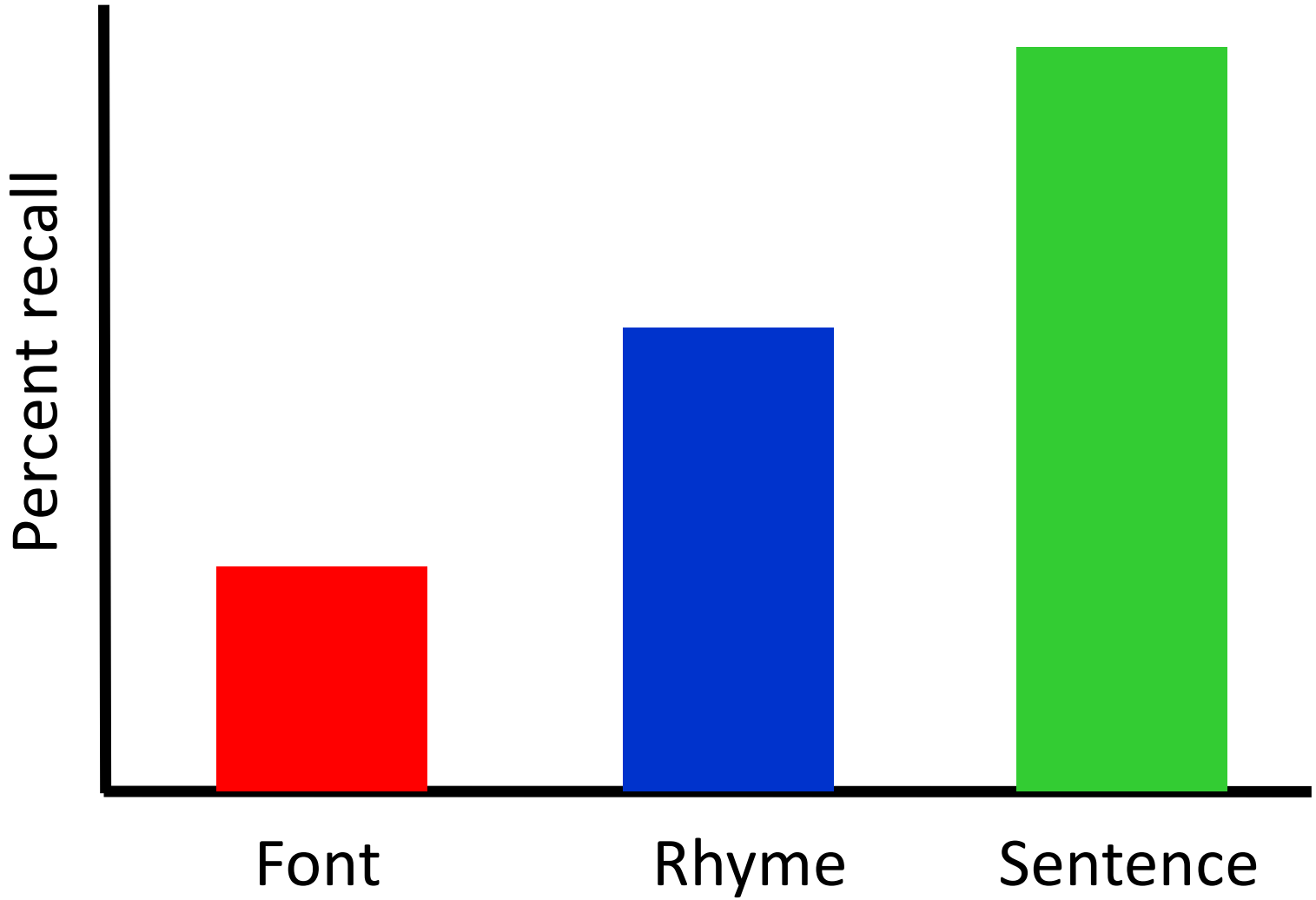
Atkinson & Shiffrin, 1968

Transfer from short term to long term memory

Rehearsal

(well, sort of ACTIVE REHEARSAL)

Depth of Processing



Relevance to Self…

+

Accuracy 

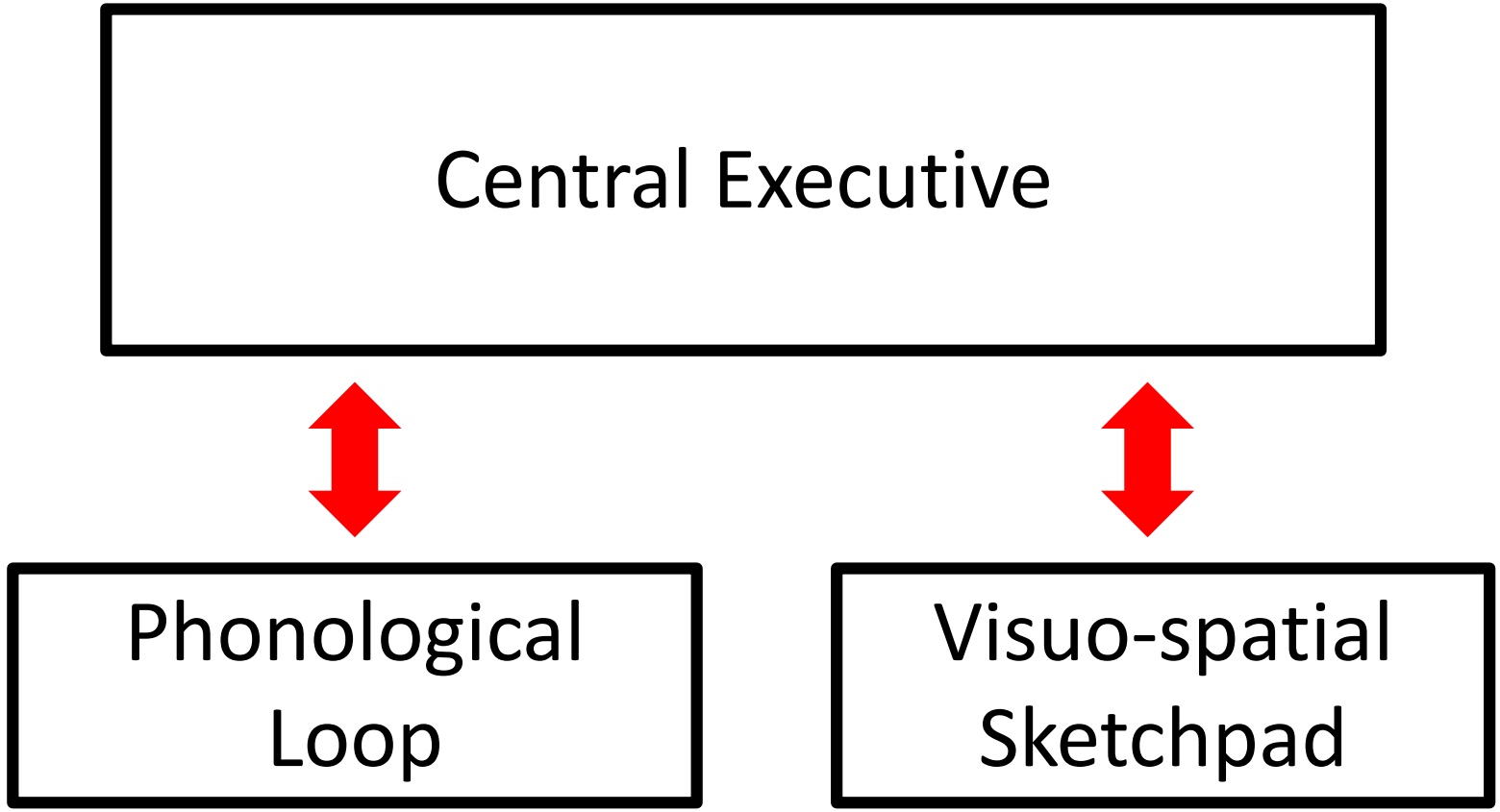
RT 

Brain 

Think of meeting someone at a party...

Do you have a better chance of remembering their name if you are introduced or if you have a conversation?

Working Memory



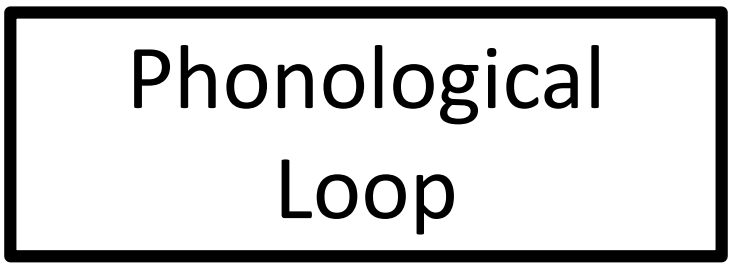
Baddeley & Hitch, 1974

maintains visual and spatial memories

Visuo-spatial Sketchpad

Baddeley & Hitch, 1974

maintains auditory memories



Baddeley & Hitch, 1974

add / delete items from working memory
selecting from items
recall from long term memory
transfer to long term memory

Baddeley & Hitch, 1974

The model defines important features:

1) Manipulation – requires central executive

2) Rehearsal – independent of central executive

3) The model is modality specific

What was that list
of words?

Sunglasses
Chair
Dress
Earrings
Boots
Bed
Counter
Shower
Floor
Shoes
Desk

Central Executive

control of working memory
setting goals and planning
task switching
stimulus response selection (inhibition)

Updating Working Memory

The “n” back task

Target = 4

3

5

1

9

4

1

3

2

8

5

0

6

7

9

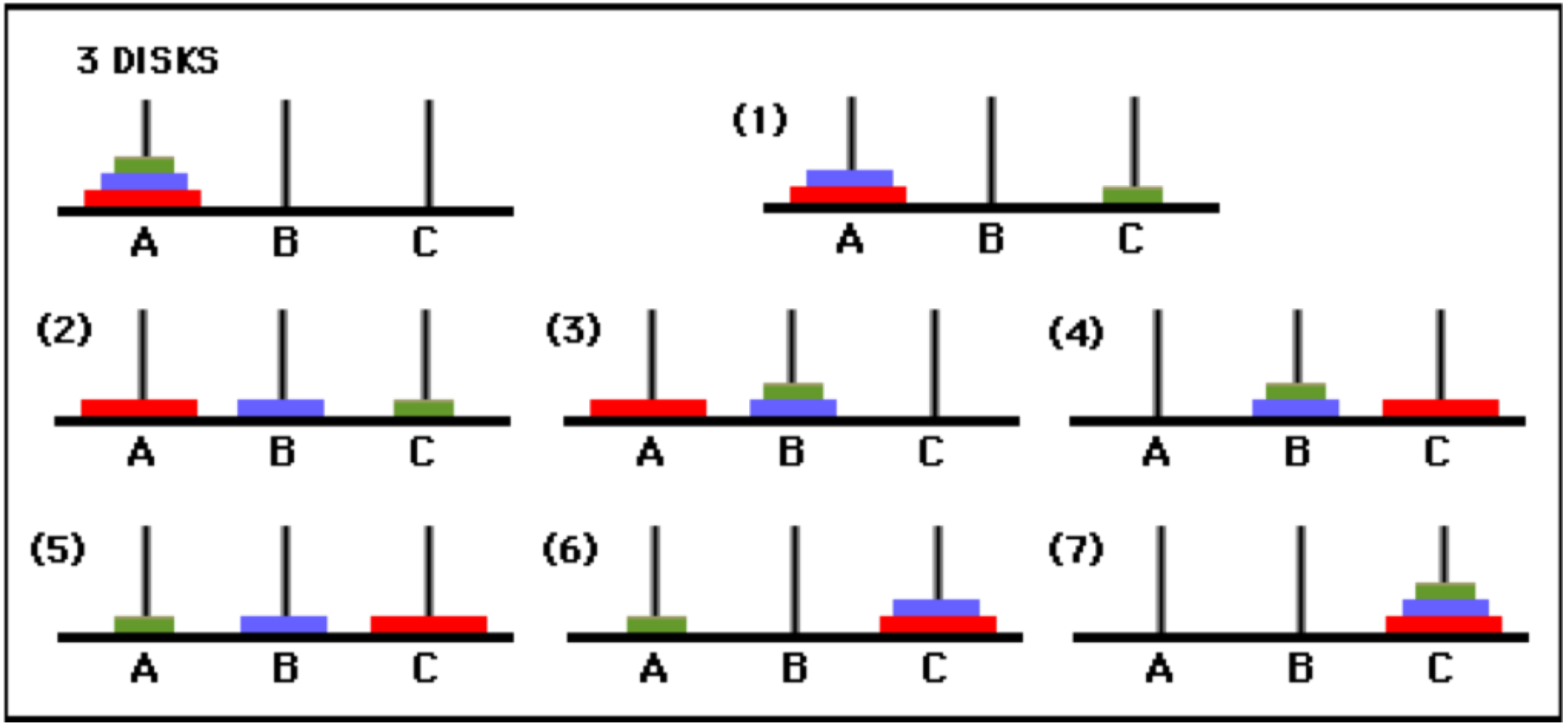
2

4

9

Setting Goals and Planning

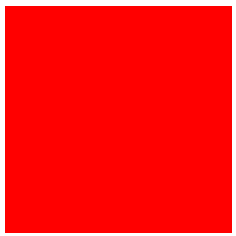
The Towers of Hanoi

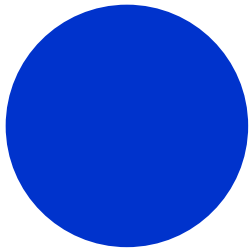

3 DISKS
A
B
C
(1)
A
B
C
(2)
A
B
C
(3)
A
B
C
(4)
A
B
C
(5)
A
B
C
(6)
A
B
C
(7)
A
B
C

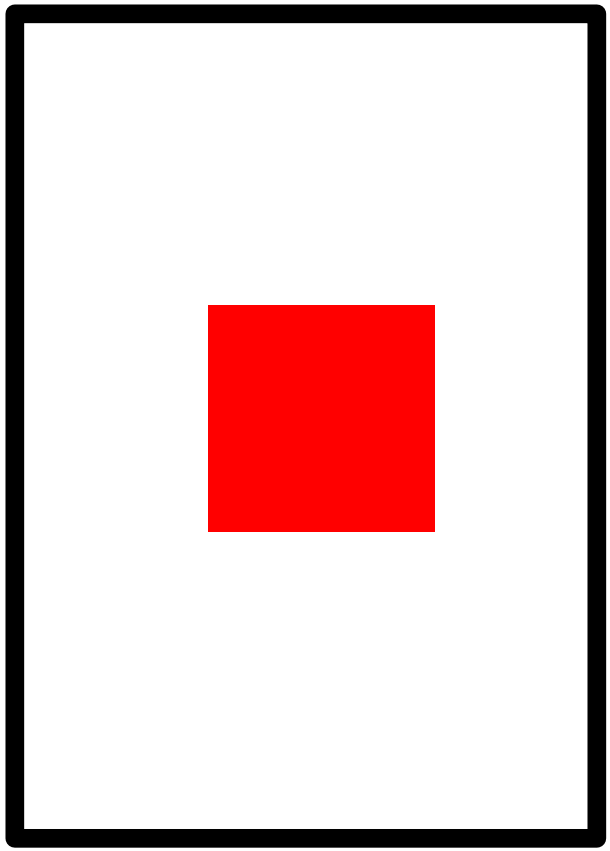
Task Switching

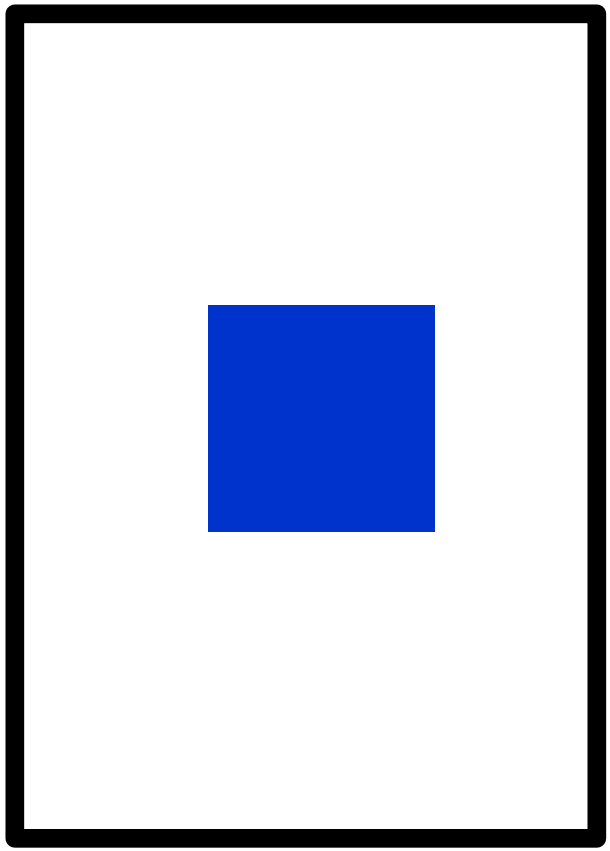
The Wisconsin Card Sort Task

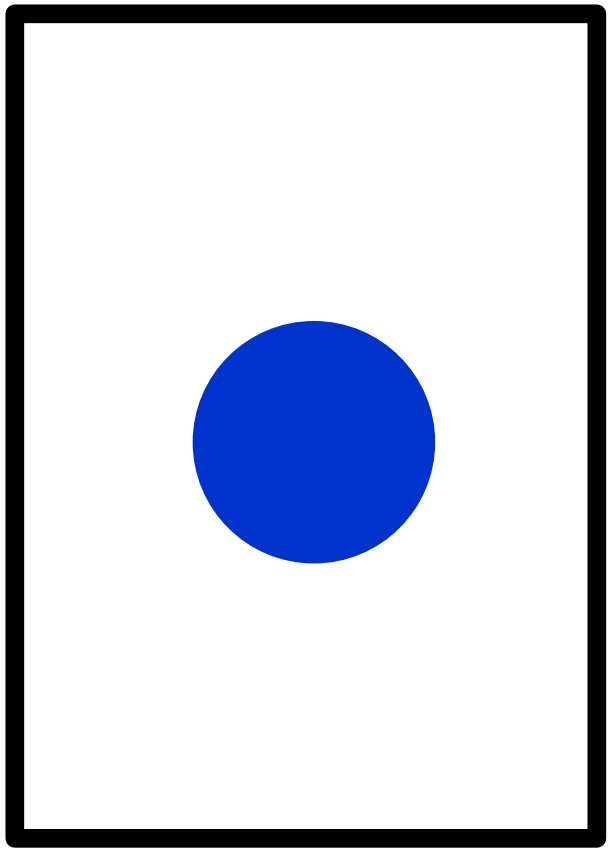
Rule: Shape

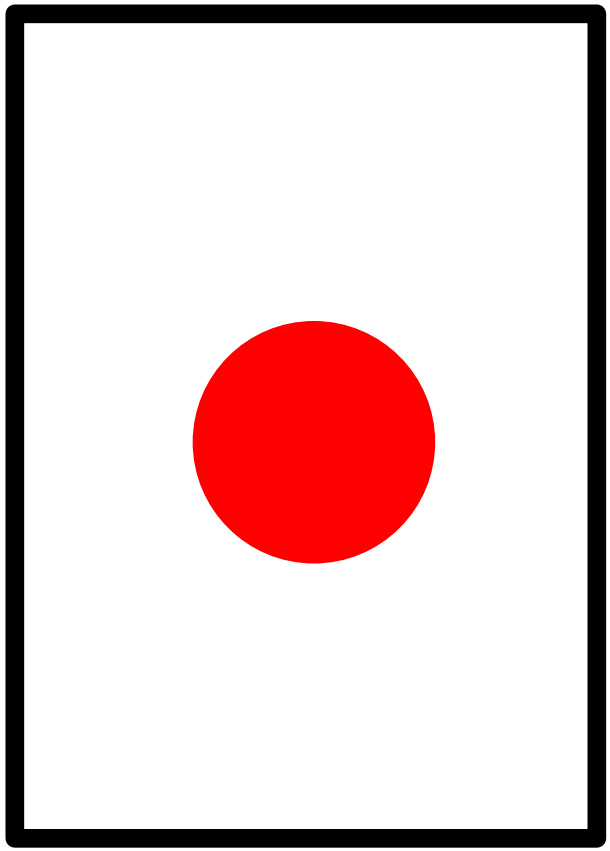


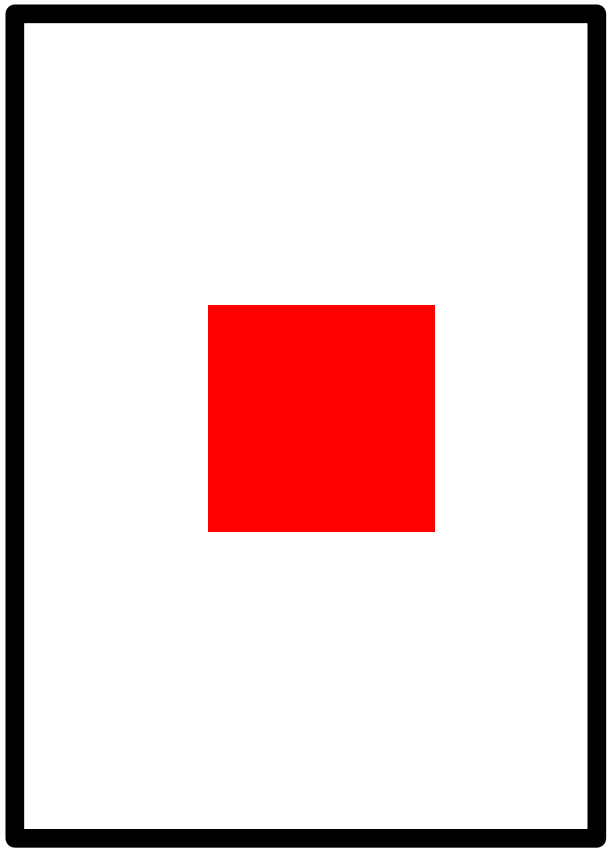


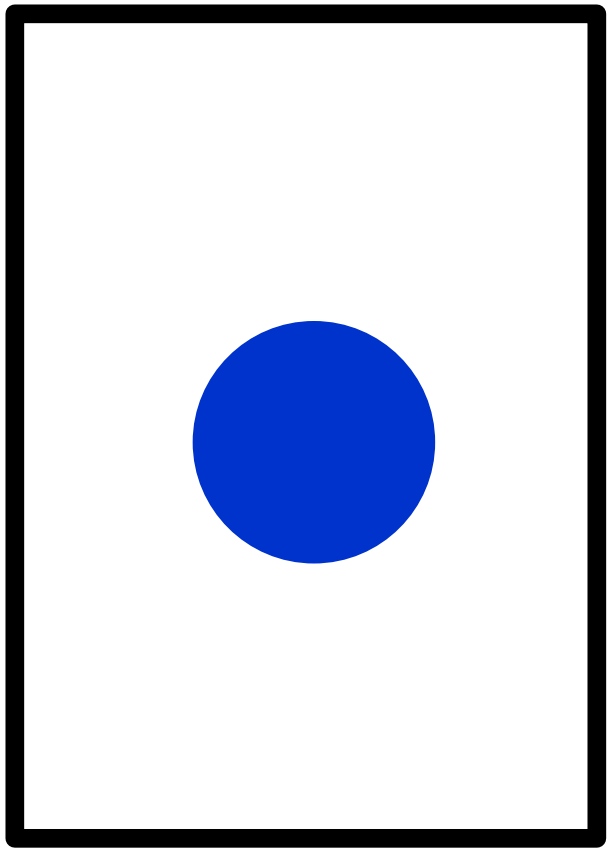


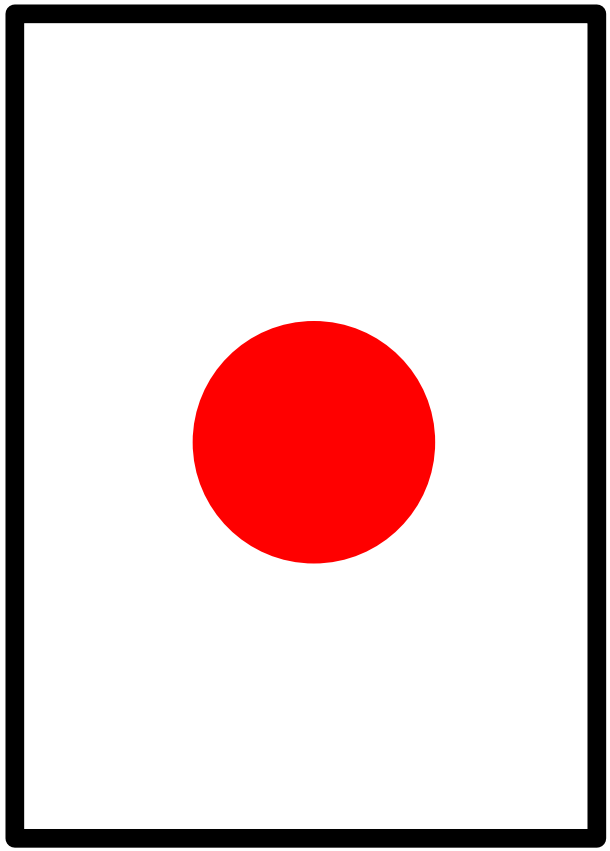




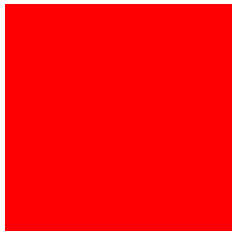


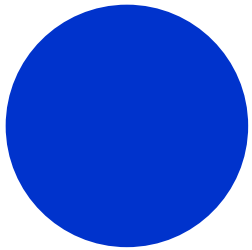


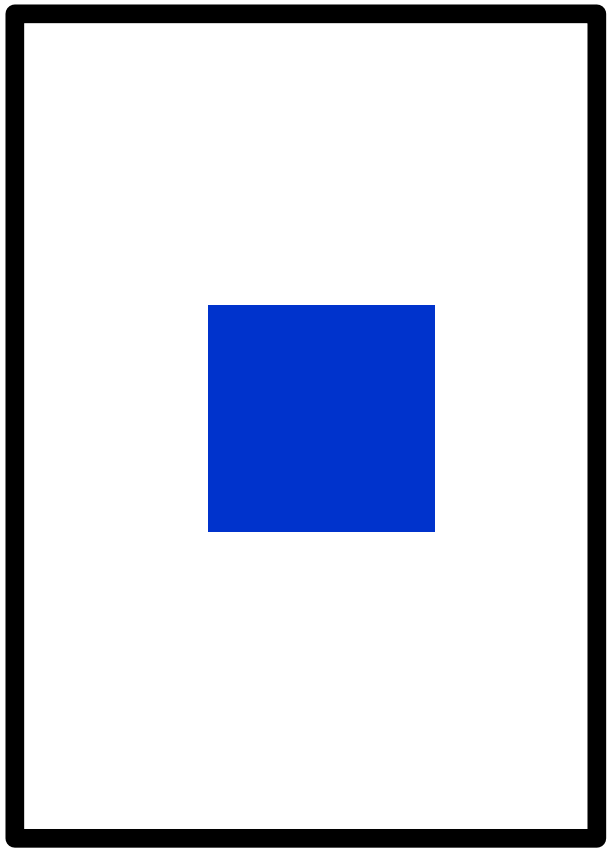


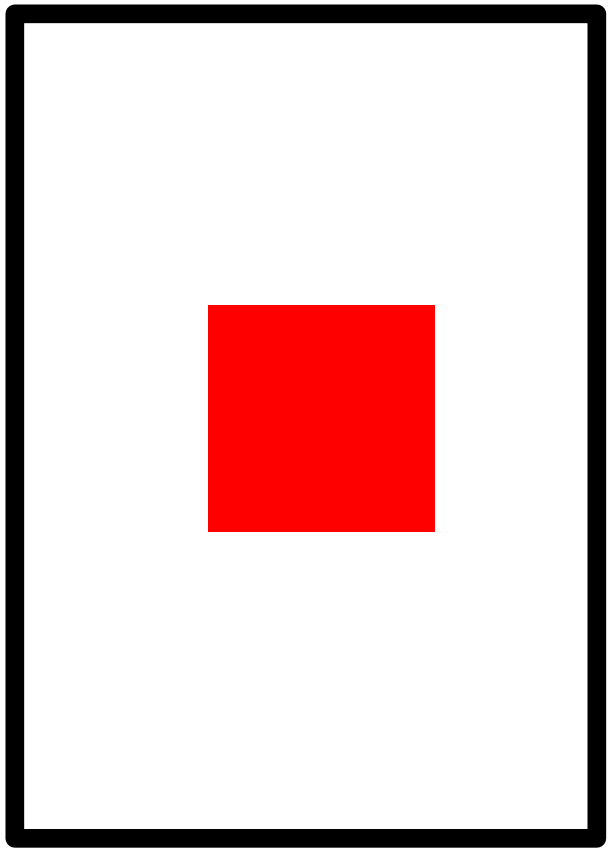


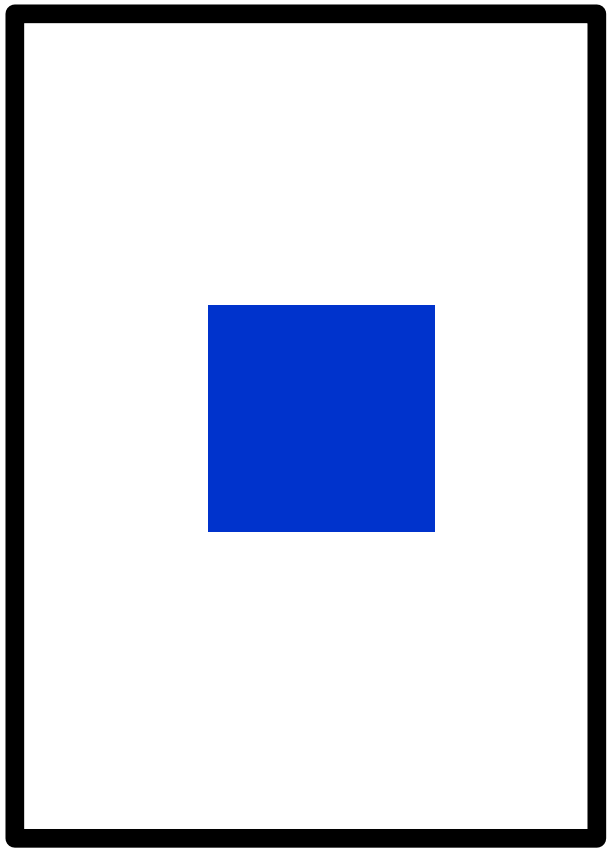
Rule: Colour

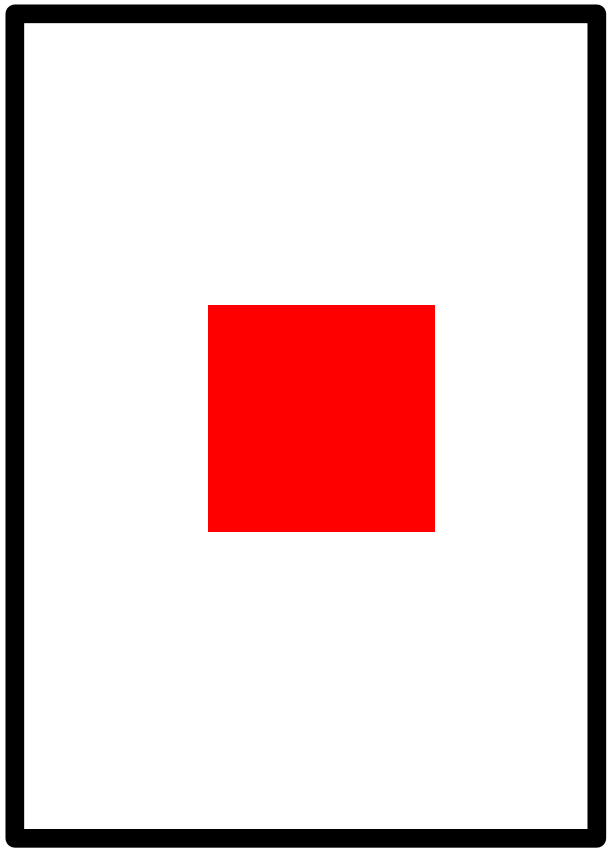


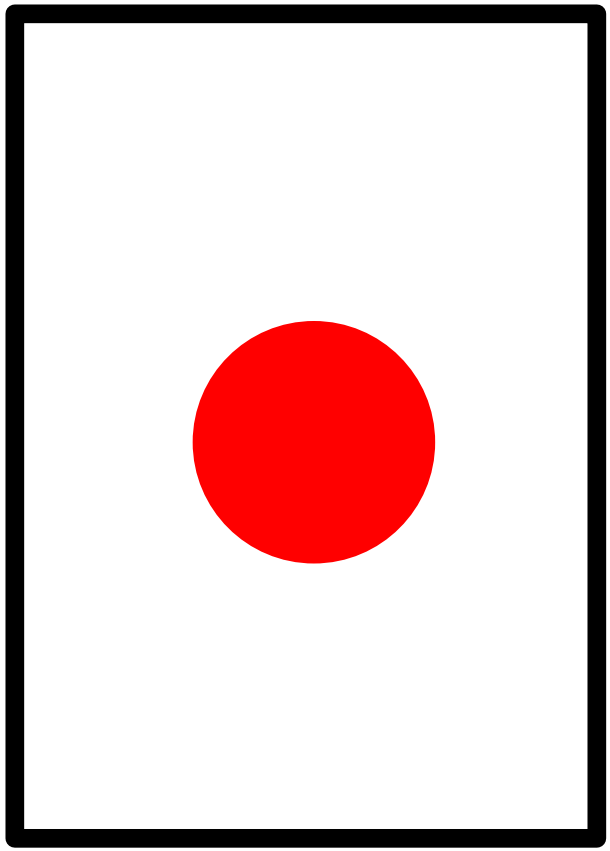


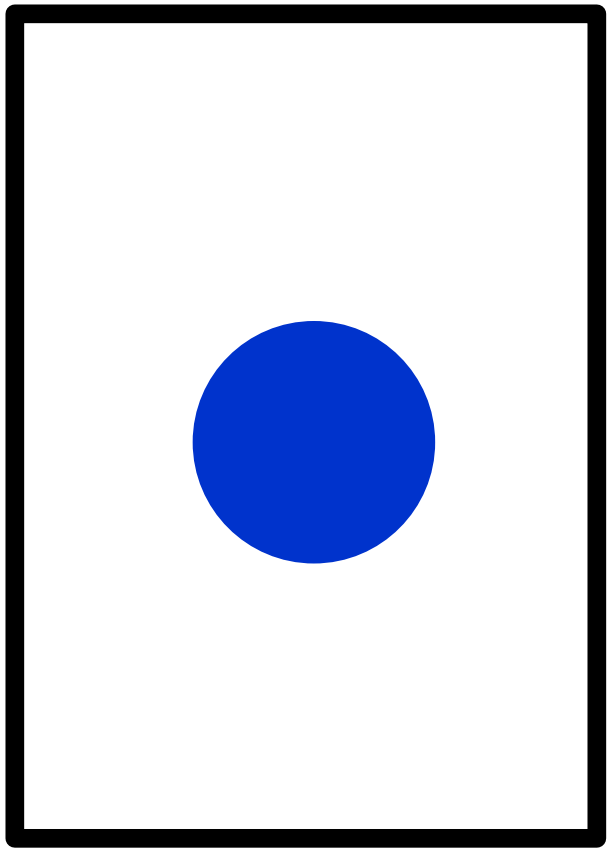


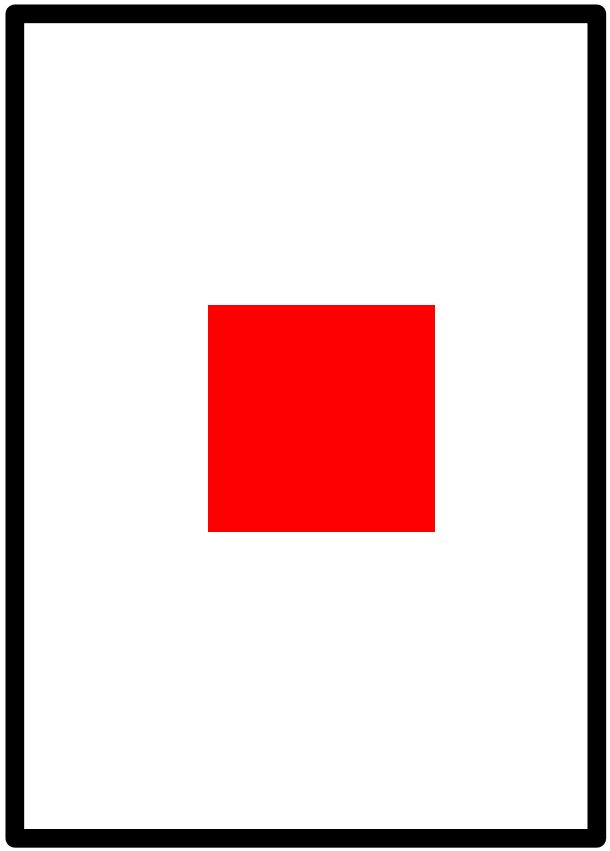


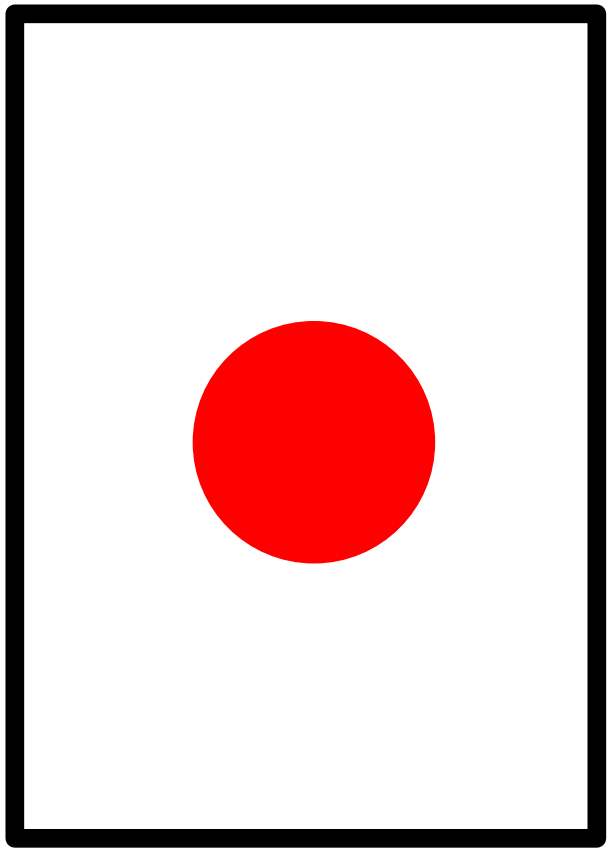




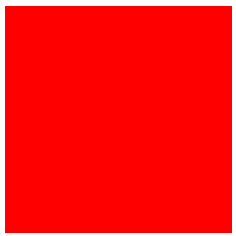


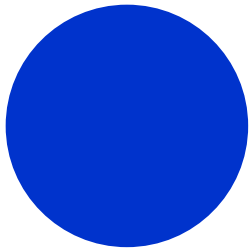


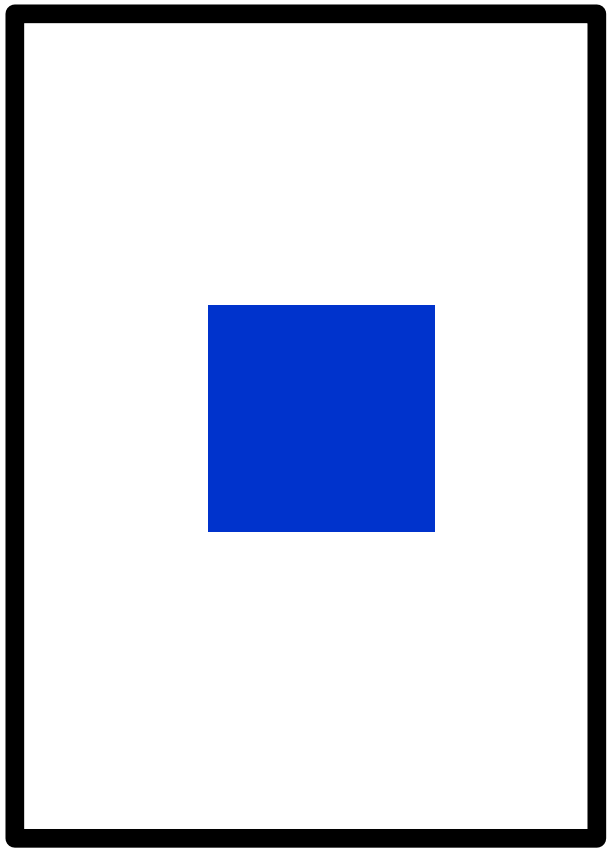


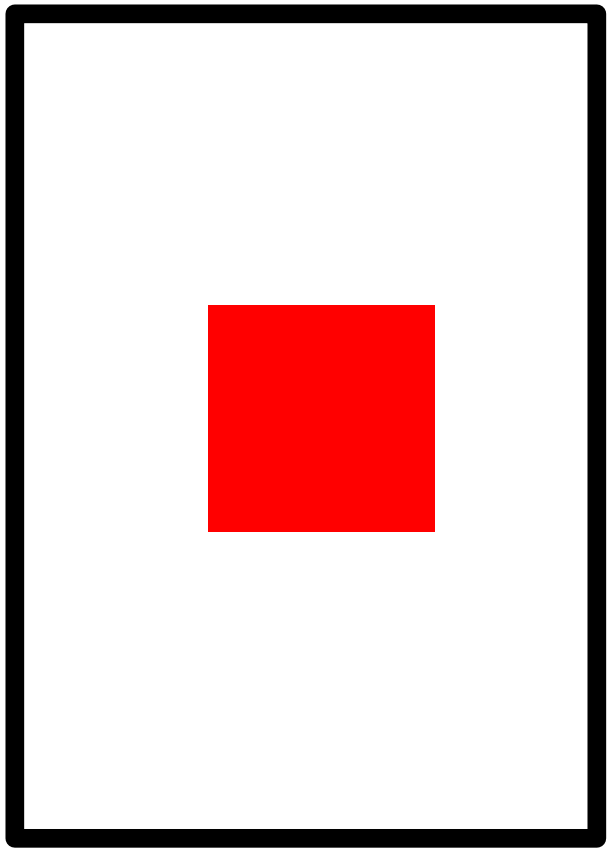


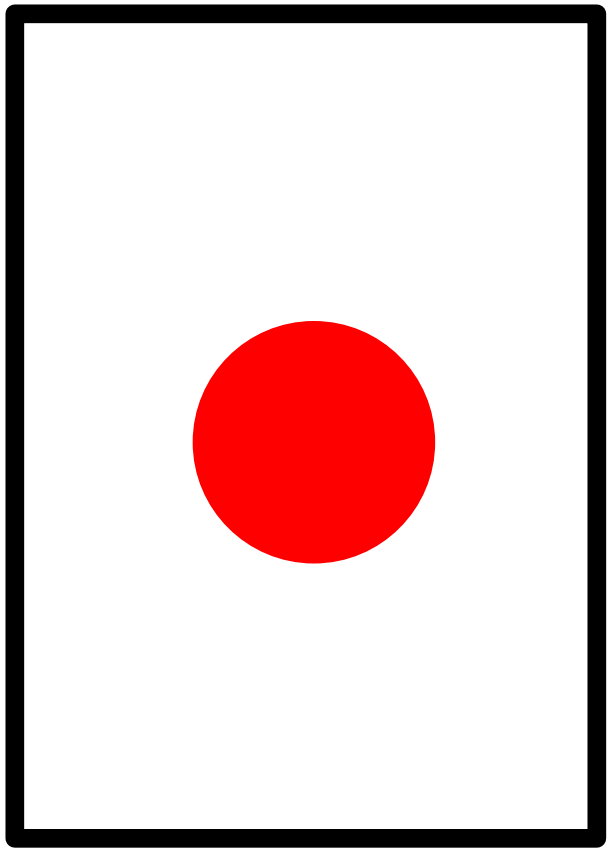
Rule: Shape

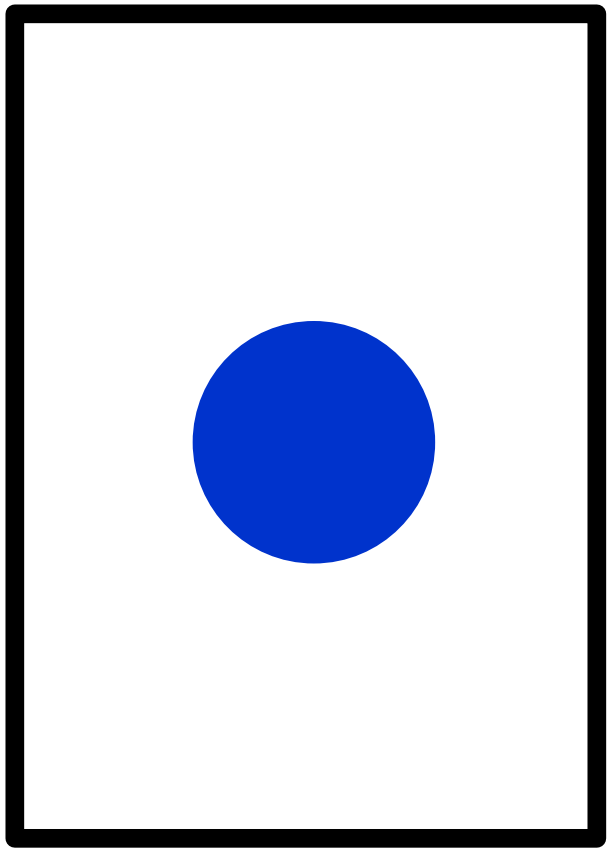


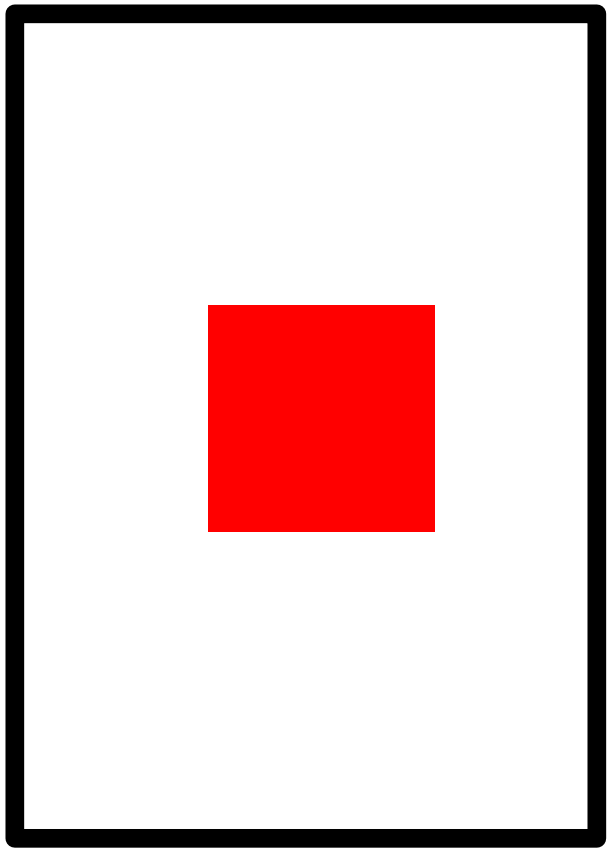












Stimulus Response Selection

The Stroop Task

Recite the colour of the words you see

Green

Red

Yellow

Blue

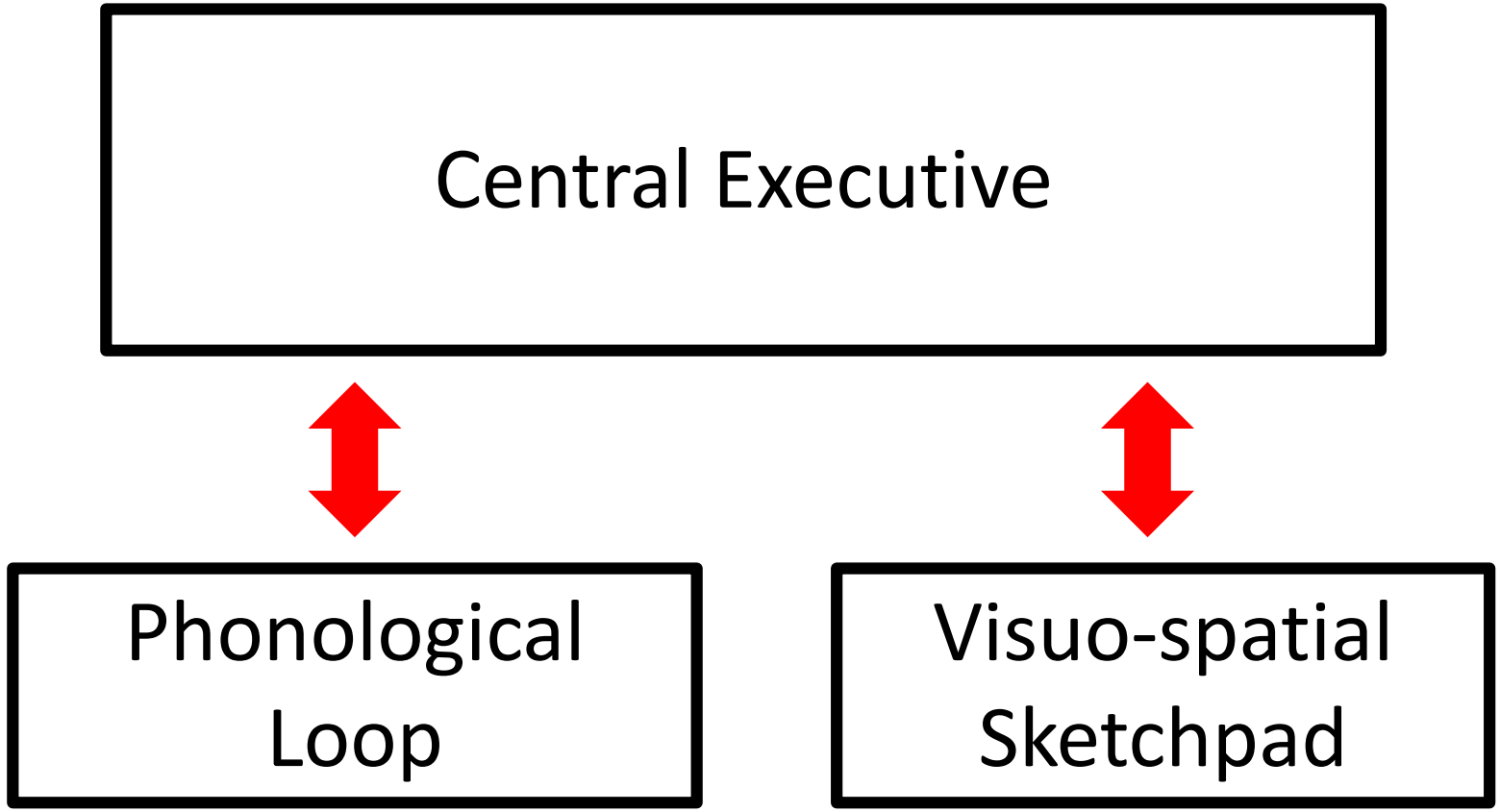
Red

Green

Blue

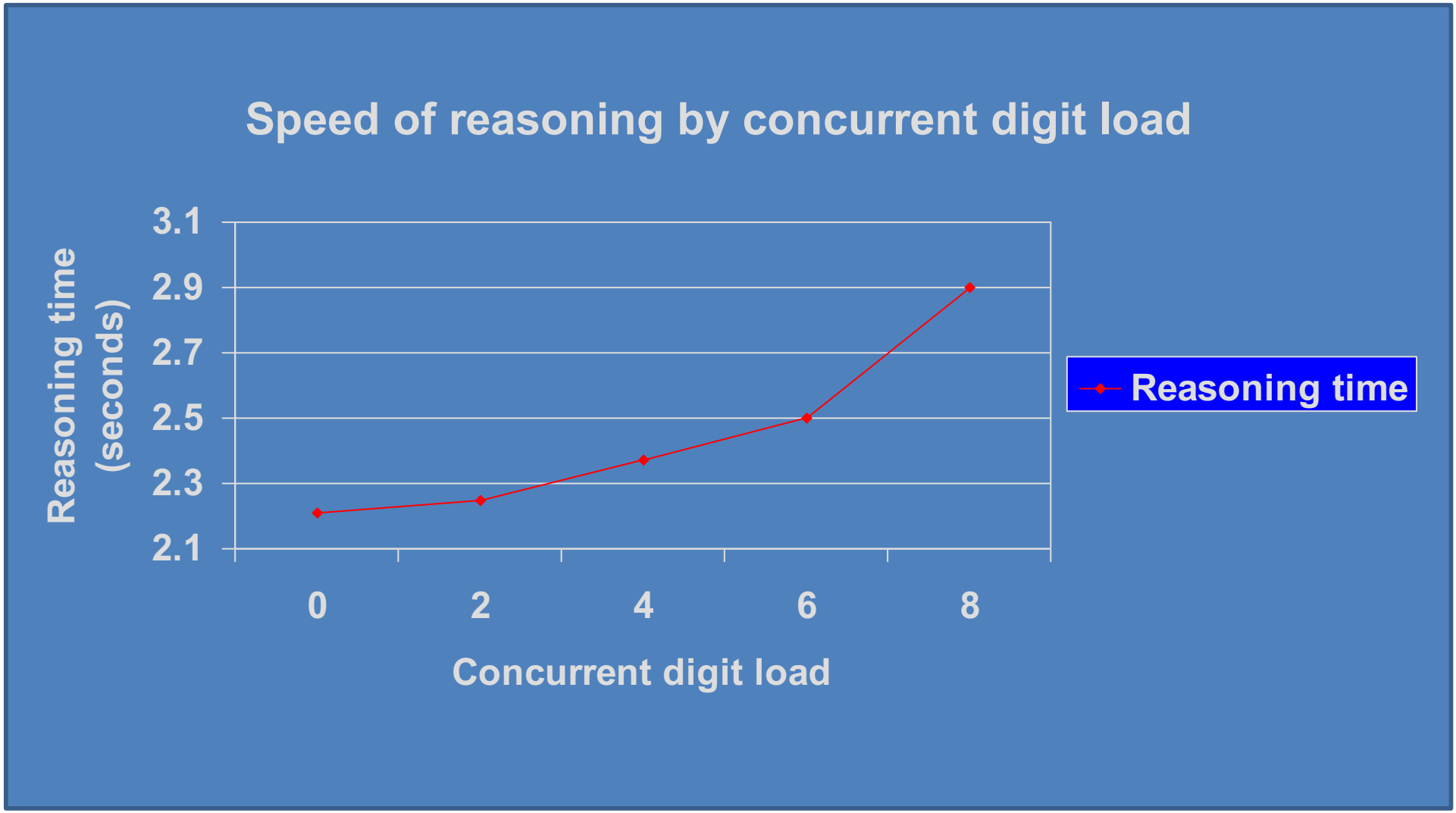
Green

Yellow



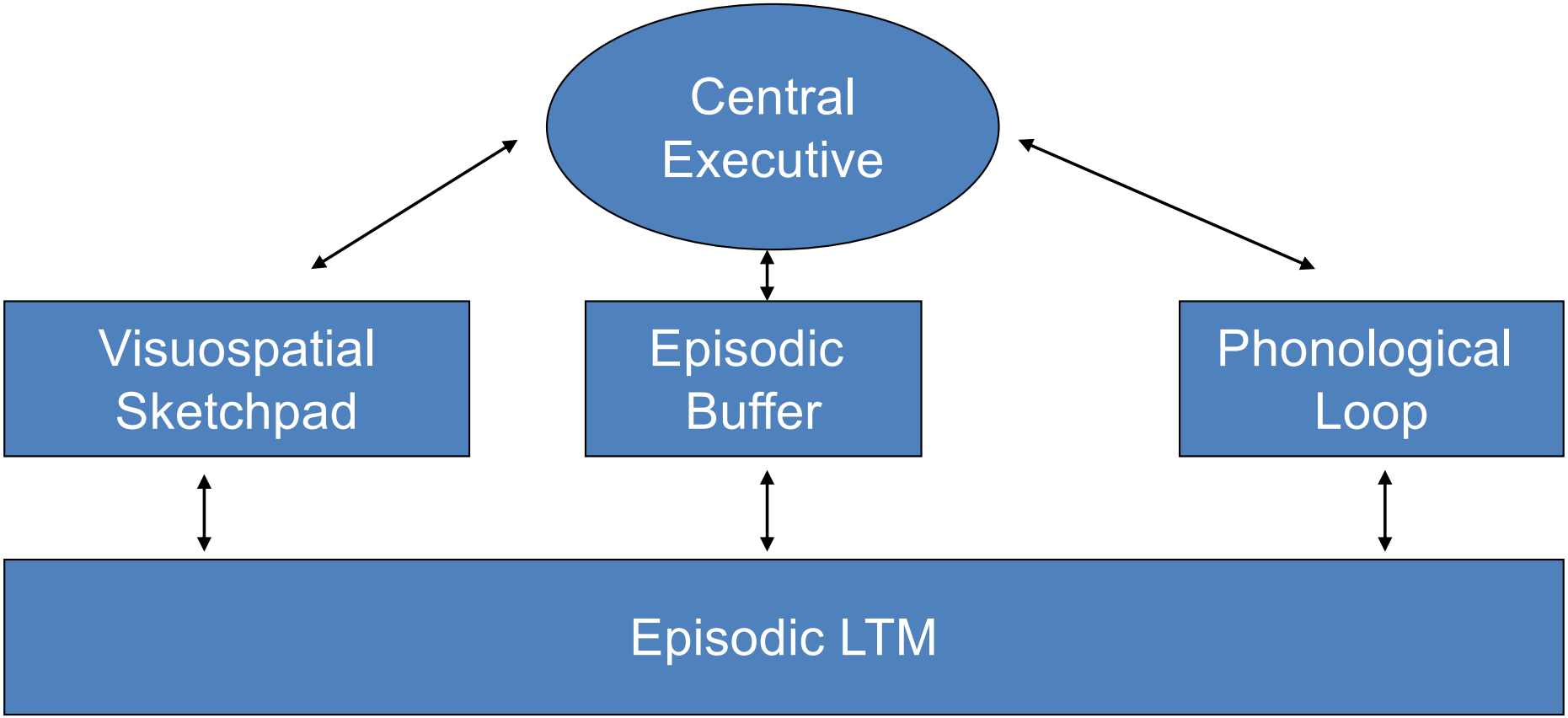
Baddeley & Hitch, 1974

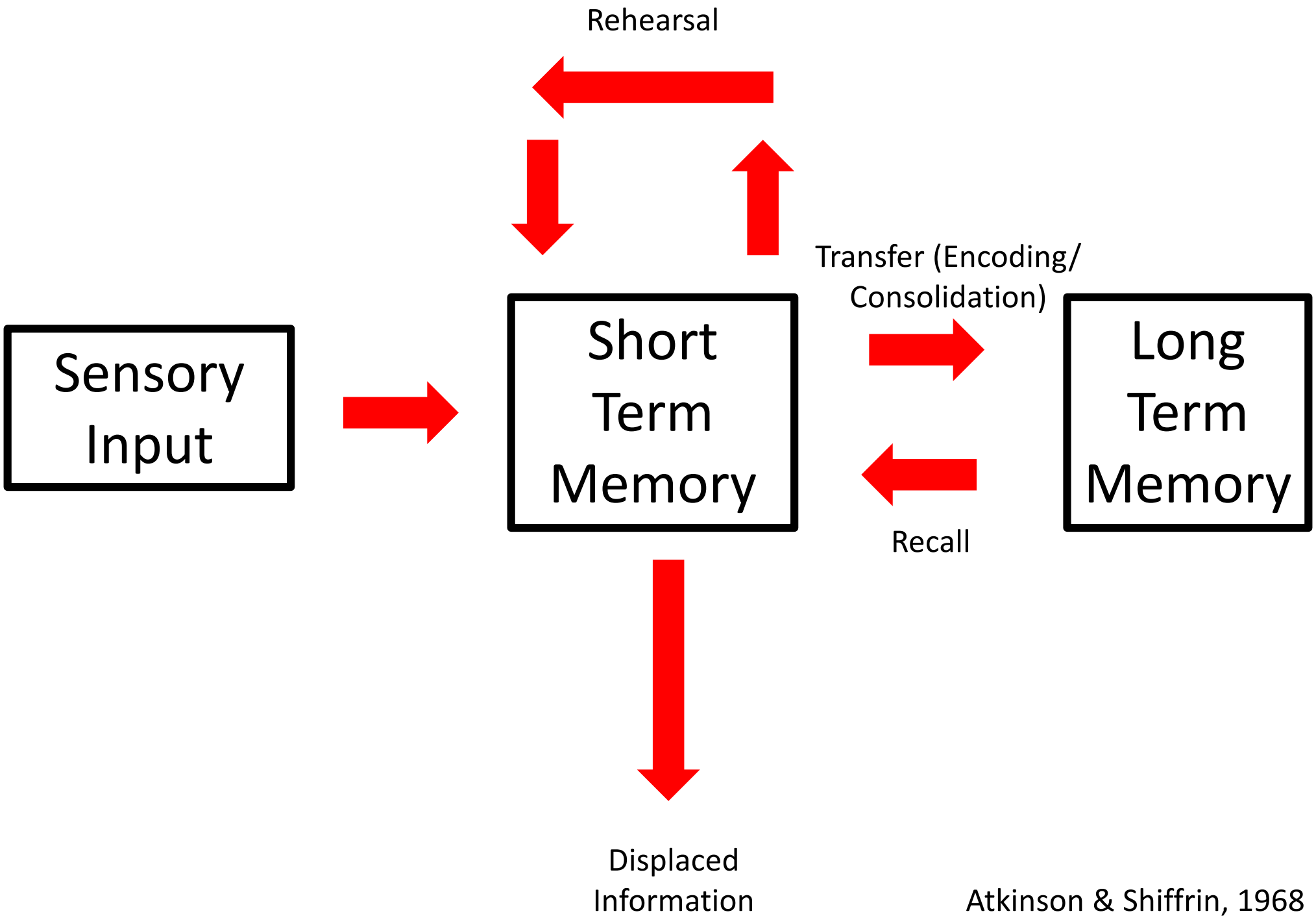
Why a central executive?



Baddeley (1986)

4-Component Model of Working Memory





Atkinson & Shiffrin, 1968

Three famous studies in memory…

Short Term Memory Capacity 7+/- 2

Miller's Magic 7 +/-2

Miller (1956) The magical 7 +/-2.

The STM can hold on average between 5 & 9 items of information.

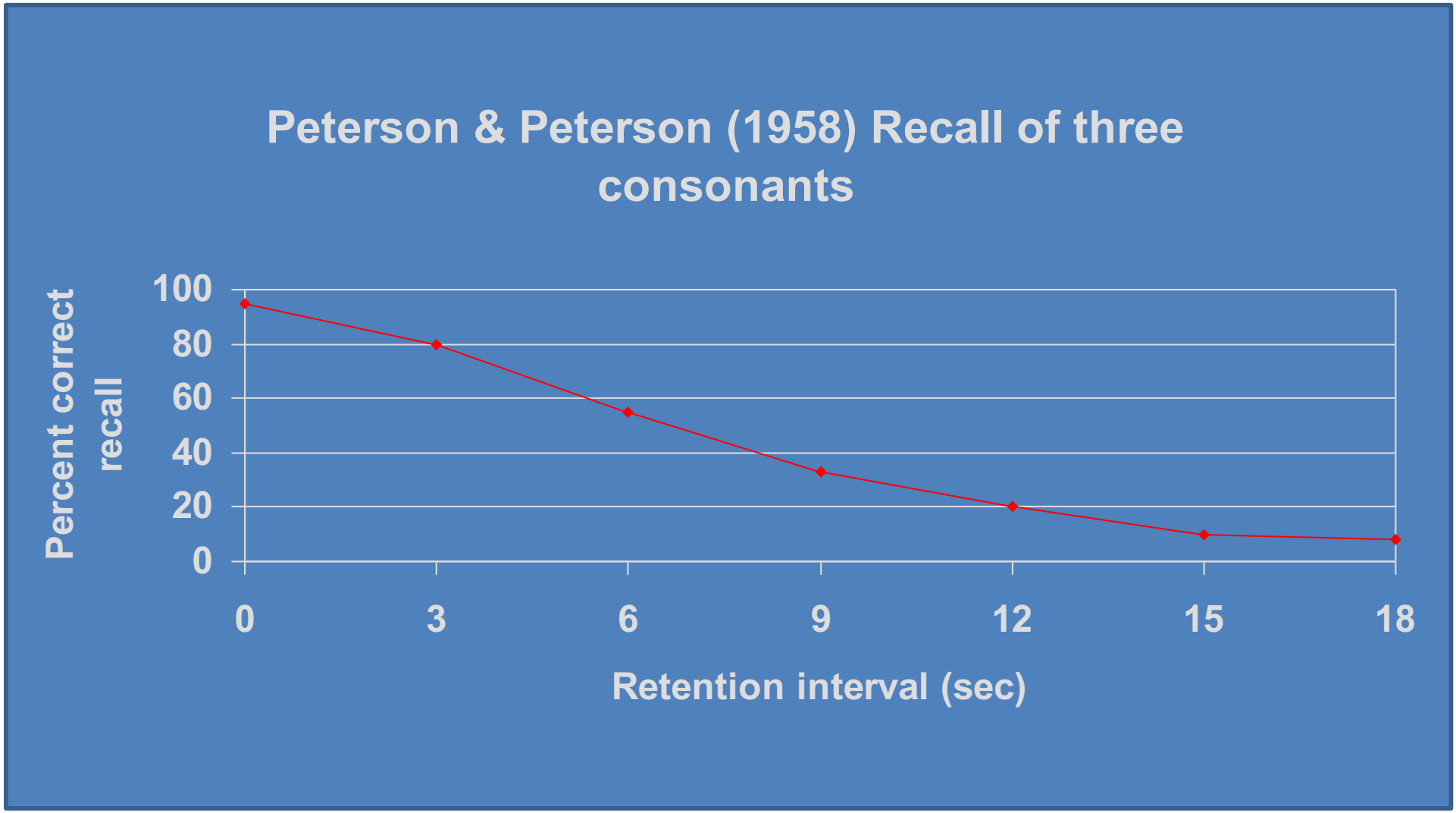
Chunking: Grouping the items together into chunks.

Telephone number: when you remember it you often recite a group of the numbers as together e.g. 01253 720 742, rather than 01255364289.

Meaningful chunks are even easier to remember:

CBC, FBI, NBC

Rapid forgetting: Distraction

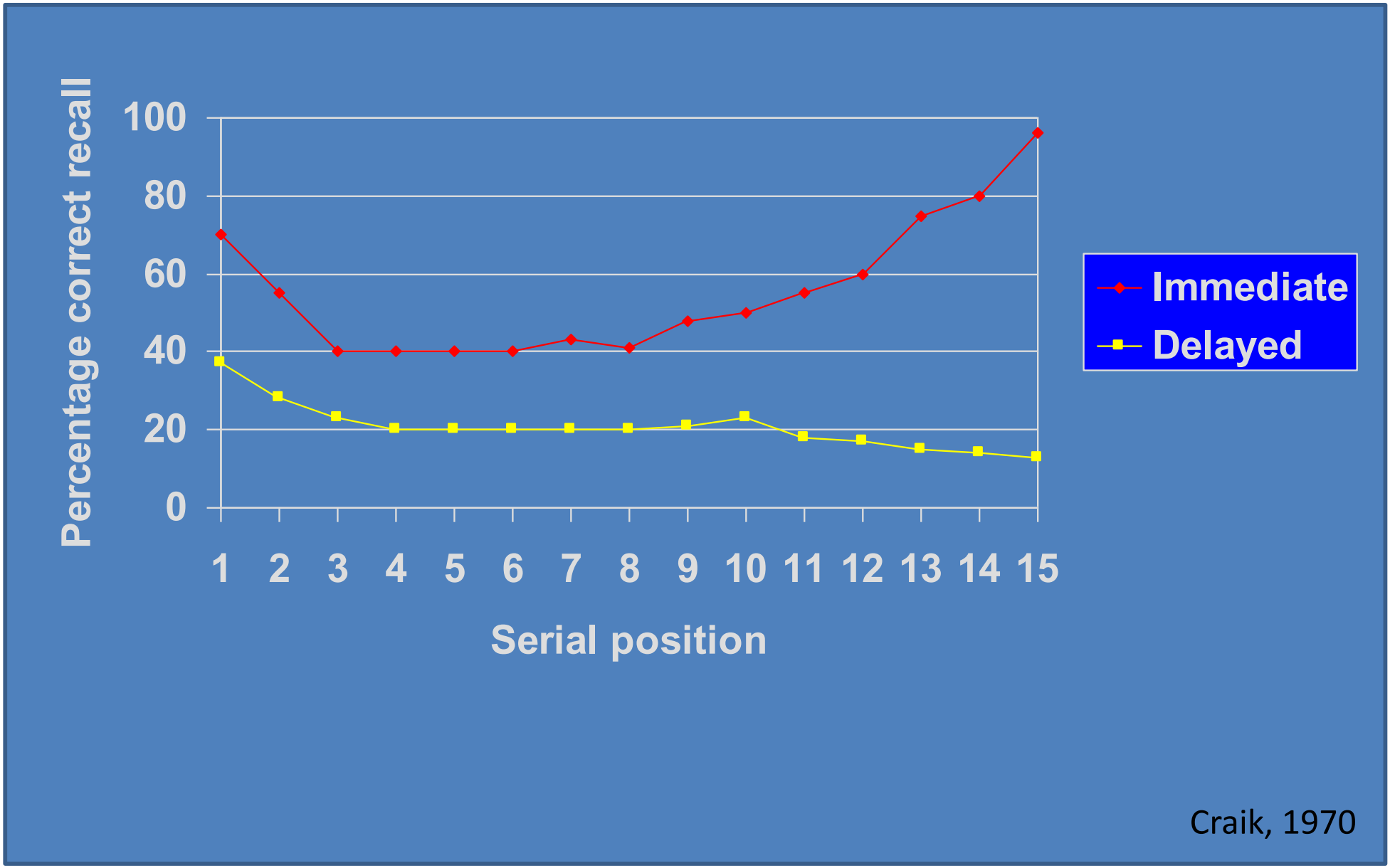


Interpretation of Peterson

- Memory loss in STM is the result of decay; “the memory trace decays” without rehearsal

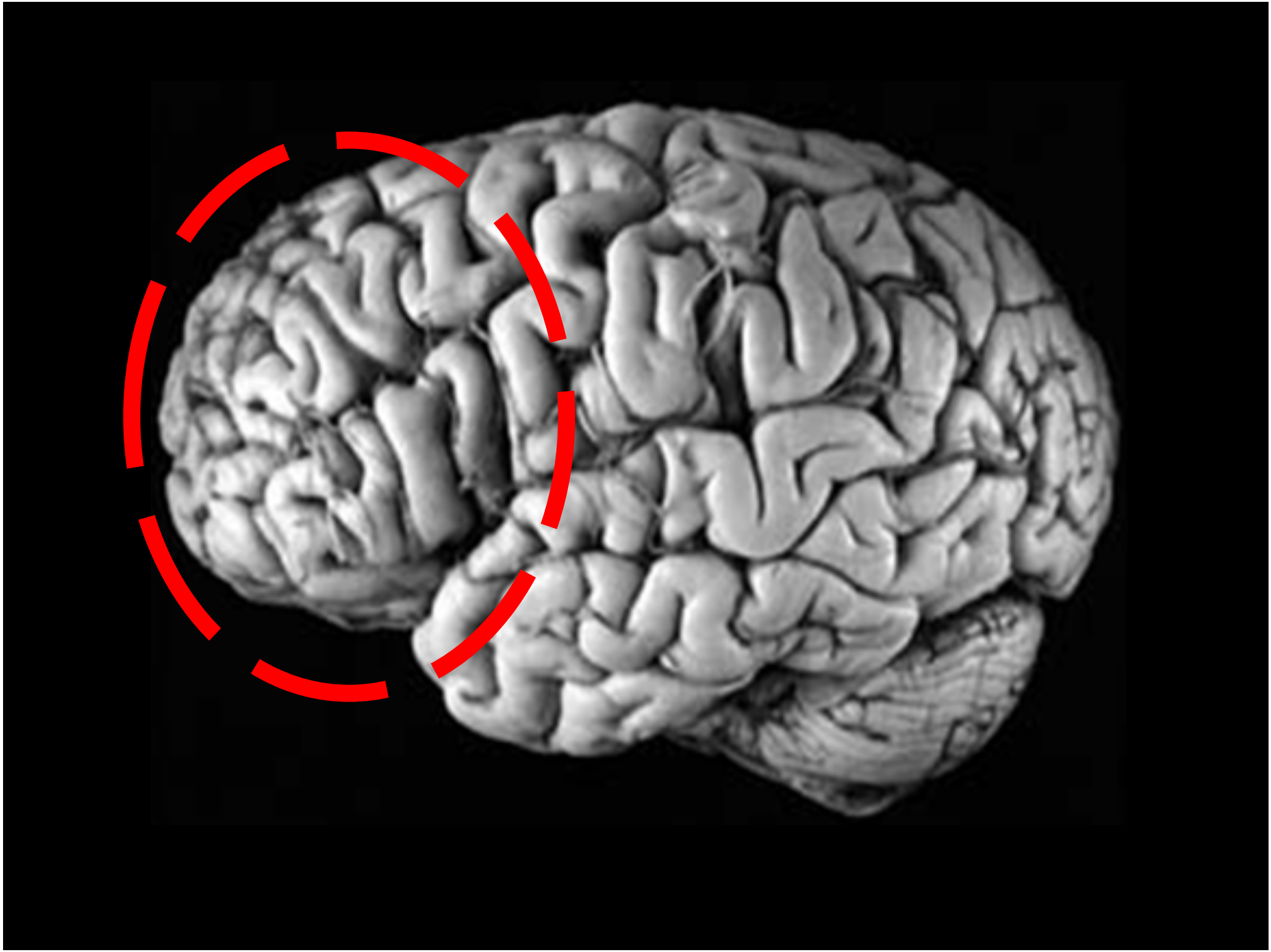
- STM different than long-term because it was believed that forgetting in long-term memory results from interference

Primacy and Recency

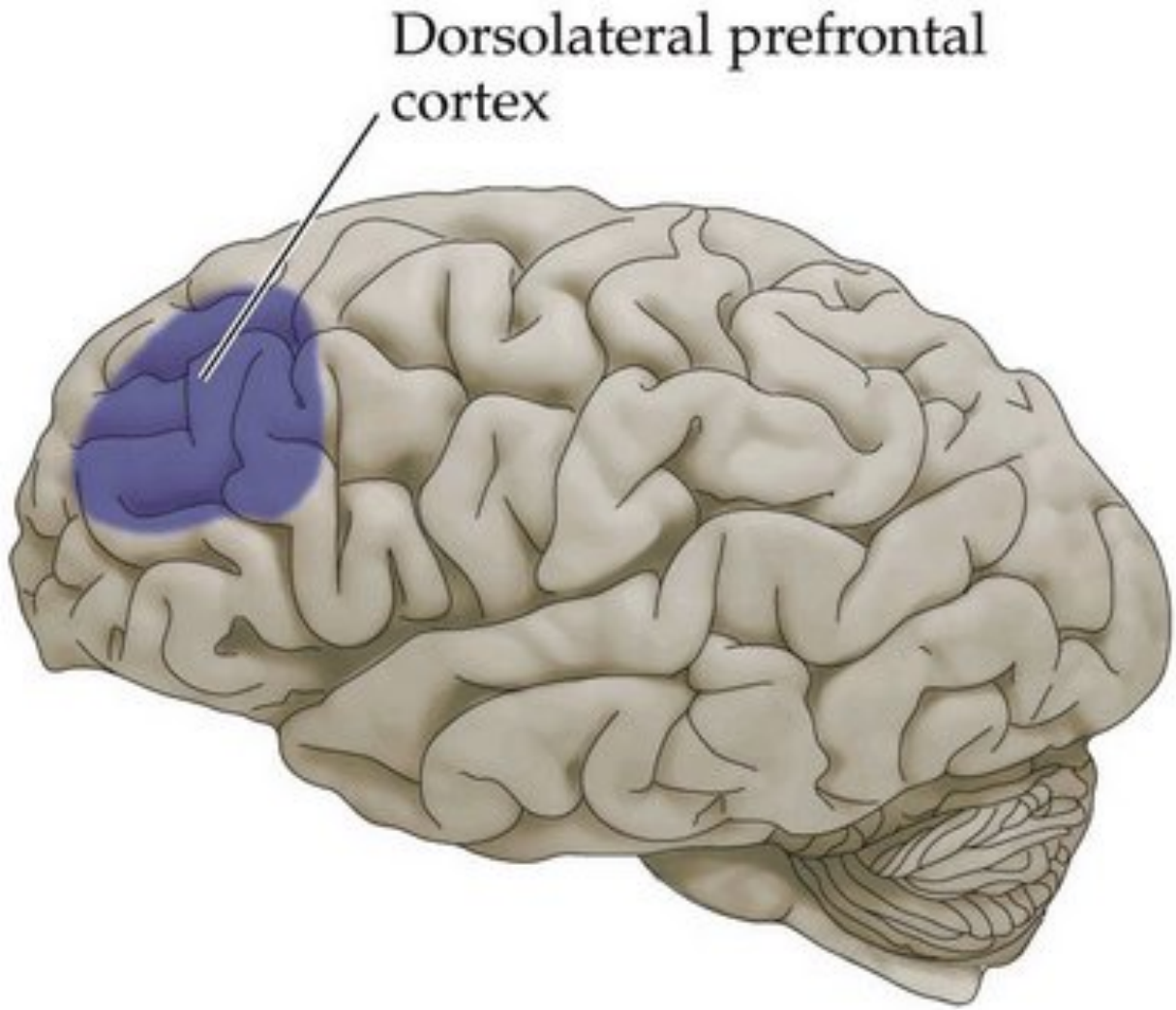


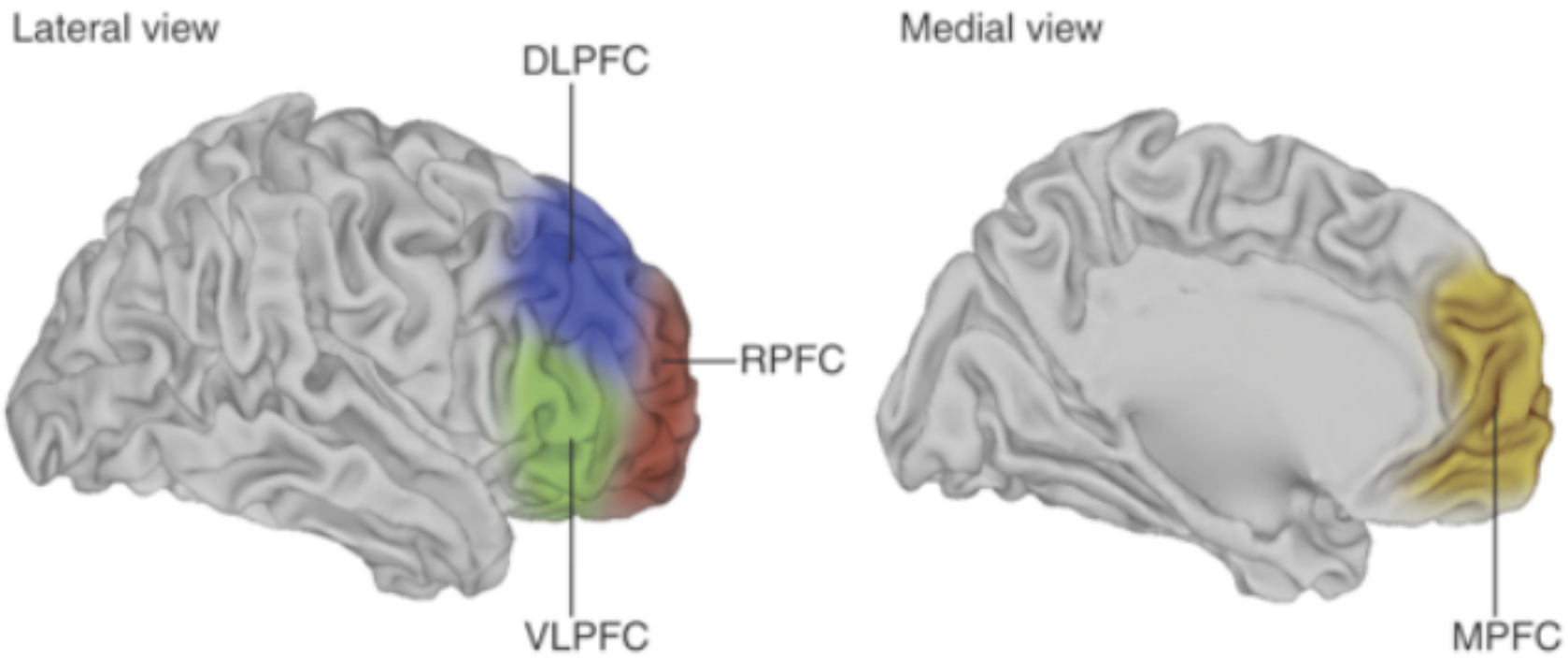
Craik, 1970

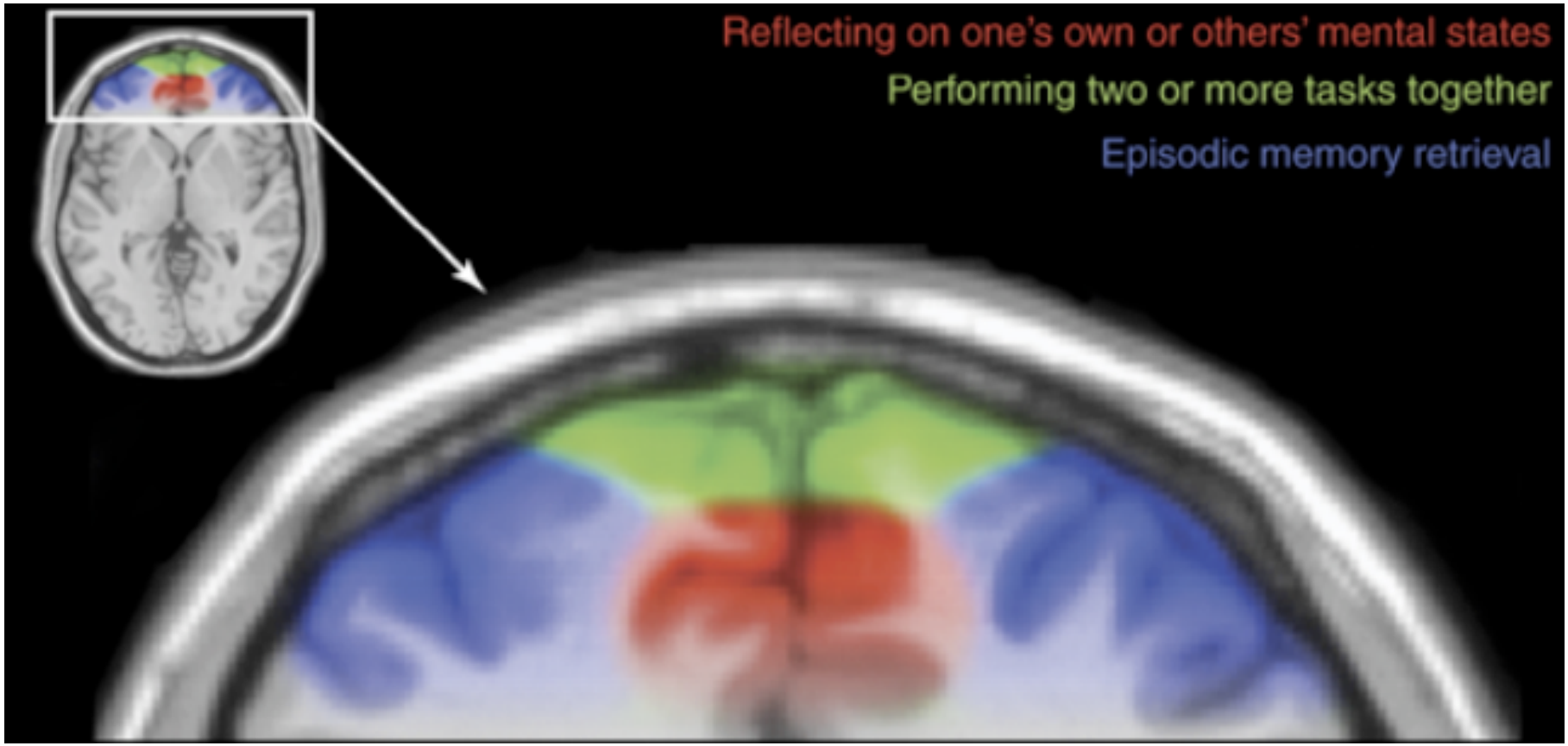
Neural Basis of WM



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

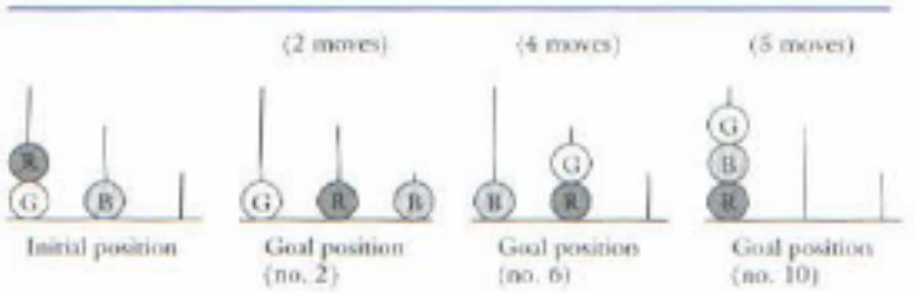


FIGURE 11.7 Example of three problems in Tower of London task. The same initial position is used in each problem. The balls must be moved to the goal position one at a time in as few moves as possible. The number of moves required to reach each goal is noted. R, red; G, green; B, blue.

- **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

Wisconsin Card Sort Test

- Adults with prefrontal cortex damage (especially dorsolateral prefrontal cortex) behave like children on tasks that tap executive control, for example, on the **Wisconsin Card Sort Test** (WCST)

- They can learn the first sorting rule, but after the sorting rule changes, they **perseverate** – they continue to apply the first rule even though it has changed

- (Although this is a fundamental finding, it has been challenged recently).

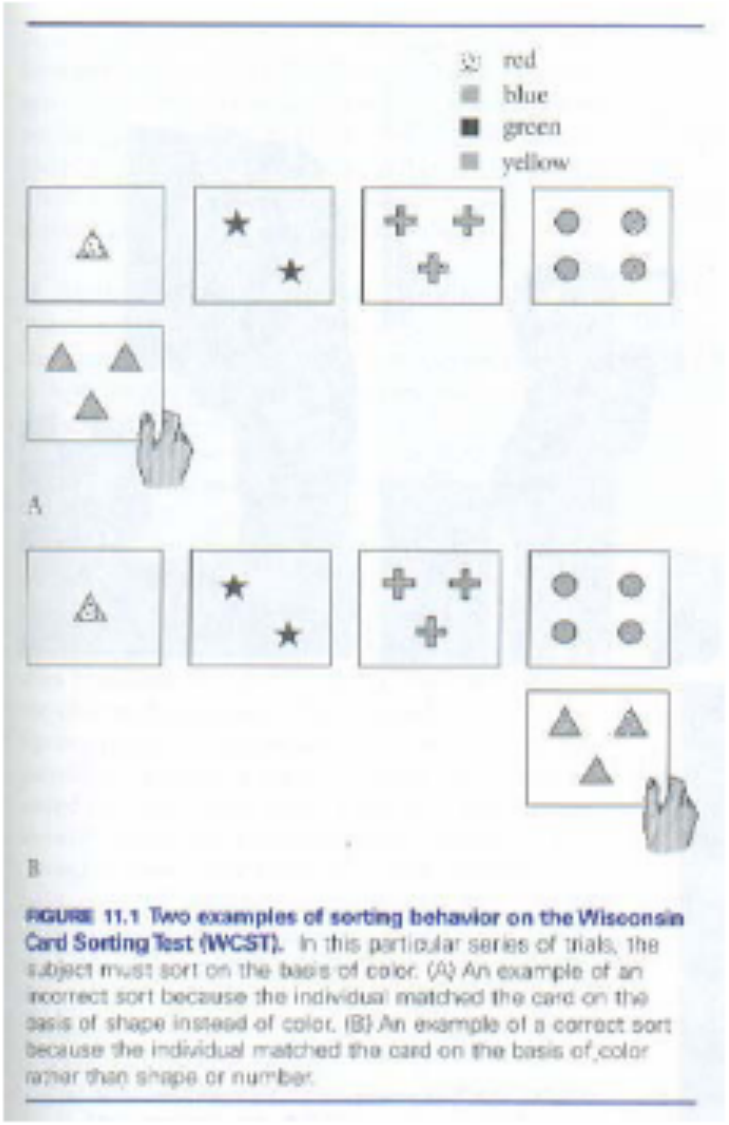
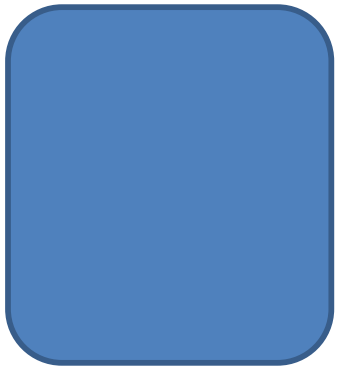


FIGURE 11.1 Two examples of sorting behavior on the Wisconsin Card Sorting Test (WCST). In this particular series of trials, the subject must sort on the basis of color. (A) An example of an incorrect sort because the individual matched the card on the basis of shape instead of color. (B) An example of a correct sort because the individual matched the card on the basis of color rather than shape or number.

Mechanisms for Working Memory



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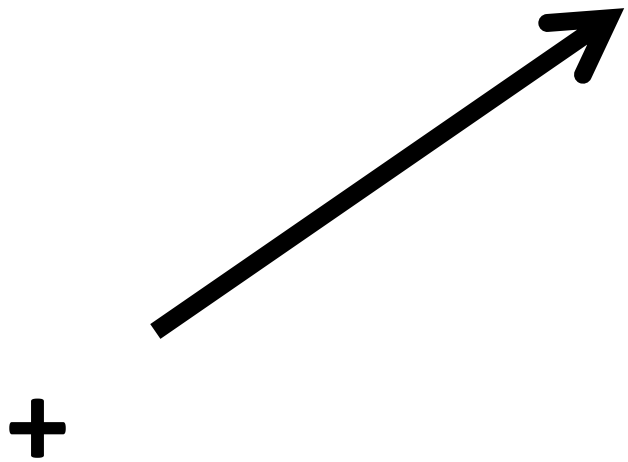
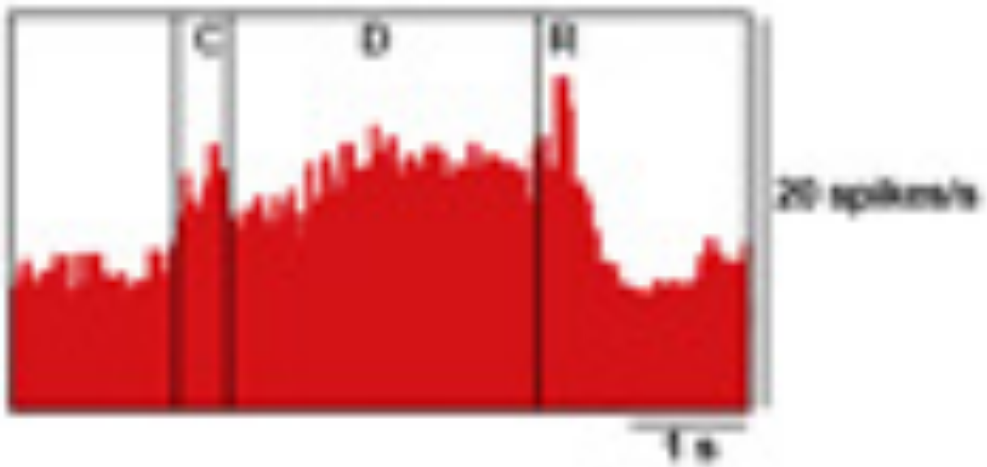
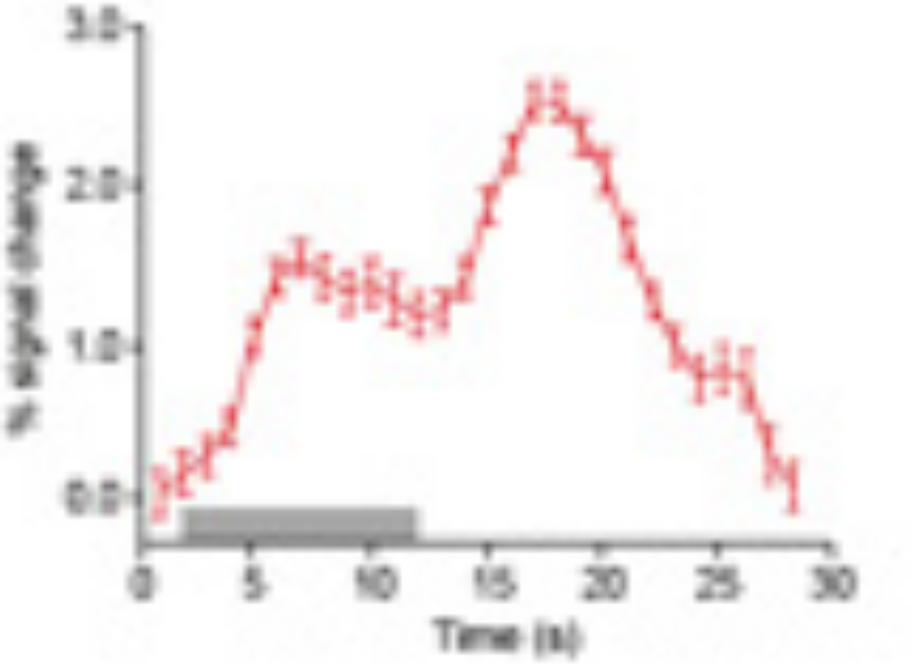
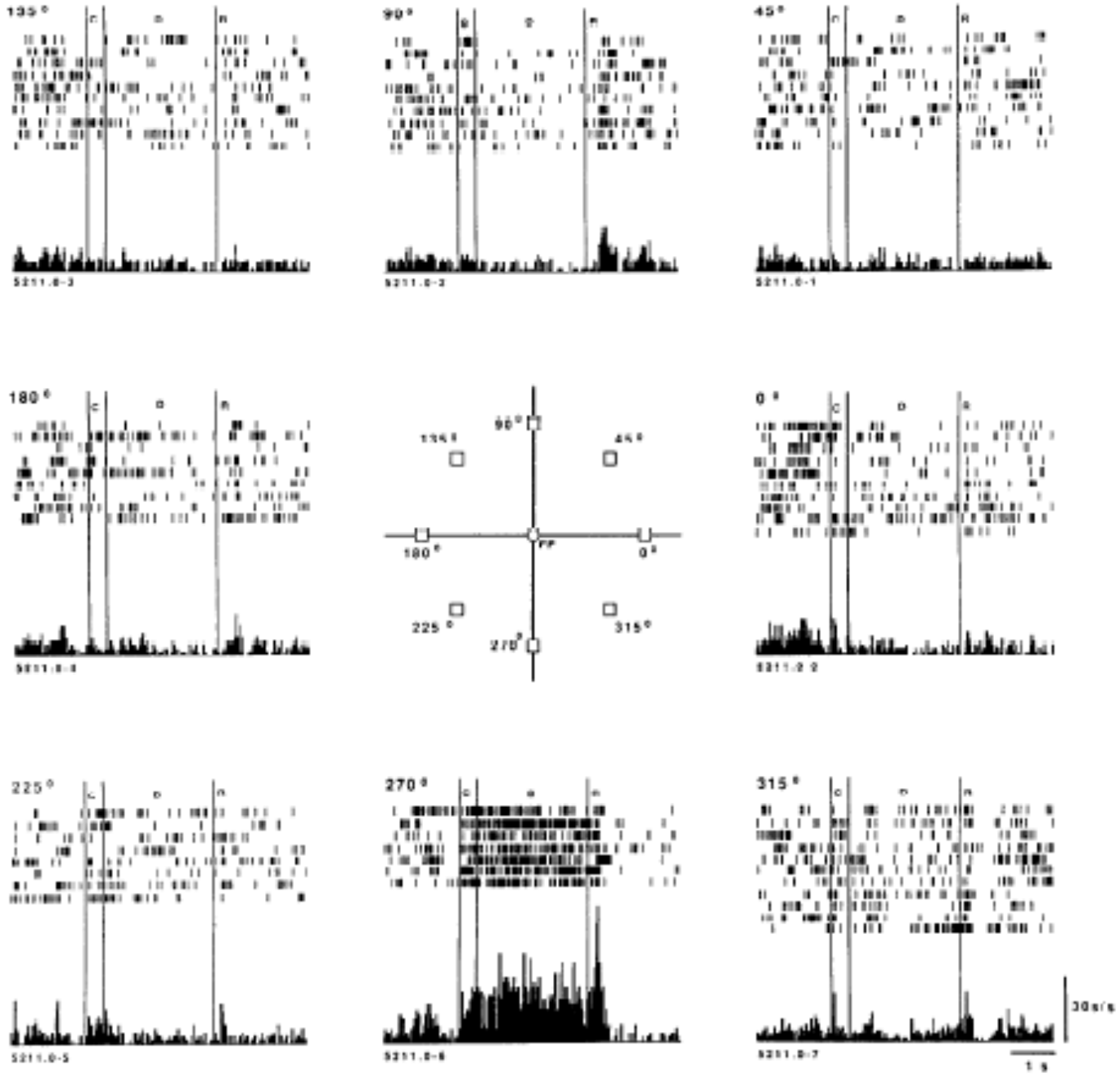


Macaque



Human




135°
90°
45°
180°
90°
135°
45°
180°
0°
225°
270°
315°
30 s/s
1 s

Dissociation of Object and Spatial Processing Domains in Primate Prefrontal Cortex

Fraser A. W. Wilson,* Séamas P. Ó Scalaidhe,
Patricia S. Goldman-Rakic

Areas and pathways subserving object and spatial vision are segregated in the visual system. Experiments show that the primate prefrontal cortex is similarly segregated into object and spatial domains. Neurons that code information related to stimulus identity are dissociable, both by function and region, from those that code information related to stimulus location. These findings indicate that the prefrontal cortex contains separate processing mechanisms for remembering "what" and "where" an object is.

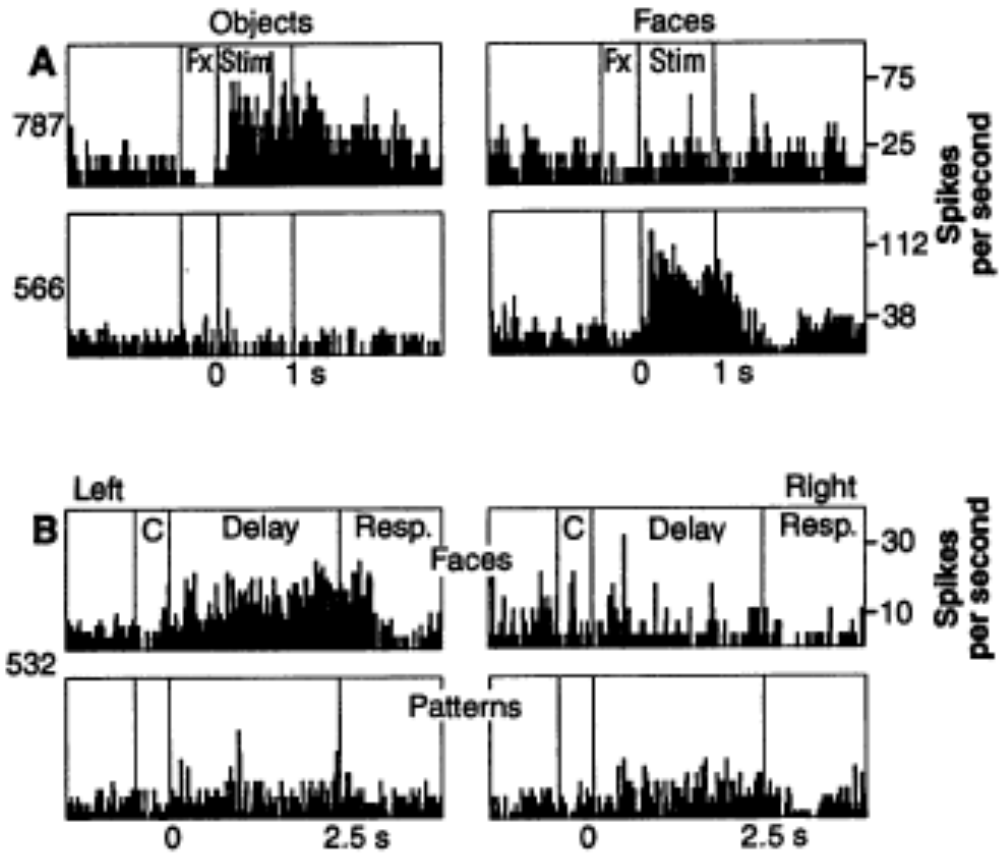


Fig. 2. (**A**) Stimulus and face-selective responses in the picture fixation task. Neuron 787 (upper panels) is responsive to a pattern stimulus and unresponsive to a face. Conversely, neuron 566 (lower panels) responds selectively to faces and is unresponsive to patterns; Fx, fixation; Stim, stimulus. (**B**) Responses of inferior convexity neuron 532 with delay-period activity after a specific monkey face in the memory task. Upper panels show differential responses to two faces (requiring left or right responses); lower panels show the lack of response to two patterns requiring left or right responses.

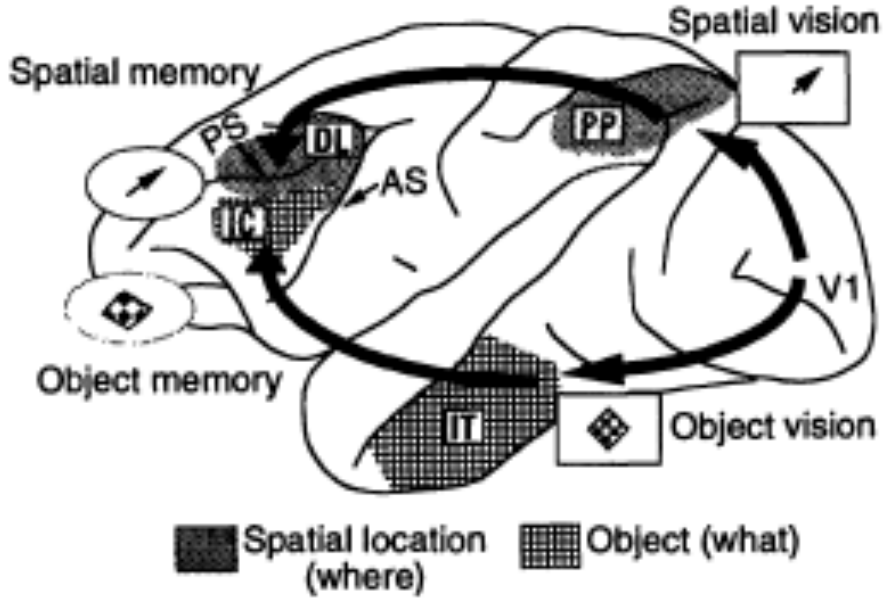
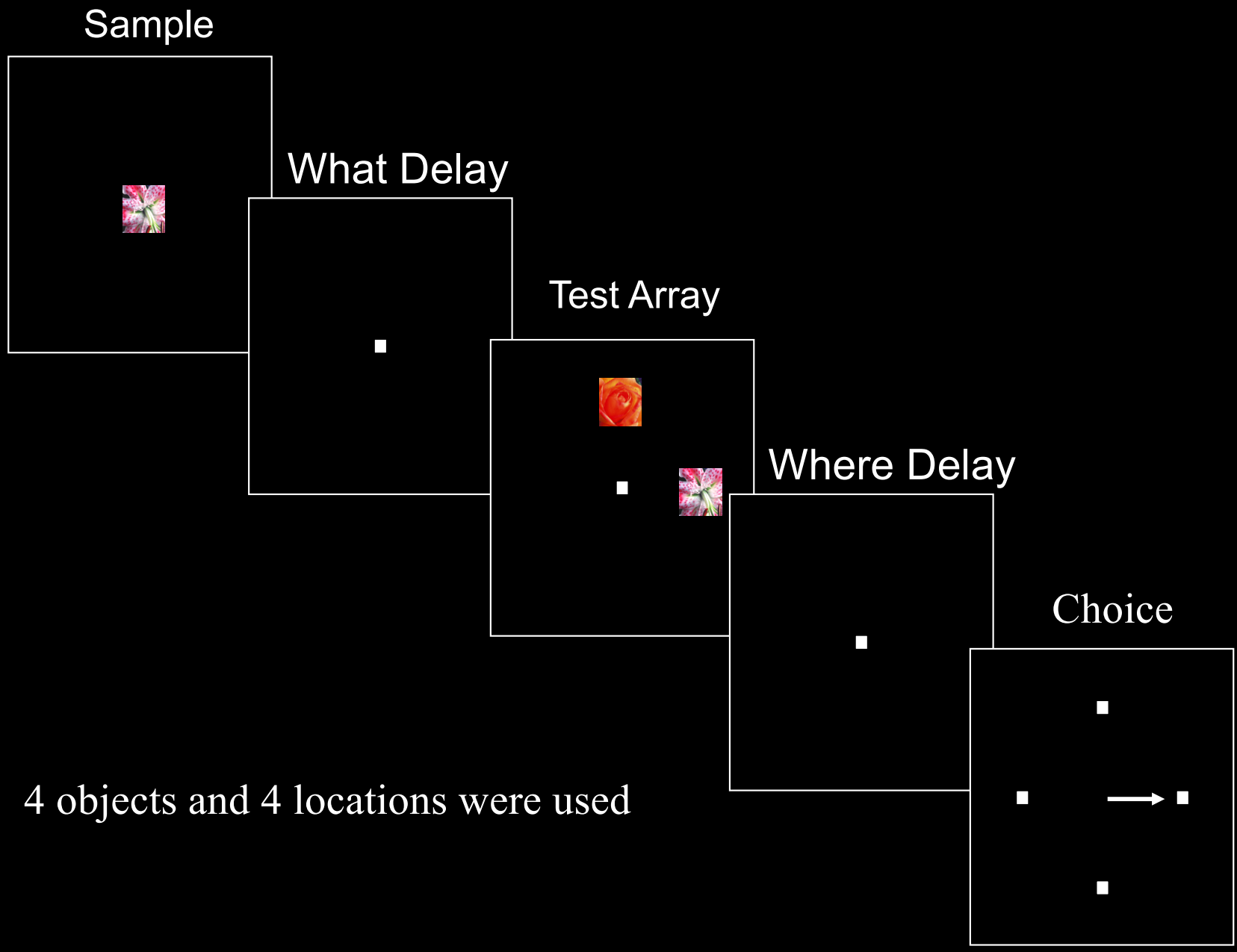
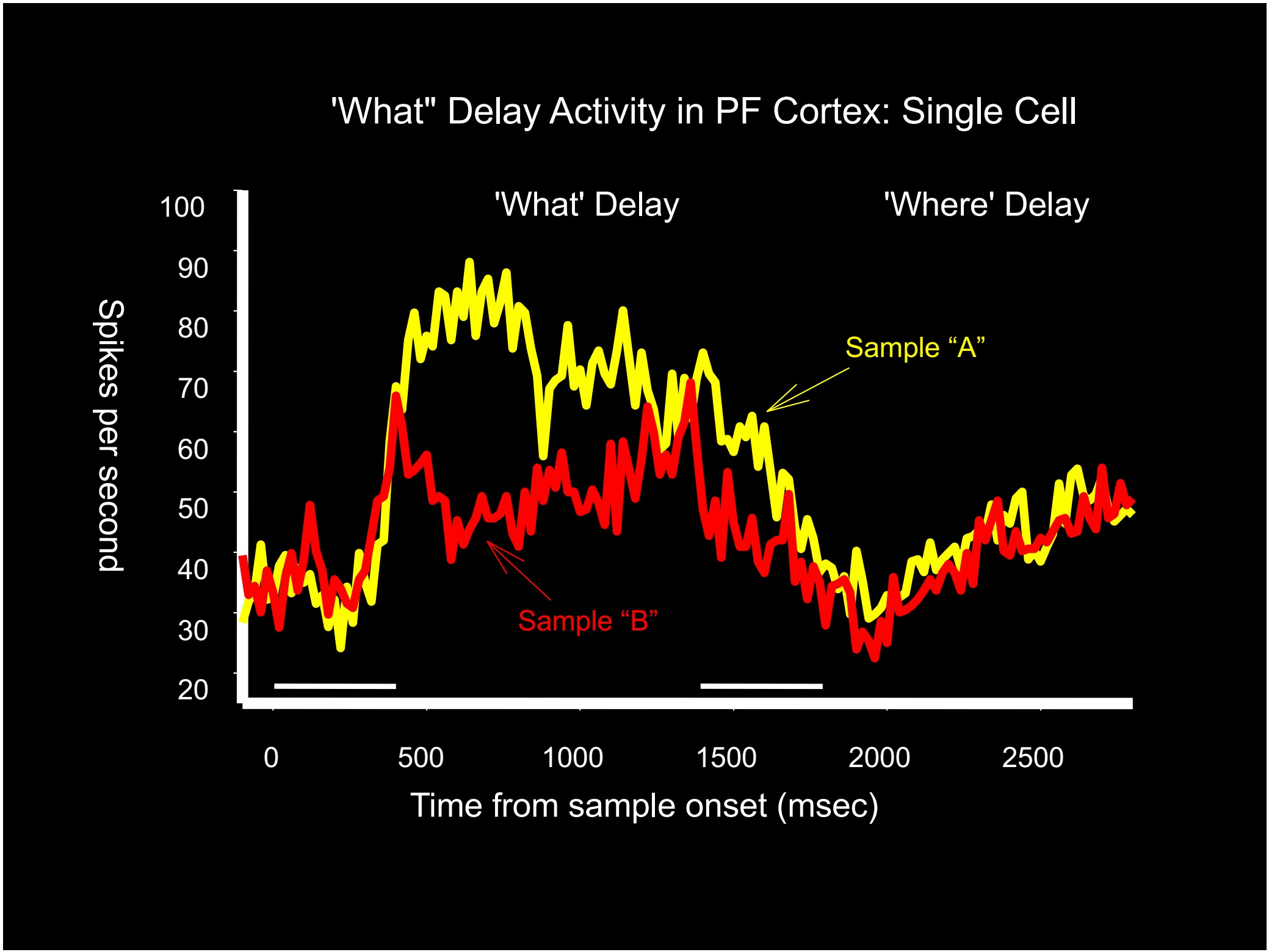


Fig. 3. Schematic diagram illustrating the primate visual systems implicated in foveal and peripheral vision and their connections with the prefrontal cortex; PS, principal sulcus; AS, arcuate sulcus. The posterior parietal (PP) cortex is concerned with spatial perception, and the inferior temporal (IT) cortex with object recognition. These regions are connected with the dorsolateral (DL) and inferior convexity (IC) prefrontal cortices (*2, 17*), where memoranda pertaining to spatial location and object identity are encoded in working memory.

What-Then-Where Task



4 objects and 4 locations were used

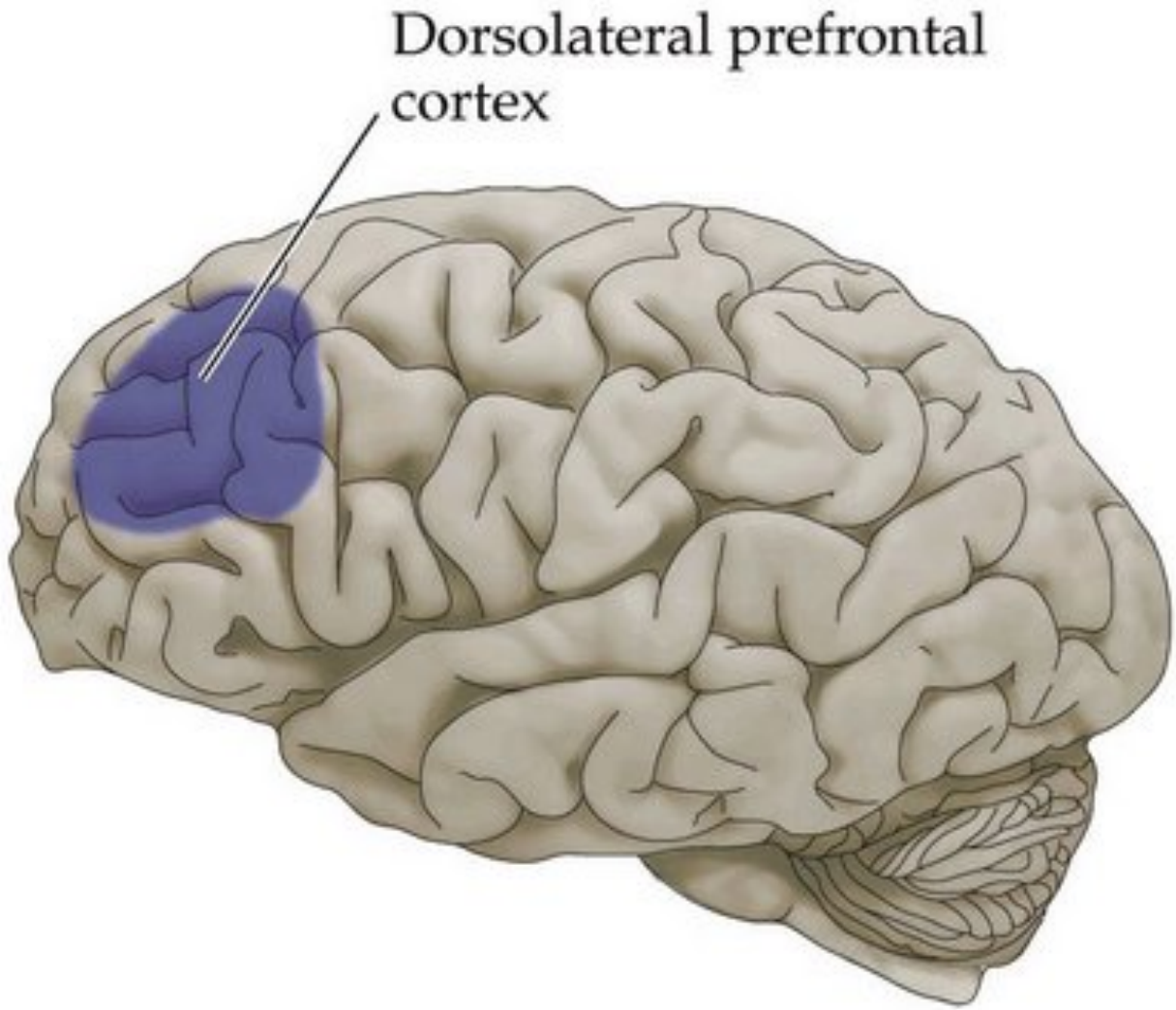

'What" Delay Activity in PF Cortex: Single Cell
'What' Delay
'Where' Delay
Sample "A"
Sample "B"
Spikes per second
100
90
80
70
60
50
40
30
20
0
500
1000
1500
2000
2500
Time from sample onset (msec)

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

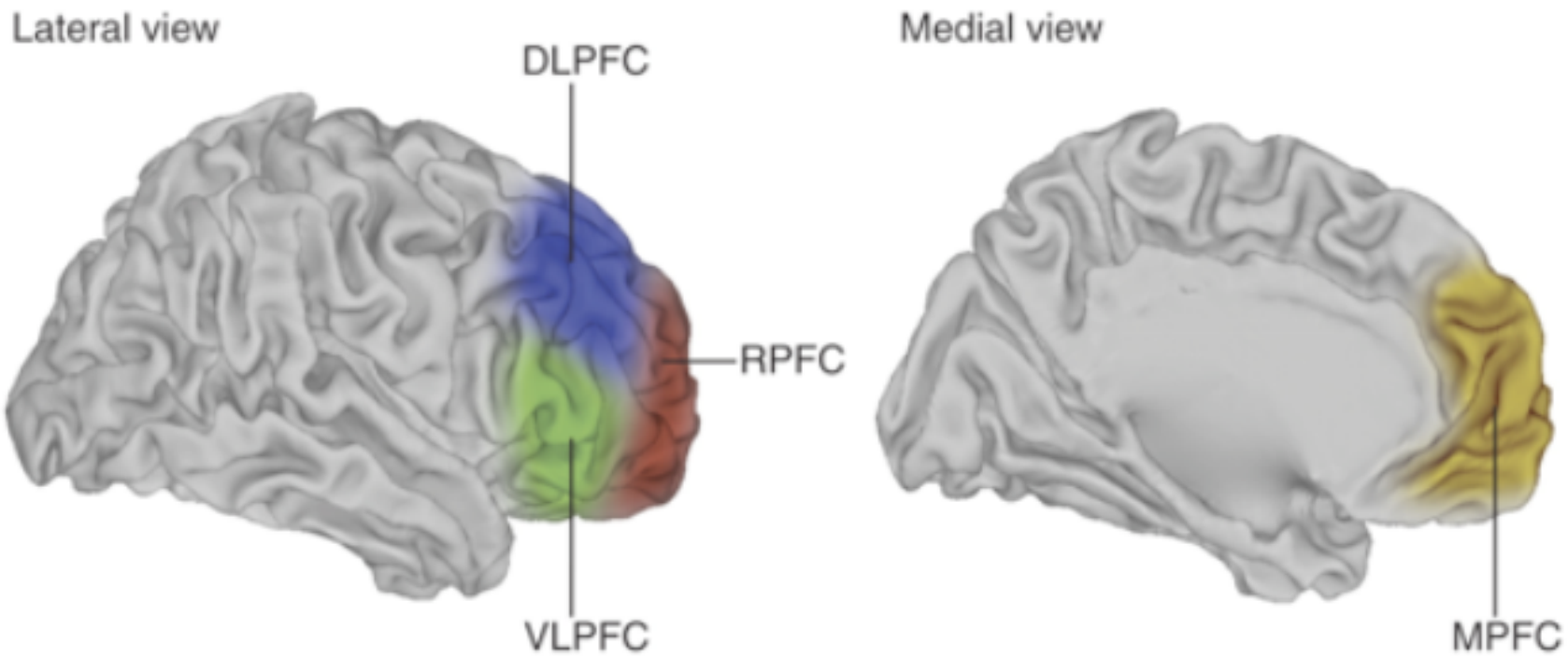

Dorsolateral prefrontal
cortex

Central Executive

Dorsolateral Prefrontal Cortex

Phonological Loop

Left Ventrolateral Prefrontal


Lateral view
DLPFC
RPFC
VLPFC
Medial view
MPFC

Central Executive

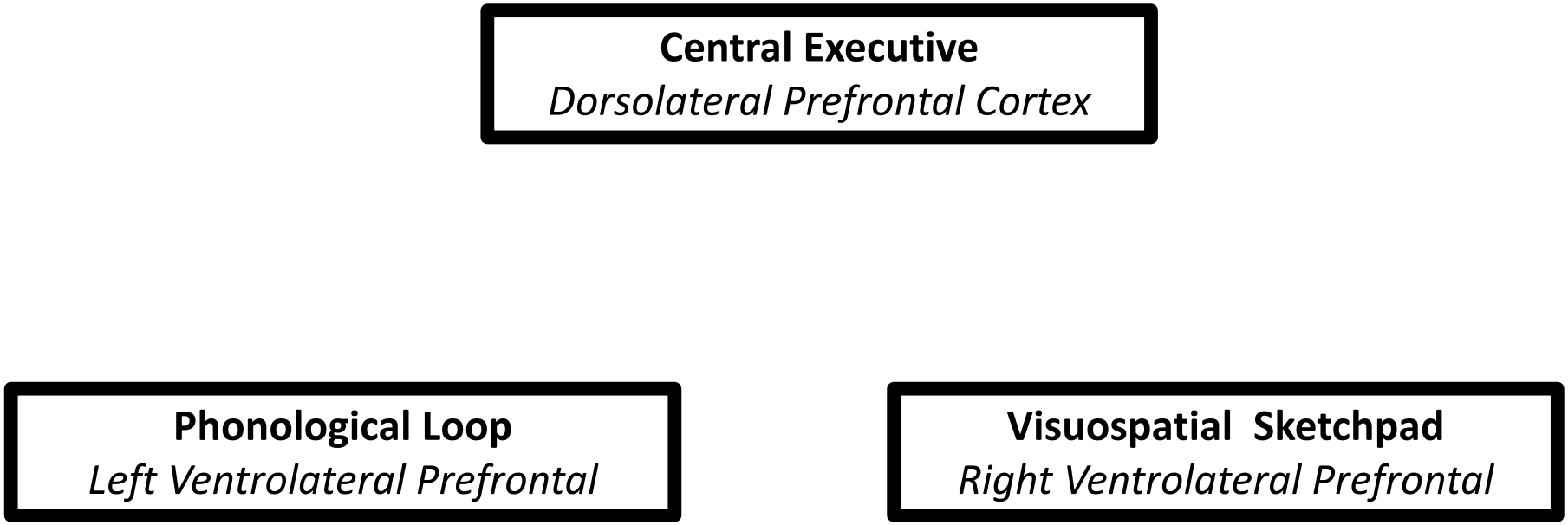
Dorsolateral Prefrontal Cortex

Phonological Loop

Left Ventrolateral Prefrontal

Anterior: Semantic

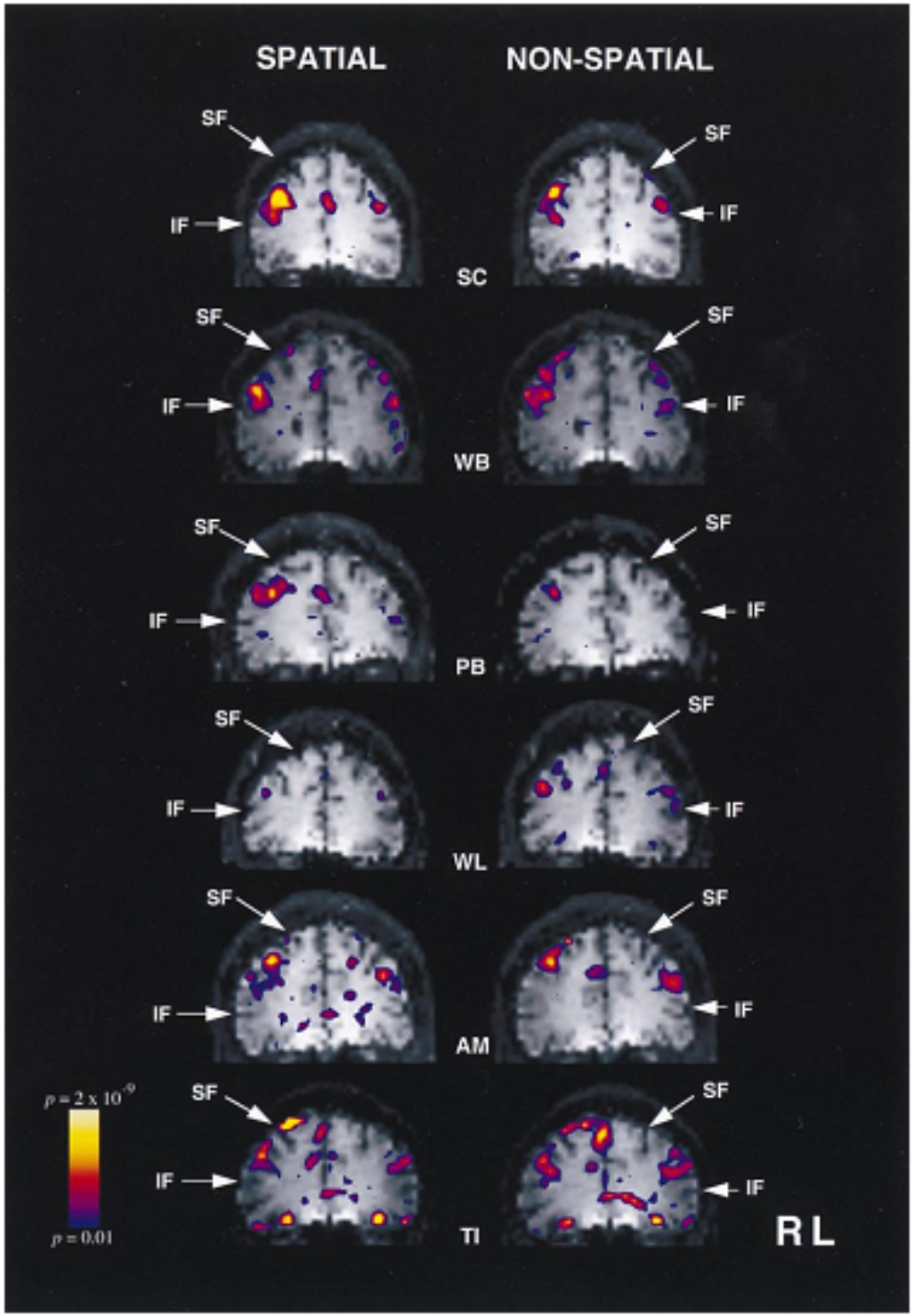
Posterior: Phonological


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

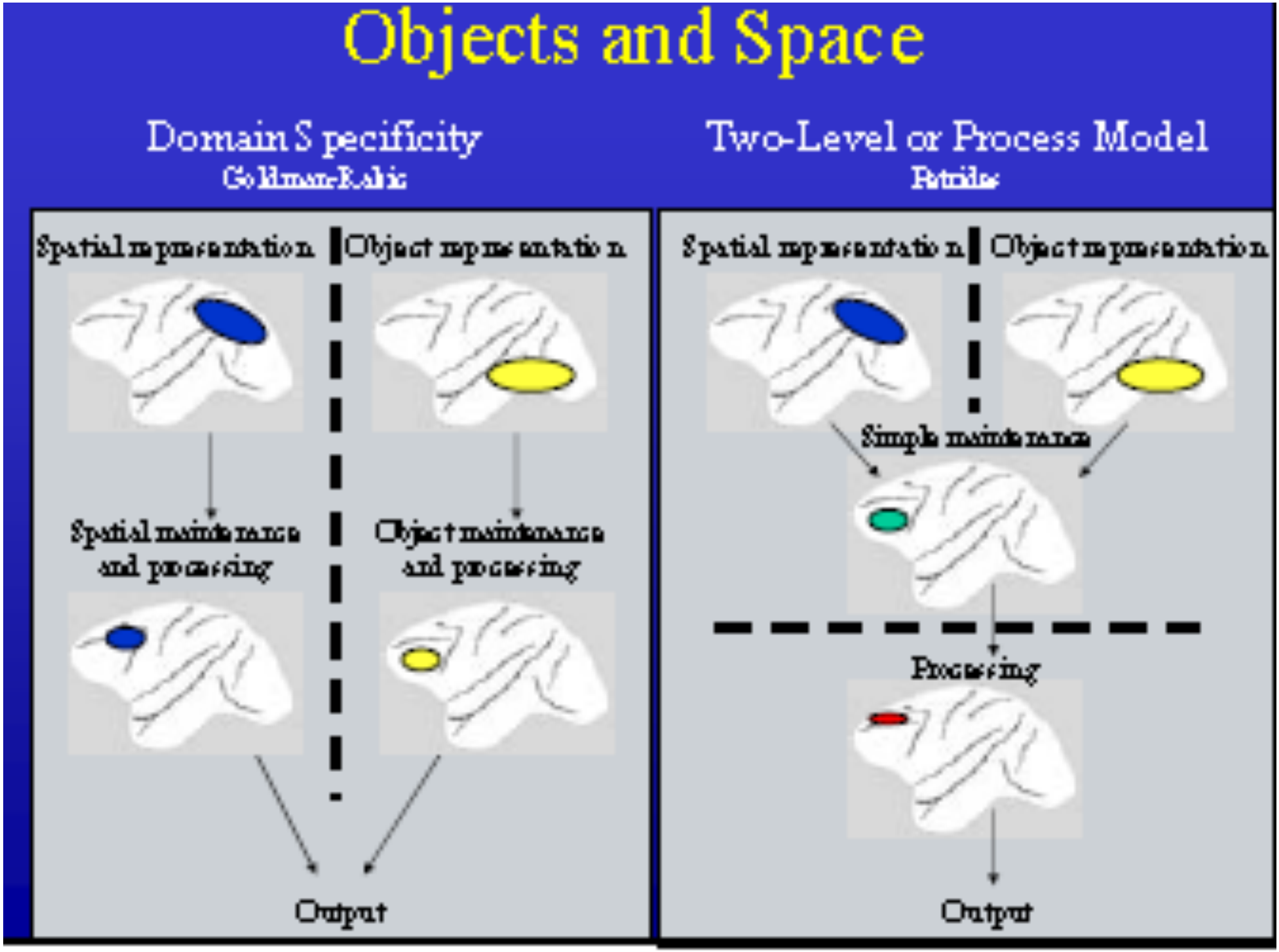
Adrian M. Owen*†‡, Chantal E. Stern§, Rodney B. Look§, Irene Tracey§, Bruce R. Rosen§, and Michael Petrides†

ABSTRACT The present study used functional magnetic resonance imaging to demonstrate that performance of visual spatial and visual nonspatial working memory tasks involve the same regions of the lateral prefrontal cortex when all factors unrelated to the type of stimulus material are appropriately controlled. These results provide evidence that spatial and nonspatial working memory may not be mediated, respectively, by mid-dorsolateral and mid-ventrolateral regions of the frontal lobe, as widely assumed, and support the alternative notion that specific regions of the lateral prefrontal cortex make identical executive functional contributions to both spatial and nonspatial working memory.


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?

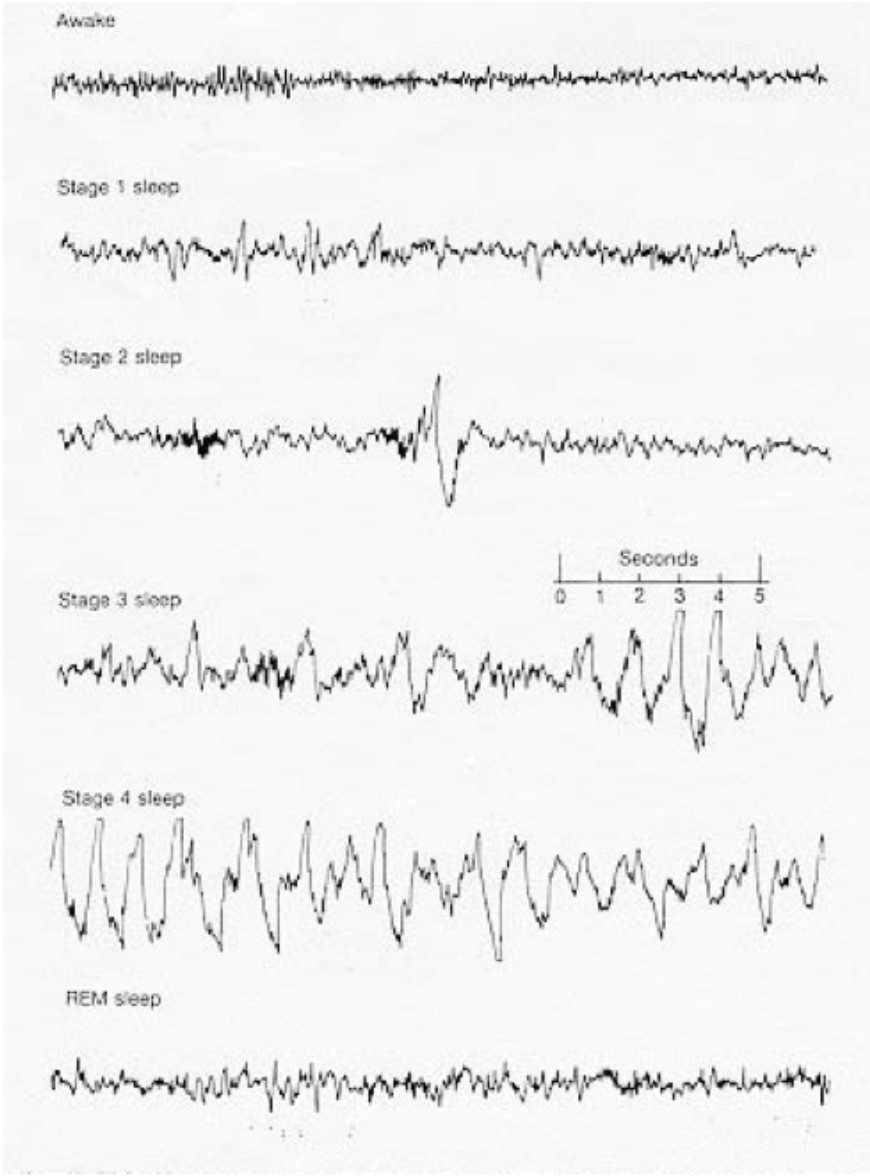
- Agreement that ventral and dorsal PFC are involved in different aspects of WM.
  - Theory(1) WM in PFC is organized according to the type of information being stored or rehearsed
  - Theory(2) WM in PFC is organized according to the operations being performed

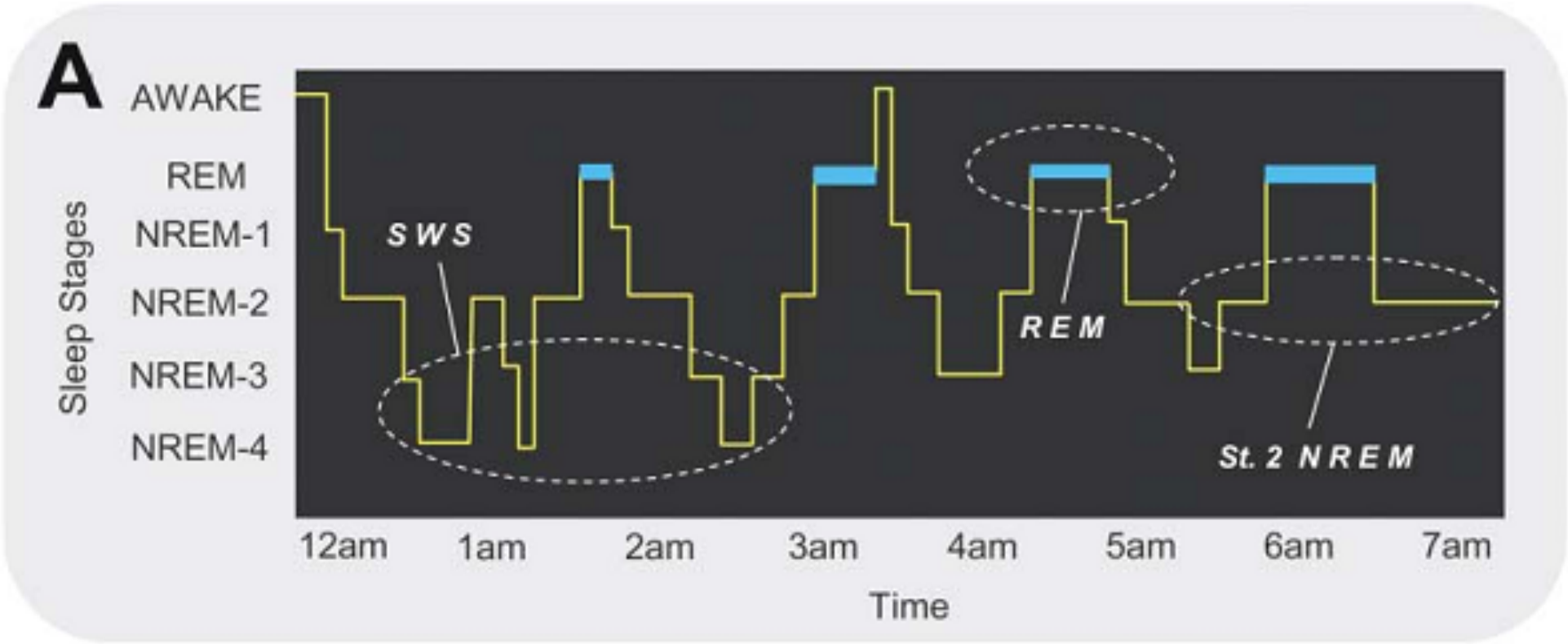

Objects and Space
Domain Specificity
Goldman-Rakic
Two-Level or Process Model
Petrides
Spatial representation
Object representation
Spatial maintenance and processing
Object maintenance and processing
Output
Spatial representation
Object representation
Simple maintenance
Processing
Output

Sleep and Memory

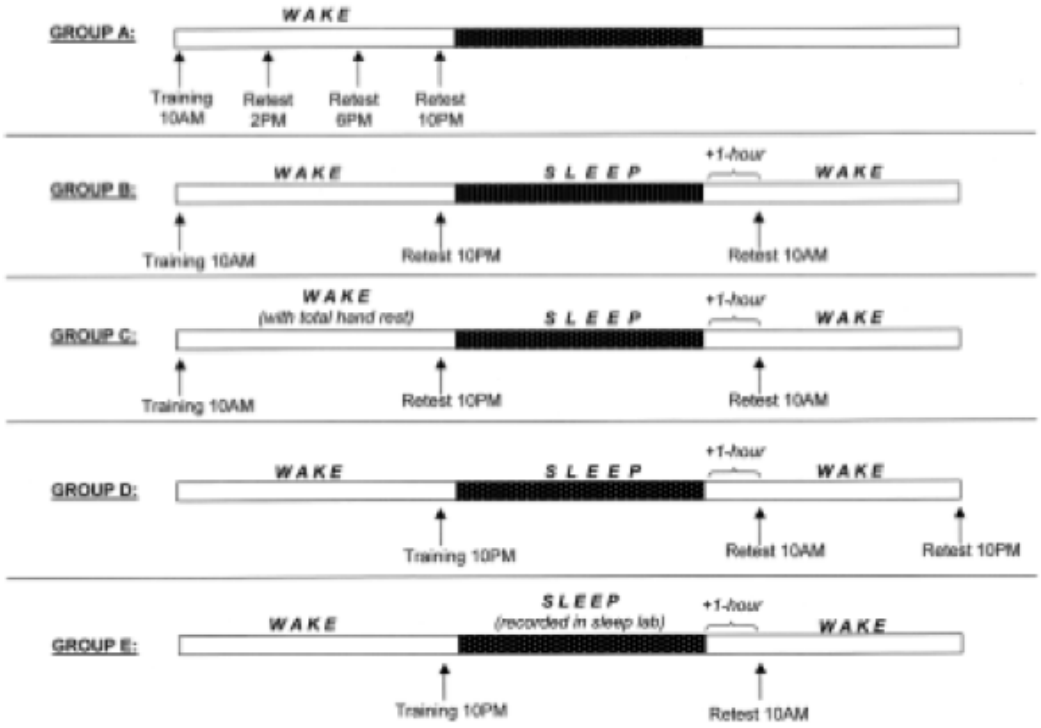
Stages of Sleep

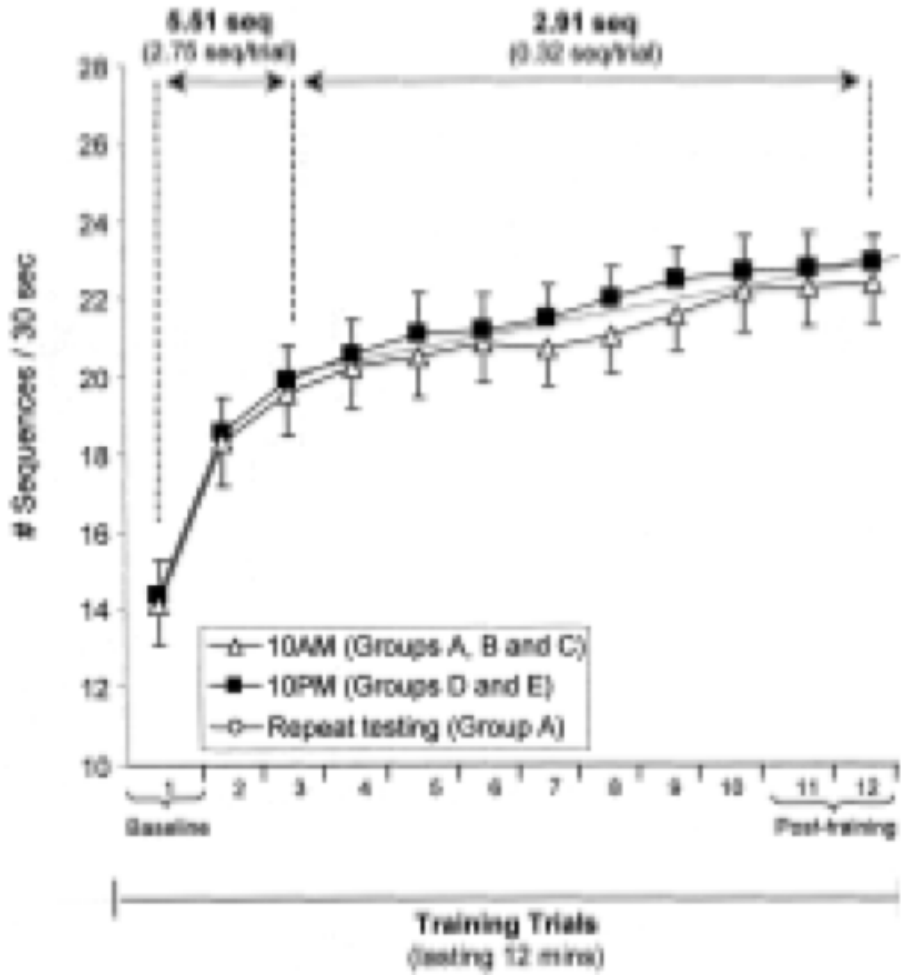
Stage 1	Light Sleep
Stage 2	Eye movements stop, change in brain activity
Stages 3 and 4	Deep Sleep
REM	Rapid Eye Movement

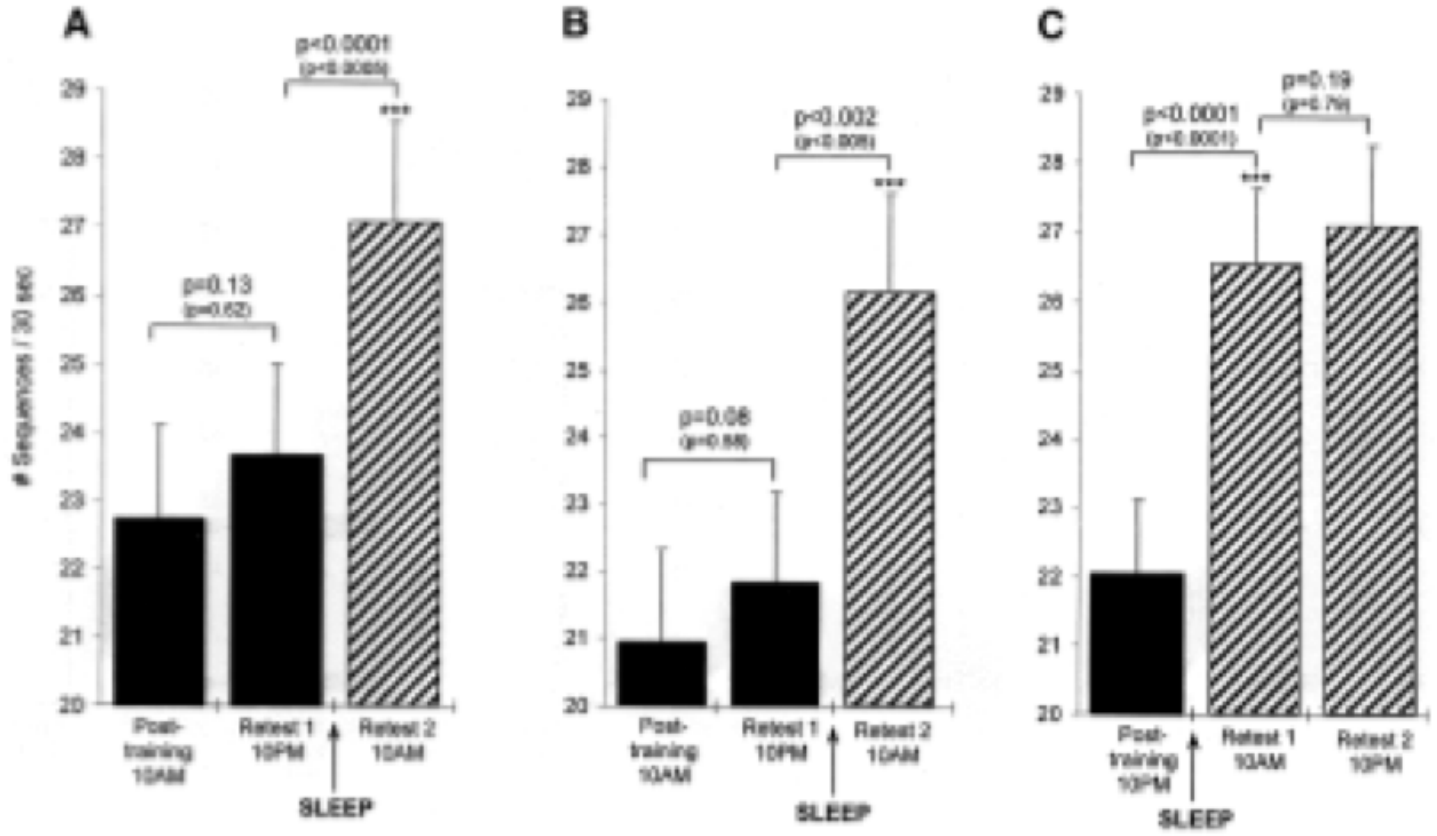

Awake
Stage 1 sleep
Stage 2 sleep
Seconds
0 1 2 3 4 5
Stage 3 sleep
Stage 4 sleep
REM sleep


A
AWAKE
REM
NREM-1
NREM-2
NREM-3
NREM-4
Sleep Stages
SWS
REM
St. 2 NREM
12am
1am
2am
3am
4am
5am
6am
7am
Time

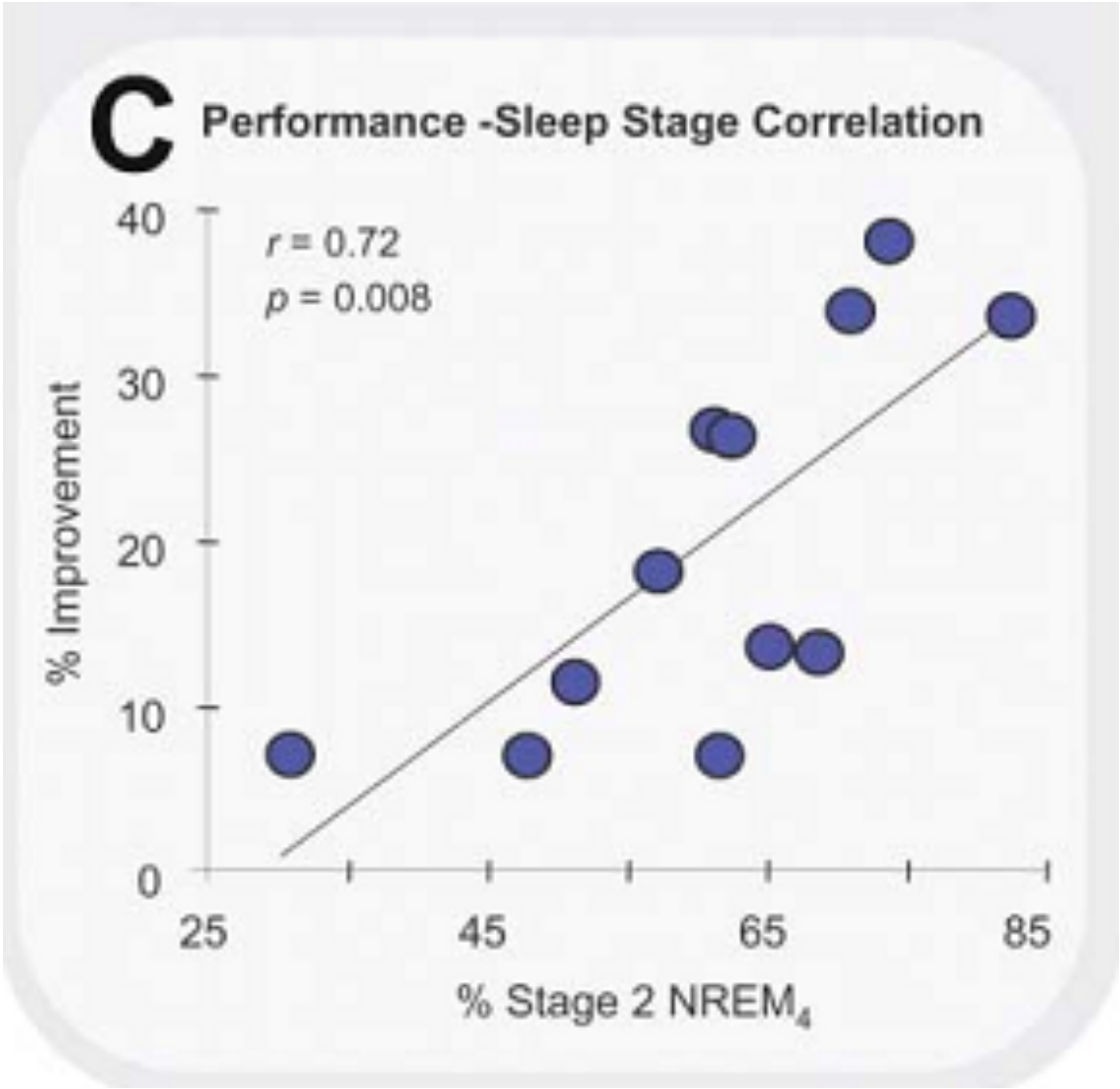
Practice With Sleep Makes Perfect: Sleep-Dependent Motor Skill Learning

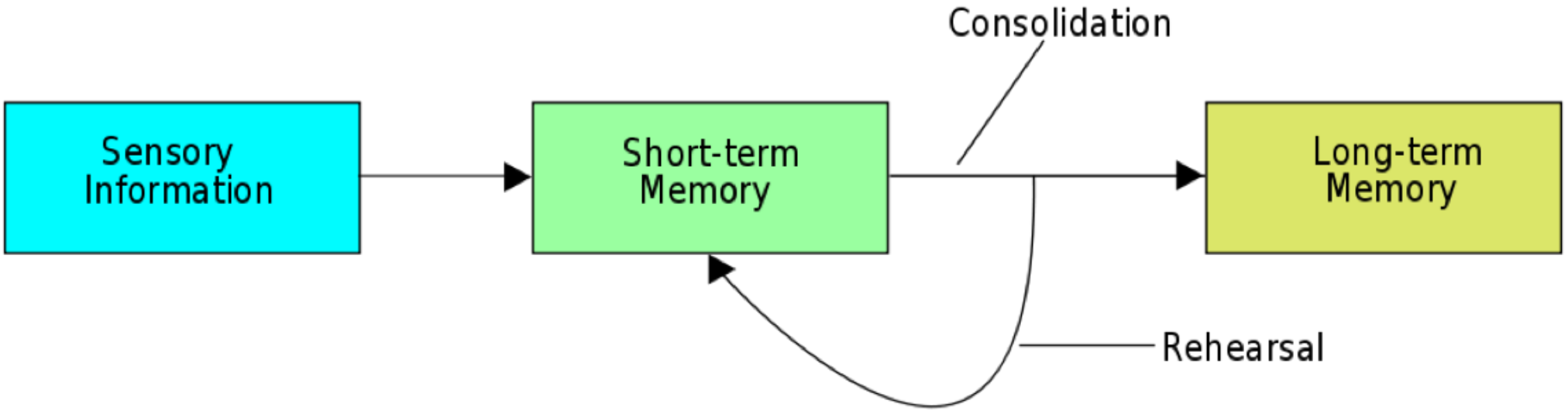

GROUP A:
WAKE
Training 10AM
Retest 2PM
Retest 6PM
Retest 10PM
GROUP B:
WAKE
SLEEP
+1-hour
WAKE
Training 10AM
Retest 10PM
Retest 10AM
GROUP C:
WAKE
(with total hand rest)
SLEEP
+1-hour
WAKE
Training 10AM
Retest 10PM
Retest 10AM
GROUP D:
WAKE
SLEEP
+1-hour
WAKE
Training 10PM
Retest 10AM
Retest 10PM
GROUP E:
WAKE
SLEEP
(recorded in sleep lab)
+1-hour
WAKE
Training 10PM
Retest 10AM

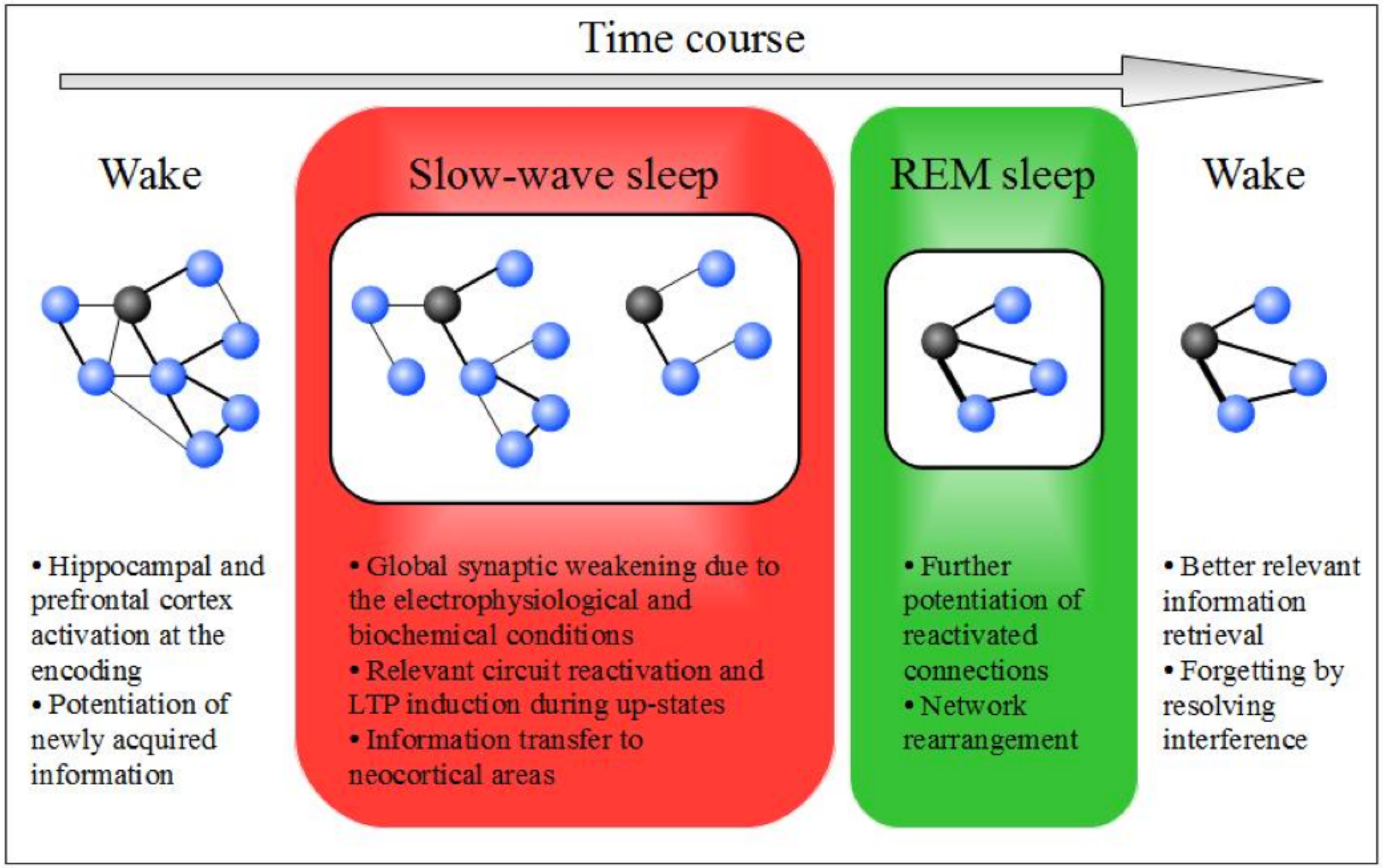

5.51 seq
(2.75 seq/trial)
2.91 seq
(0.32 seq/trial)
Sequences / 30 sec
28
26
24
22
20
18
16
14
12
10
10AM (Groups A, B and C)
10PM (Groups D and E)
Repeat testing (Group A)
1
2
3
4
5
6
7
8
9
10
11
12
Baseline
Post-training
Training Trials
(lasting 12 mins)



Group B Group C Group D


C
Performance -Sleep Stage Correlation
r = 0.72
p = 0.008
% Improvement
40
30
20
10
0
25
45
65
85
% Stage 2 NREM4


Consolidation
Sensory Information
Short-term Memory
Long-term Memory
Rehearsal


Time course
Wake
Slow-wave sleep
REM sleep
Wake
• Hippocampal and prefrontal cortex activation at the encoding
• Potentiation of newly acquired information
• Global synaptic weakening due to the electrophysiological and biochemical conditions
• Relevant circuit reactivation and LTP induction during up-states
• Information transfer to neocortical areas
• Further potentiation of reactivated connections
• Network rearrangement
• Better relevant information retrieval
• Forgetting by resolving interference