Temporary Memory: Short-Term and Working Memory

Learning & Memory

Arlo Clark-Foos, Ph.D.

Support for a Multi Store Model

Distinctions between STM and LTM

Behavior	Biological	Neurological
• Ebbinghaus – no effort to recall 1-5 nonsense syllables; considerable effort to recall >5 syllables	• Inhibiting protein synthesis does not impair within-session memory but prevents build-up of memory across sessions.	• Neurological patients can show specific deficits in STM, LTM, or in transition from STM to LTM (e.g., HM).

What are these systems, and how do they interact?

Information Processing Model & The Modal Model of Memory

Atkinson & Shiffrin (1968)

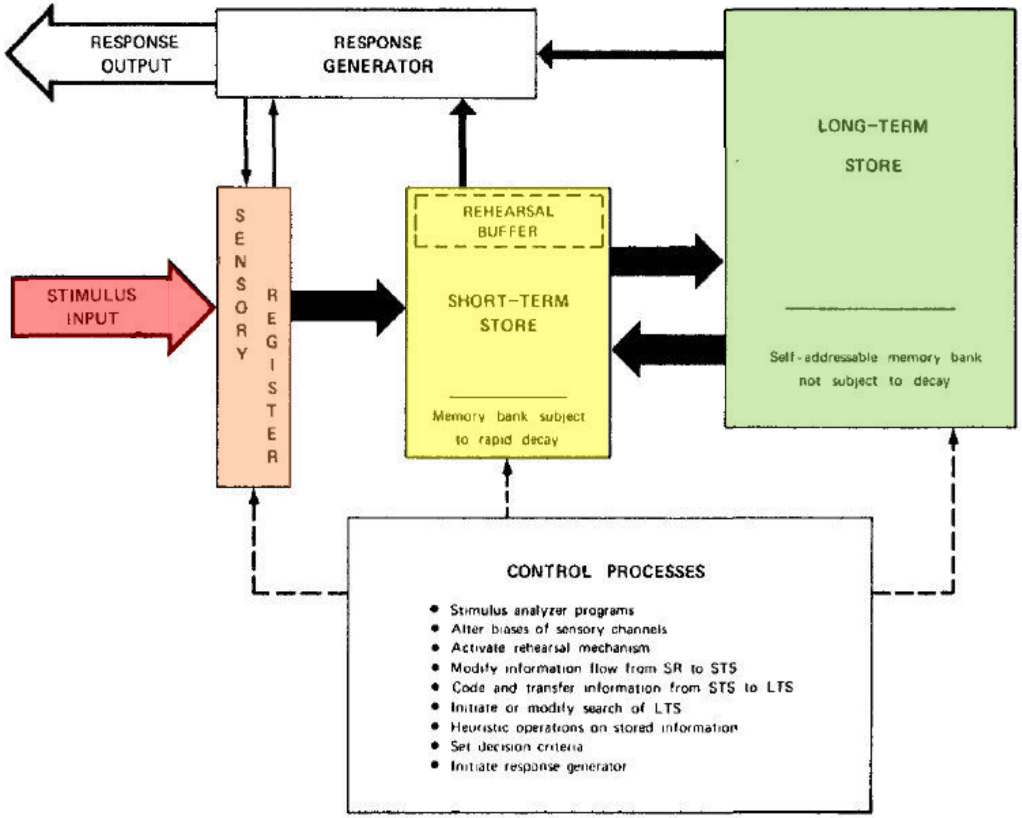


FIG. 1. A flow chart of the memory system. (Solid lines indicate paths of information transfer. Dashed lines indicate connections which permit comparison of information arrays residing in different parts of the system; they also indicate paths along which control signals may be sent which activate information transfer, rehearsal mechanisms, etc.)

Short-Term Memory

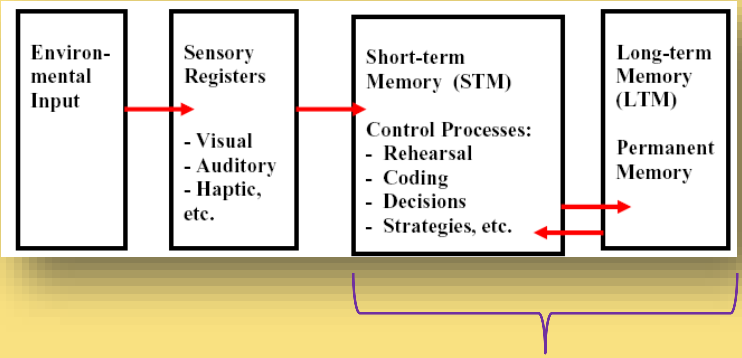
- *Ability to store information in current consciousness without active rehearsal*

- Tasks to measure capacity
  - Span (Digit, Letter, etc.)
  - *n*-back
  - Operation Span
  - Serial Addition
    - PASAT

- Working Memory?
  - We'll come back to this…

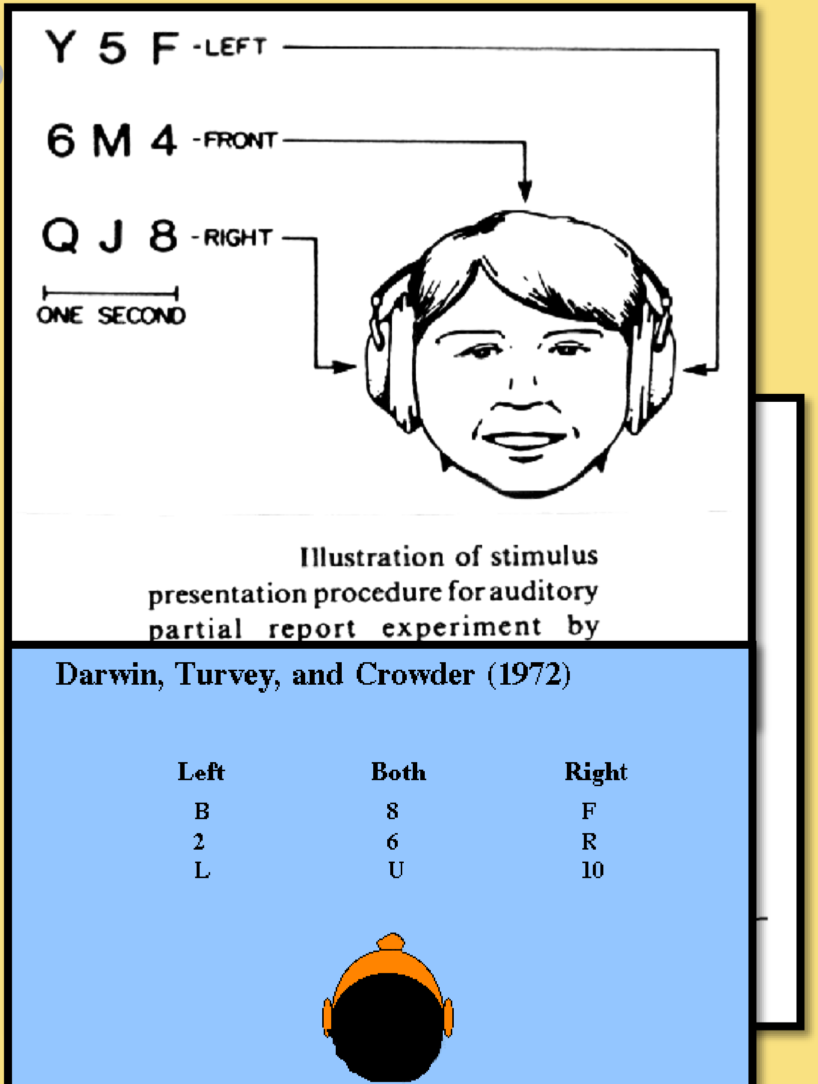
How many memory systems are there?

- Support for Multi-Store Models (e.g., Atkinson & Shiffrin)
  - Capacity
  - Forgetting
  - Components and Functions
  - Animal WM?
  - Neural representations of WM

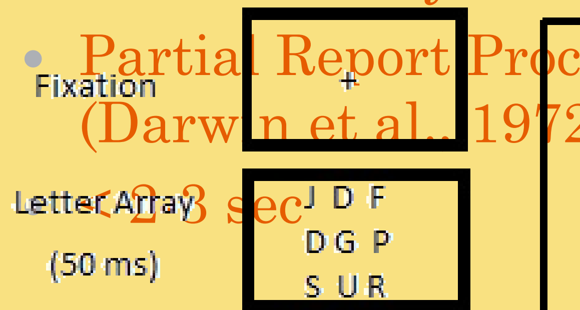


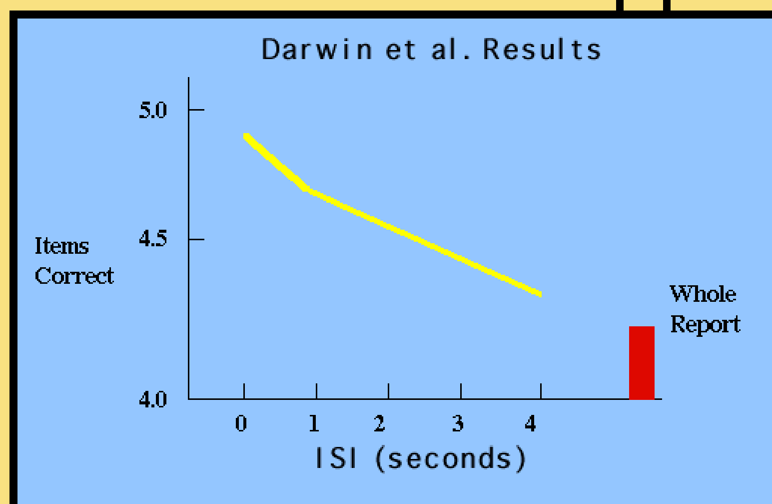
Do we have evidence for this distinction?

How Short is Short-Term Memory?



- Echoic Memory
  - Partial Report Procedure (Darwin et al., 1972)
  - < 2-3 sec

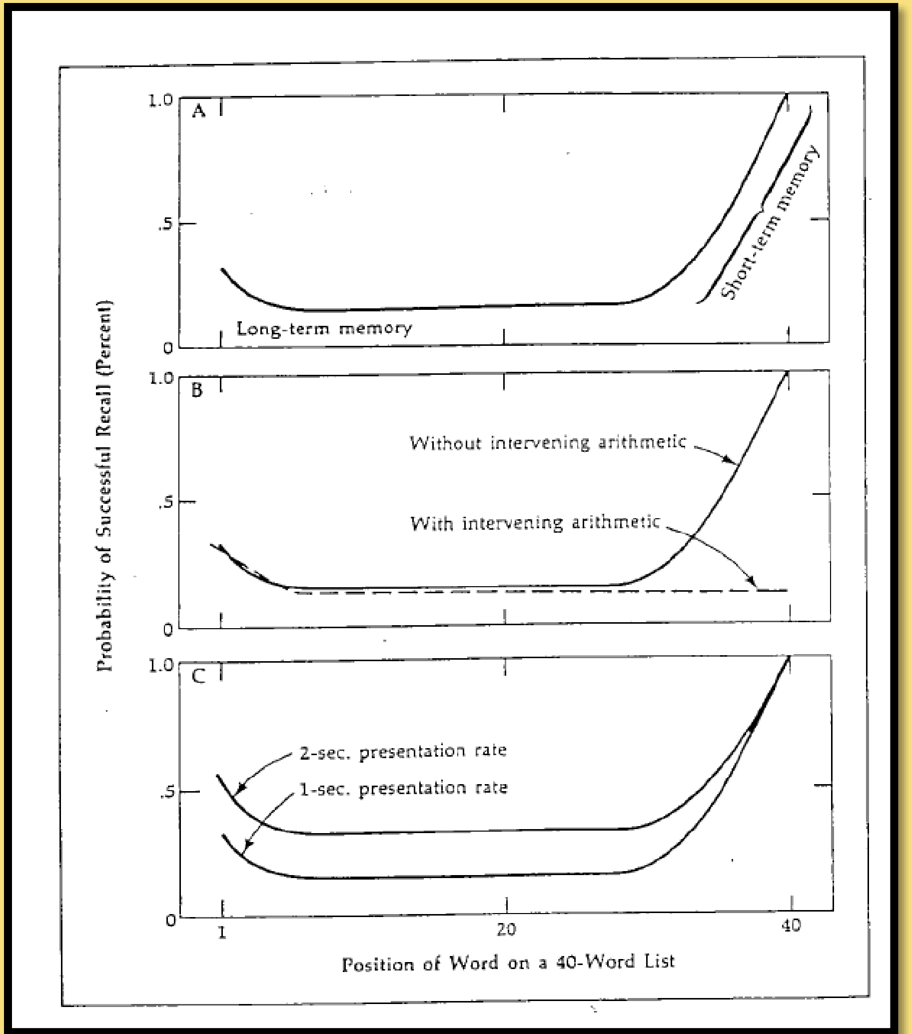


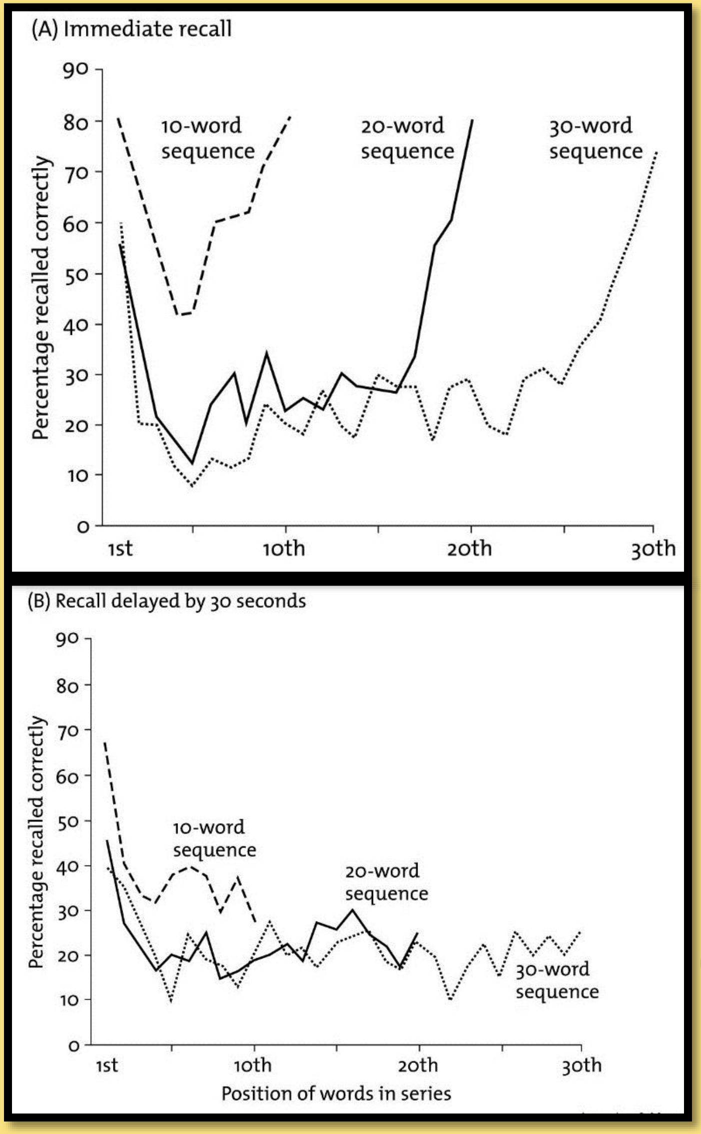


Short-Term Memory Capacity

- Miller's Magic Number 7 ± 2 (1956)
  - Persecuted by a number
  - Digit Span
  - Other Span Tests (Reading, Sentence, O-Span, etc.)
- Free Recall
  - Serial Position Effects
    - Primacy
    - Recency
    - Role of long-term vs. short-term memory?

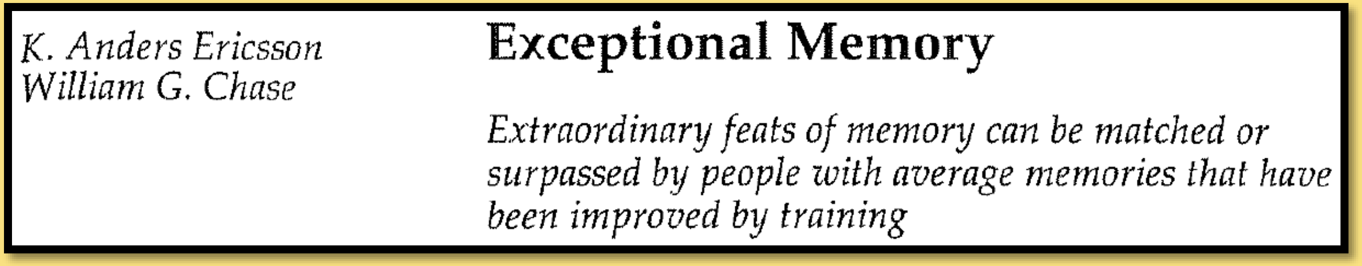
Serial Position Effects





IMPROVING STM CAPACITY

- Chunking

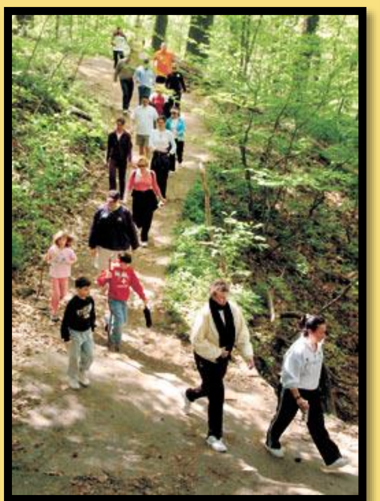


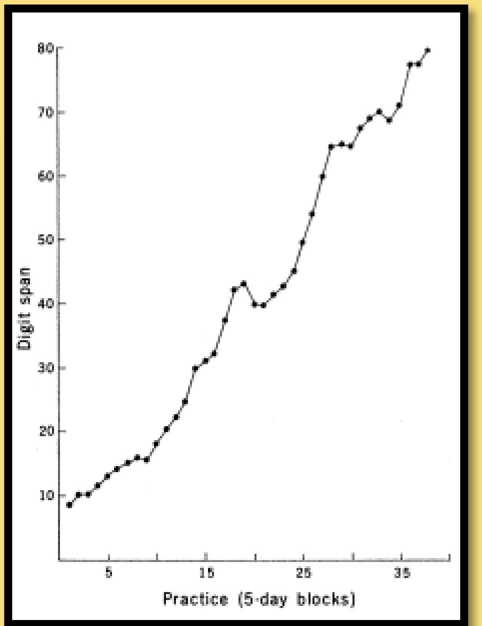
K. Anders Ericsson
William G. Chase

Exceptional Memory

Extraordinary feats of memory can be matched or surpassed by people with average memories that have been improved by training

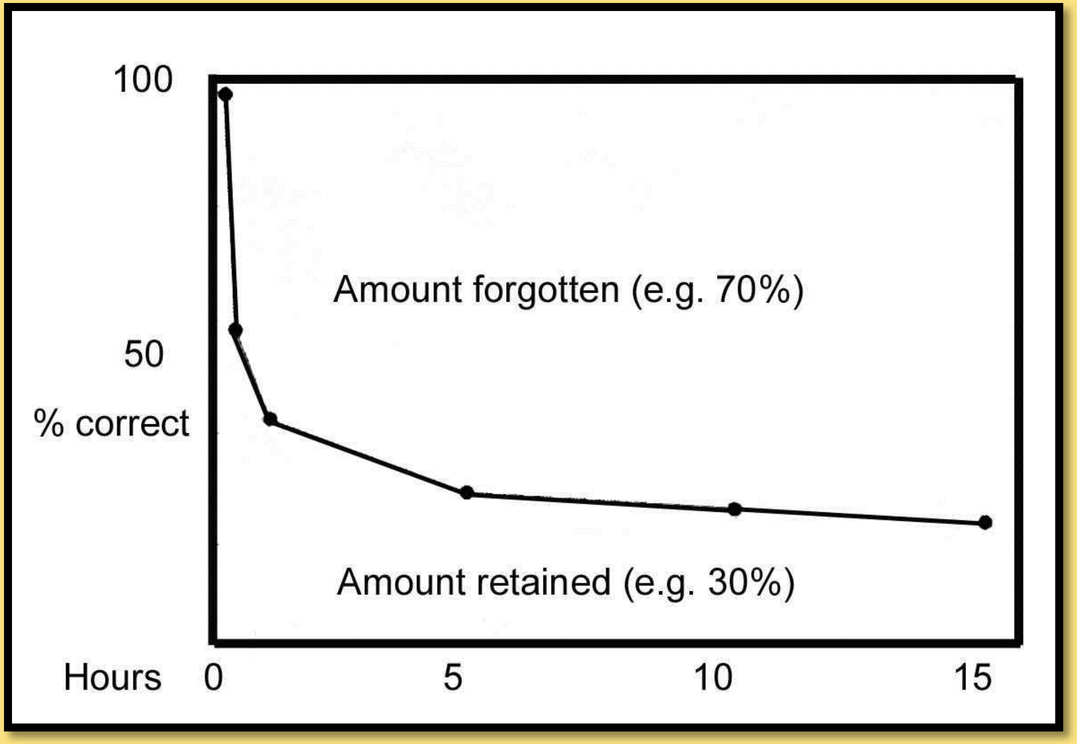
- Ericcson, Chase, & Faloon (1980)





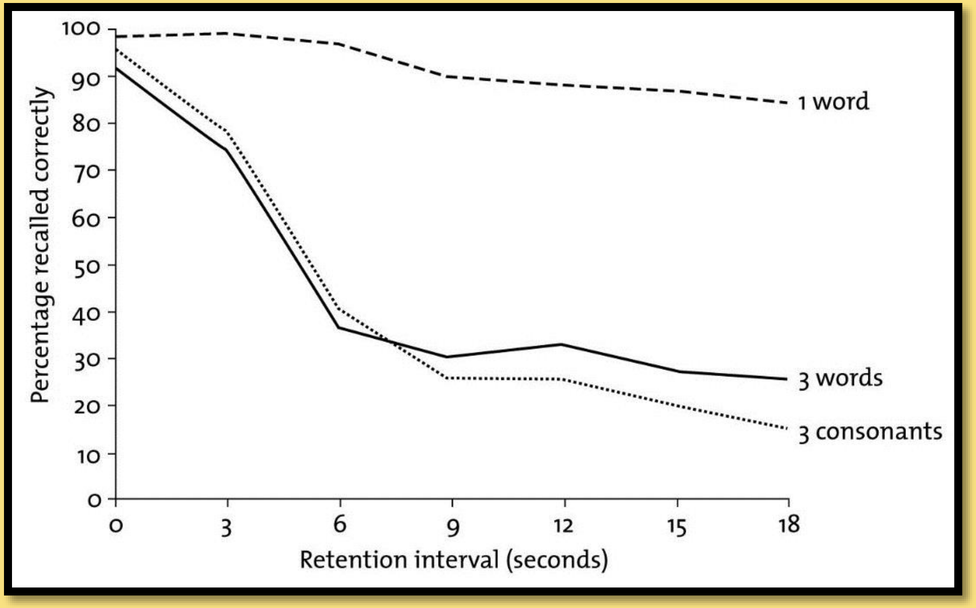
Hermann Ebbinghaus & Forgetting curves

- Ubiquitous!



Forgetting Curves again…

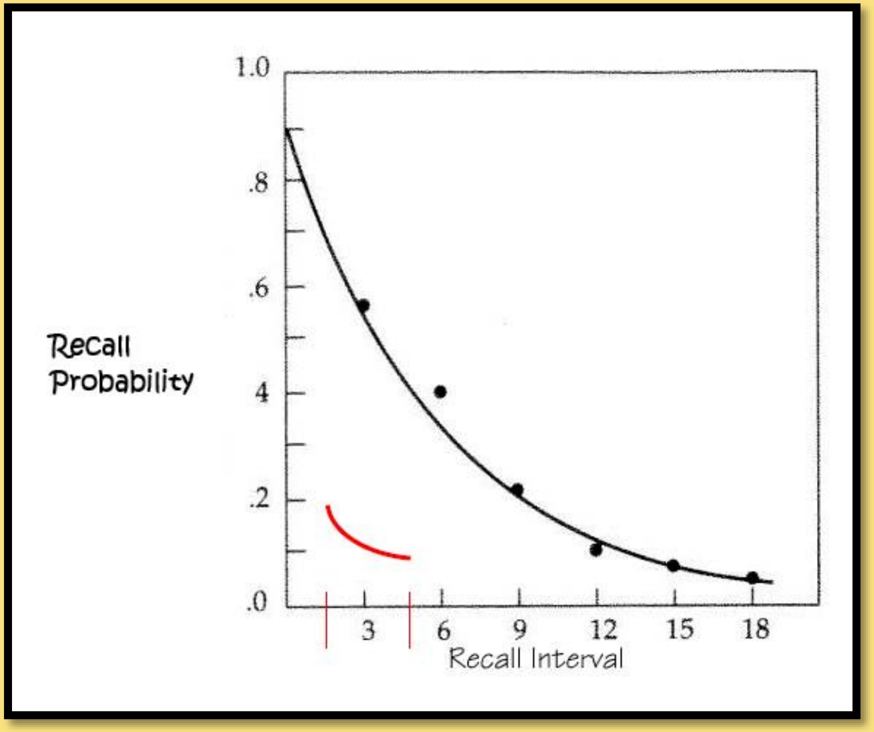
- Different Modalities
- Similar patterns



- Single cause of forgetting?

Duration of Short-Term Memory

- Brown-Peterson Task
  - Brown (1958) & Peterson and Peterson (1959)
  - Forgetting Curve
  - Decay?



Duration of Short-Term Memory

- Proactive Interference
  - Keppel & Underwood (1968)
    - Decay or Interference? Final word?

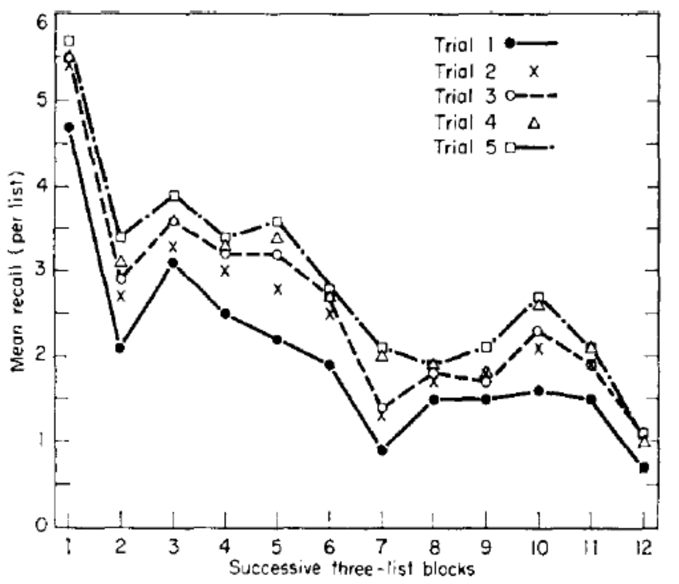
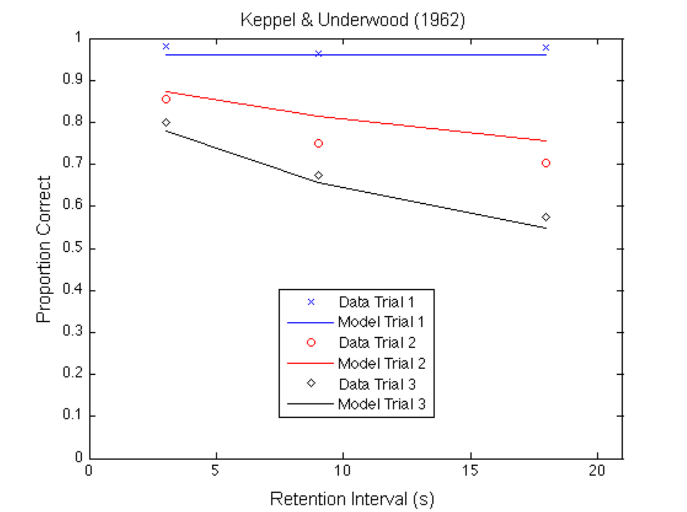


FIG. 3. Mean recall after 48 hr on five recall trials as a function of successive blocks of three lists.



Short-Term Memory and Interference

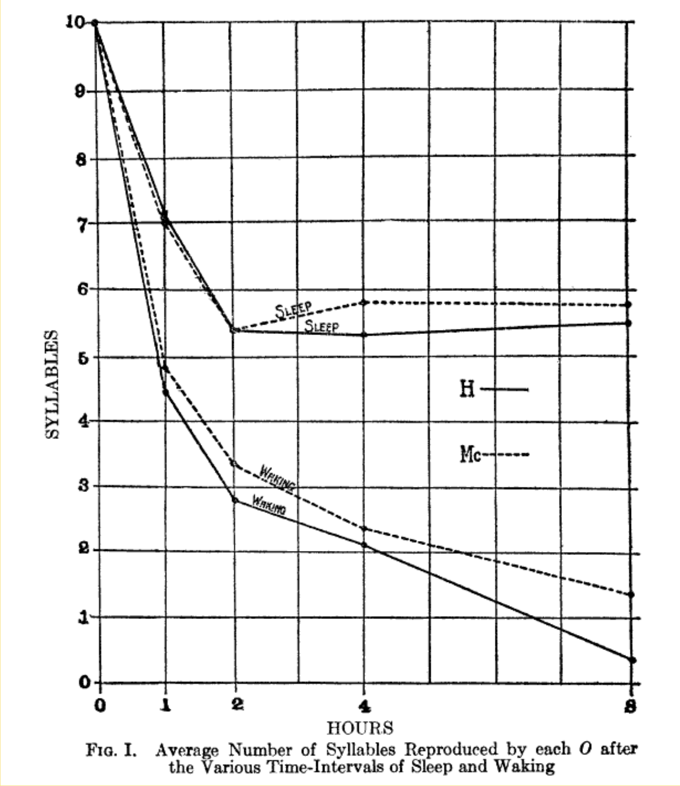
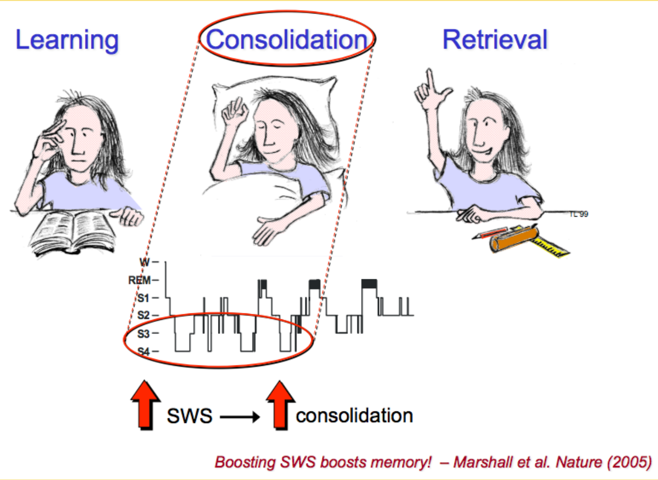
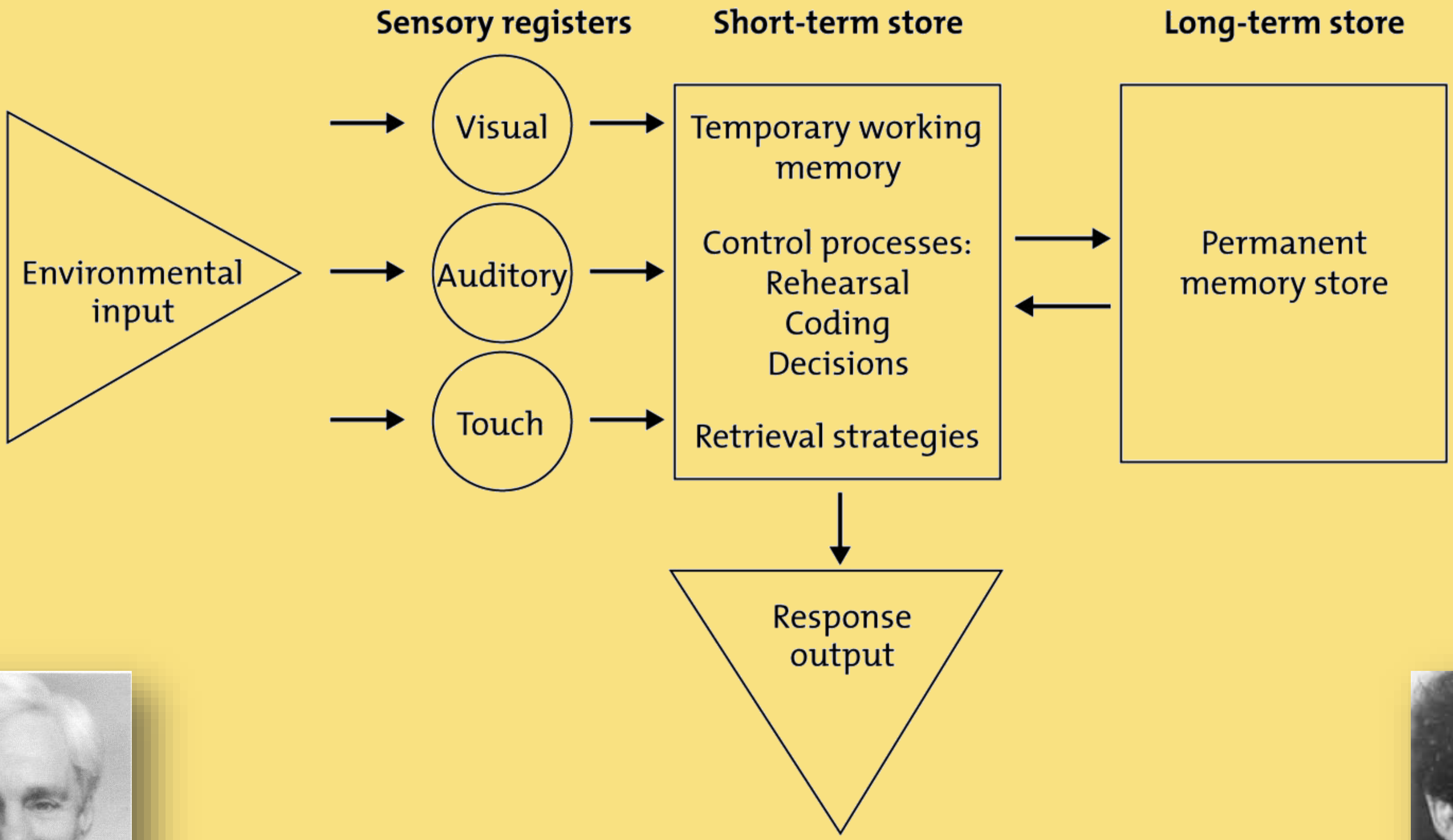


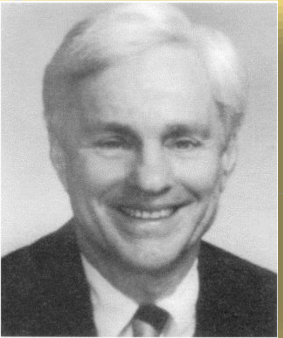
Fig. I. Average Number of Syllables Reproduced by each *O* after the Various Time-Intervals of Sleep and Waking

- Jenkins & Dallenbach (1924)
  - Reducing interference or disrupting consolidation?



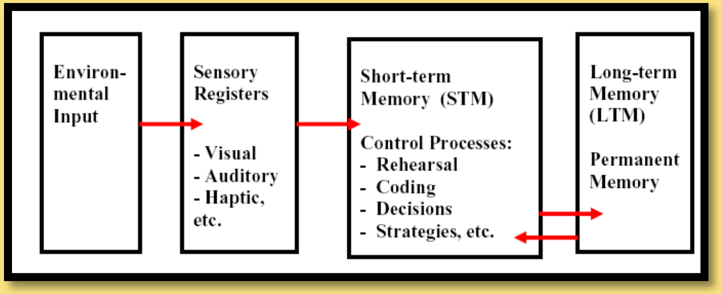
Atkinson & Shiffrin (1968): STS





Short-Term vs. Long-Term

- Distinctions
  - Capacity/Forgetting
  - Representational Coding
  - Anatomical (more later)



- Similarity
  - Interactions (e.g., proactive interference)
  - Spreading Activation (more later)

Representational Coding

- Kintsch & Buschke (1969)
  - Serial Position & Errors
  - Synonyms vs. Homophones
  - Semantic vs. Perceptual Similarity

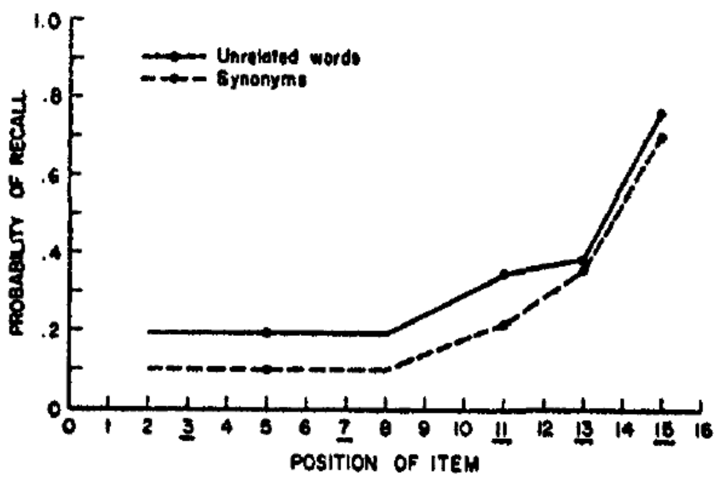


Fig. 1. Probability of recall of synonyms and unrelated words as a function of serial position.

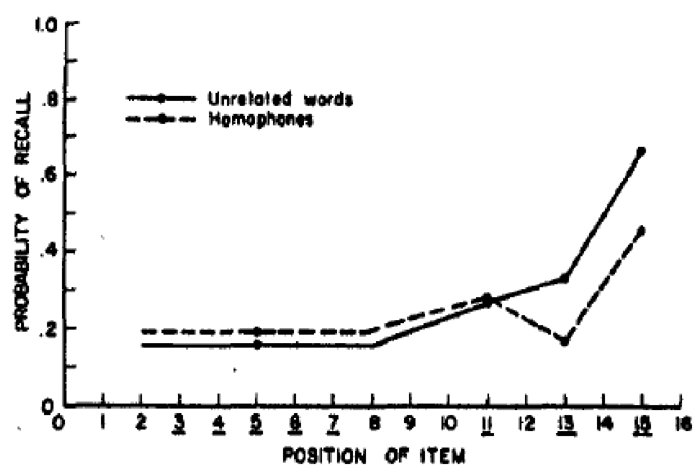
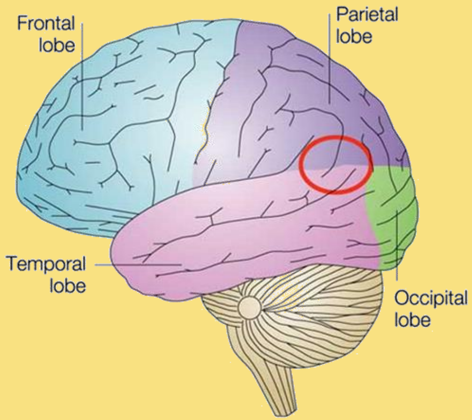


Fig. 3. Probability of recall of homophones and unrelated words as a function of serial position.

Anatomical Distinctions

- Amnesics (Baddeley & Warrington, 1970)
  - Hippocampus
  - H.M.
  - Korsakoff's
  - etc.



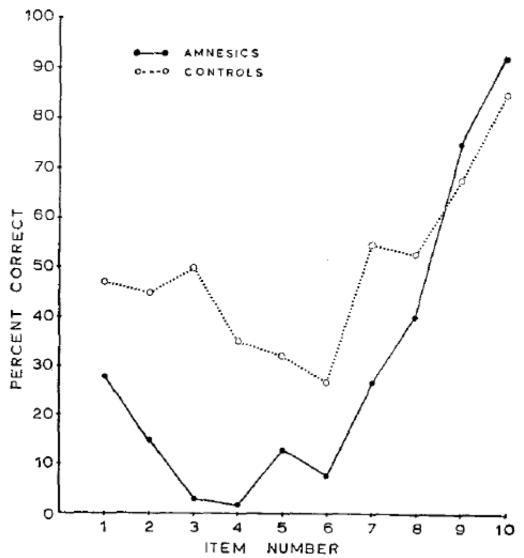


FIG. 1. Mean percentage correct recall as a function of order of presentation for amnesic and control *Ss* with immediate recall.

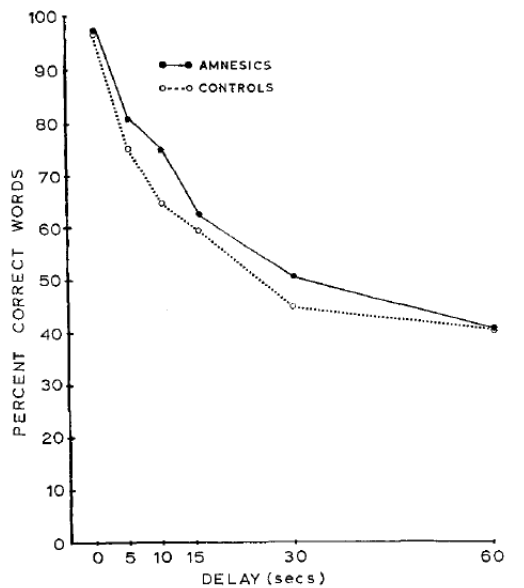


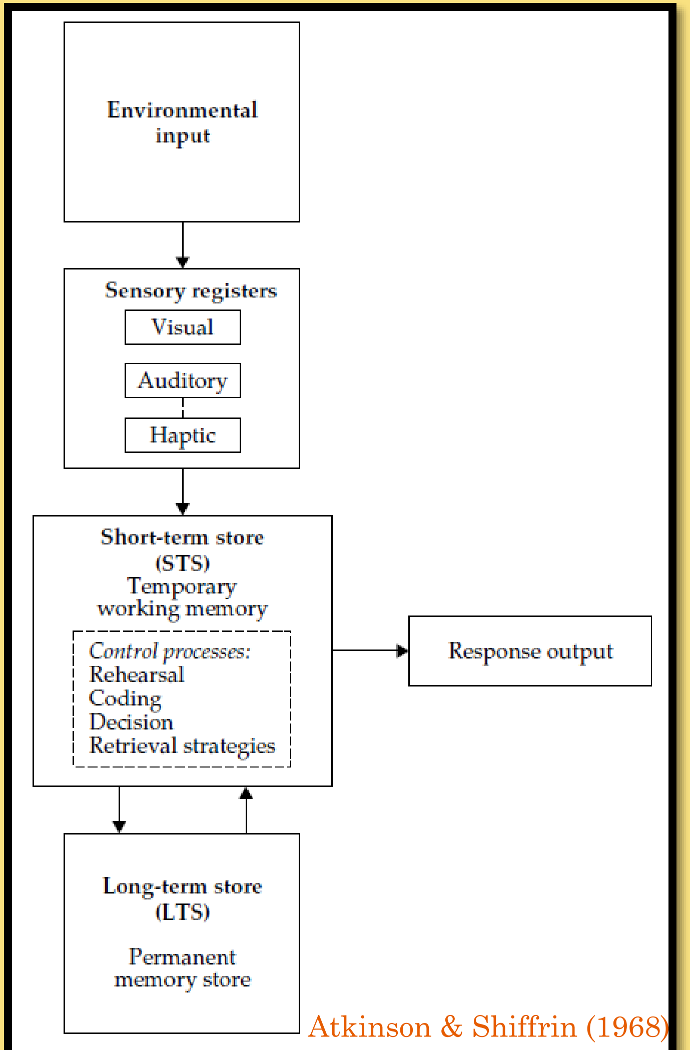
FIG. 3. Short-term retention of word triads by amnesic and control *Ss*.

- Temporoparietal Damage (Shallice & Warrington, 1970)
  - No STM (recency of one), intact LTM

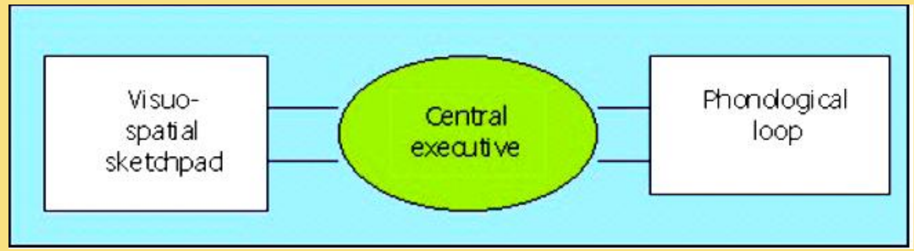
Digit Span

Operation Span

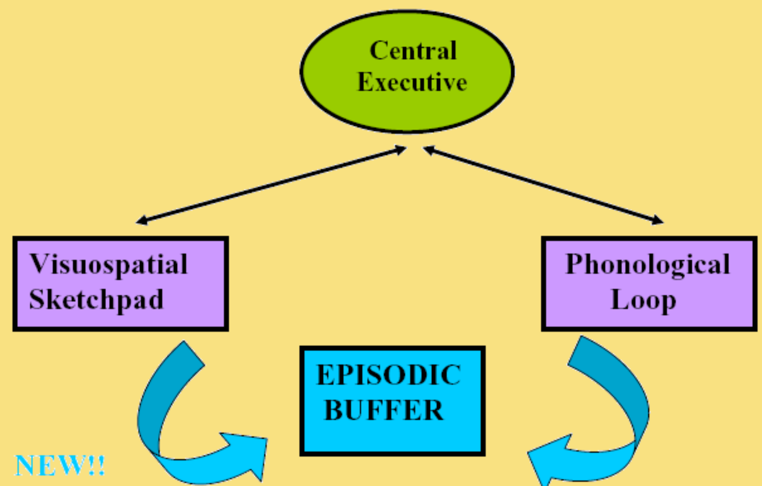
SHORT-TERM STORE VS. WORKING MEMORY



Atkinson & Shiffrin (1968)



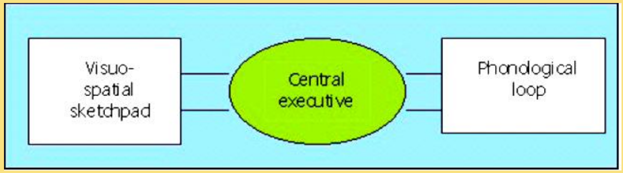
Baddeley & Hitch (1974)



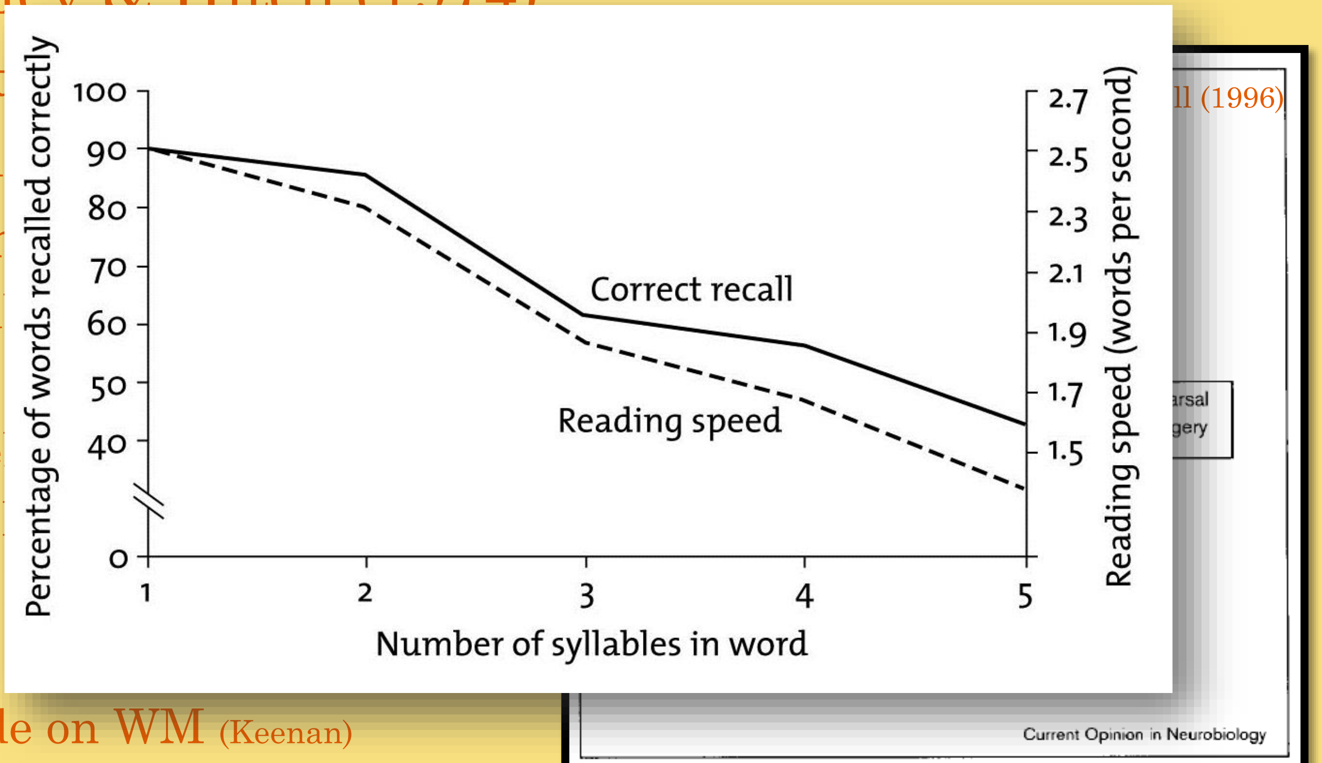
NEW!!

Baddeley (2000)

Working Memory

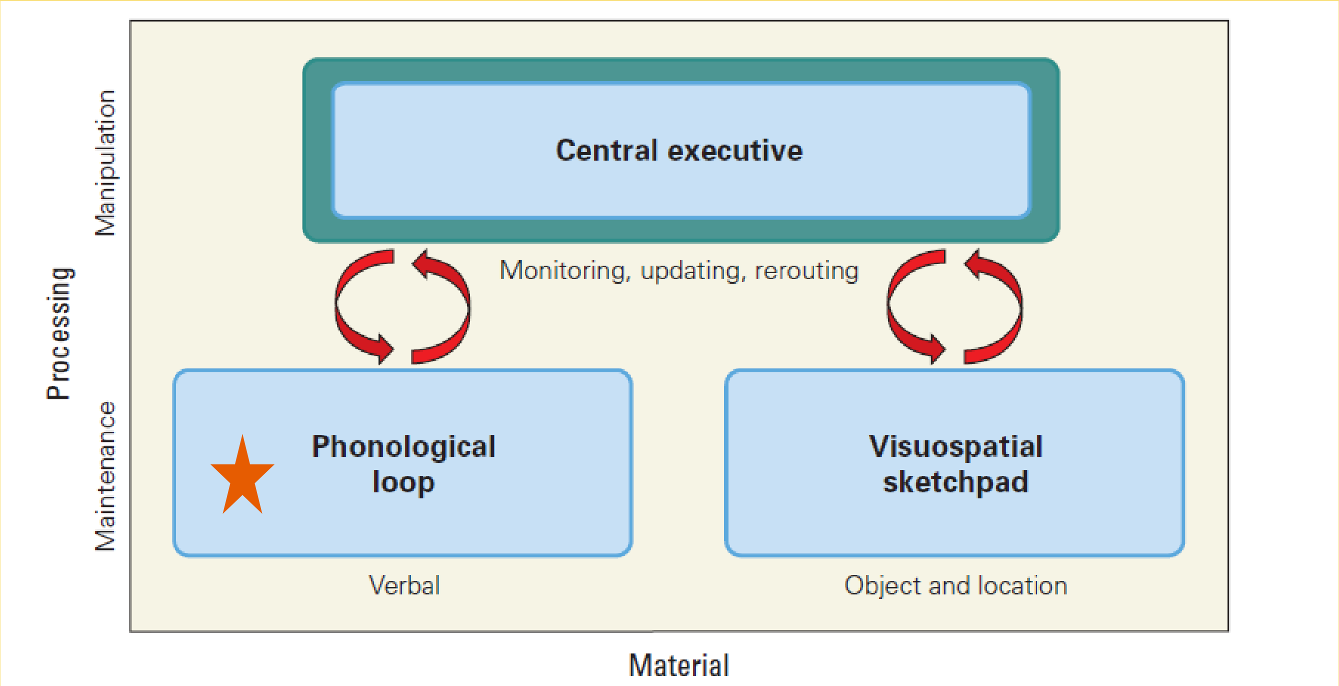


- Baddeley & Hitch (1974)
  - Cent
  - Visu
  - Phon
    - Su
    - Re
    - Ode on WM (Keenan)



Evidence for separate visual and verbal coding in memory. Subjects attempted to learn a list of words using either visual imagery or rote verbal repetition, while trying to ignore either a flickering visual pattern or background speech. When subjects used imagery, only the flickering light impaired performance; when they used rote repetition, the opposite pattern was found [32••].

Working Memory



- Stores about 2 s of auditory information
- Example: 7 numbers will be presented for 2 s; remember them!
    - Learn: 5 6 2 8 1 7 3
    - Delay…
    - Remember: 5 6 2 8 1 7 3

Did you repeat the numbers mentally? This is the

Working Memory

- Properties of the Phonological Loop
  - Salame & Baddeley (1987; 1989)

TABLE 2
Experiment 2: Mean Percentage Error-rate as a Function of Musical Background

Vocal			*Instrumental*			*Silent Control*	
(a)	Mozart (♀)	29.3	(a)	The Shadows	24.4	(a)	24.2
(b)	Rossini (♂)	29.3	(a)	Mike Oldfield	25.5	(b)	22.9
(c)	Schubert (♂)	34.6	(c)	Duke Ellington	26.5	(c)	21.4
(d)	Mozart (♀)	25.4	(d)	Human League	24.7	(d)	21.3
	Mean	29.7			25.3		22.2

(♂) Male singer (♀) Female singer

Visuospatial Sketchpad: Example

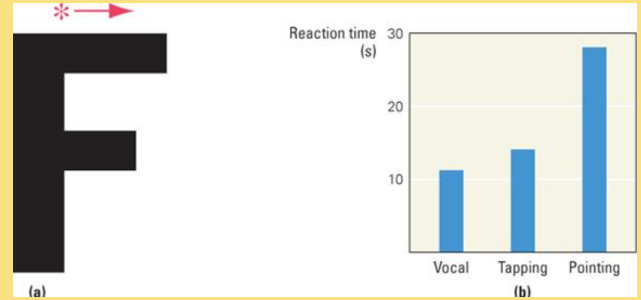
- Imagine a 4 × 4 grid (16 squares) with a 1 in the second column of the second row.
- Place a 2 to the right of the 1.
- In the square above the 2, put a 3.
- To the right of the 3, put a 4.
- Below the 4, put a 5.
- Below that, put a 6.
- Then to the left of that, a 7.
- What number is above the 7?

		3	4
	1	2	5
		7	6

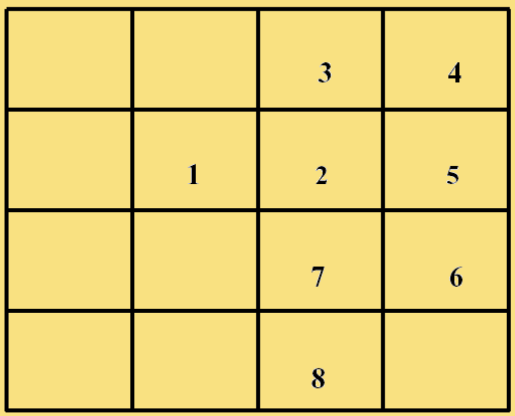
Answer: 2!

Getting this right (or near right) requires a visuospatial sketchpad.

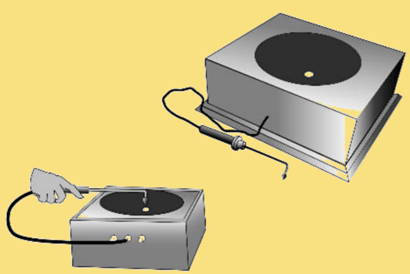
Working Memory

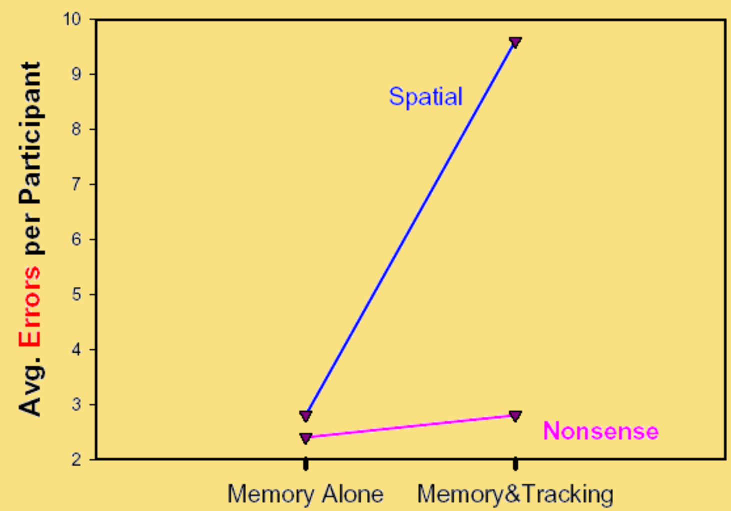


- Properties of the Visuospatial Sketchpad
  - Baddeley et al. (1975)



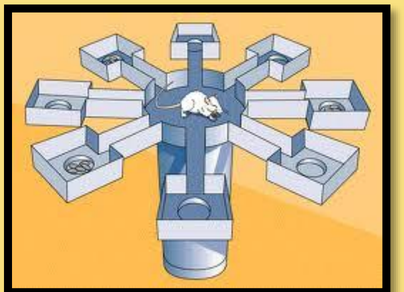
Spatial material	Nonsense material
In the starting square put a 1.	In the starting square put a 1.
In the next square to the ***right*** put a 2.	In the next square to the ***quick*** put a 2.
In the next square ***up*** put a 3.	In the next square to the ***good*** put a 3.
In the next square to the ***right*** put a 4.	In the next square to the ***quick*** put a 4.
In the next square ***down*** put a 5.	In the next square to the ***bad*** put a 5.
In the next square ***down*** put a 6.	In the next square to the ***bad*** put a 6.
In the next square to the ***left*** put a 7.	In the next square to the ***slow*** put a 7.
In the next square ***down*** put an 8.	In the next square to the ***bad*** put an 8.





Do Animals Have Working Memory?

- Serial Probe Recognition Task (Wright et al. 1985)



Also: rats can remember up to 17 arms in win-shift!

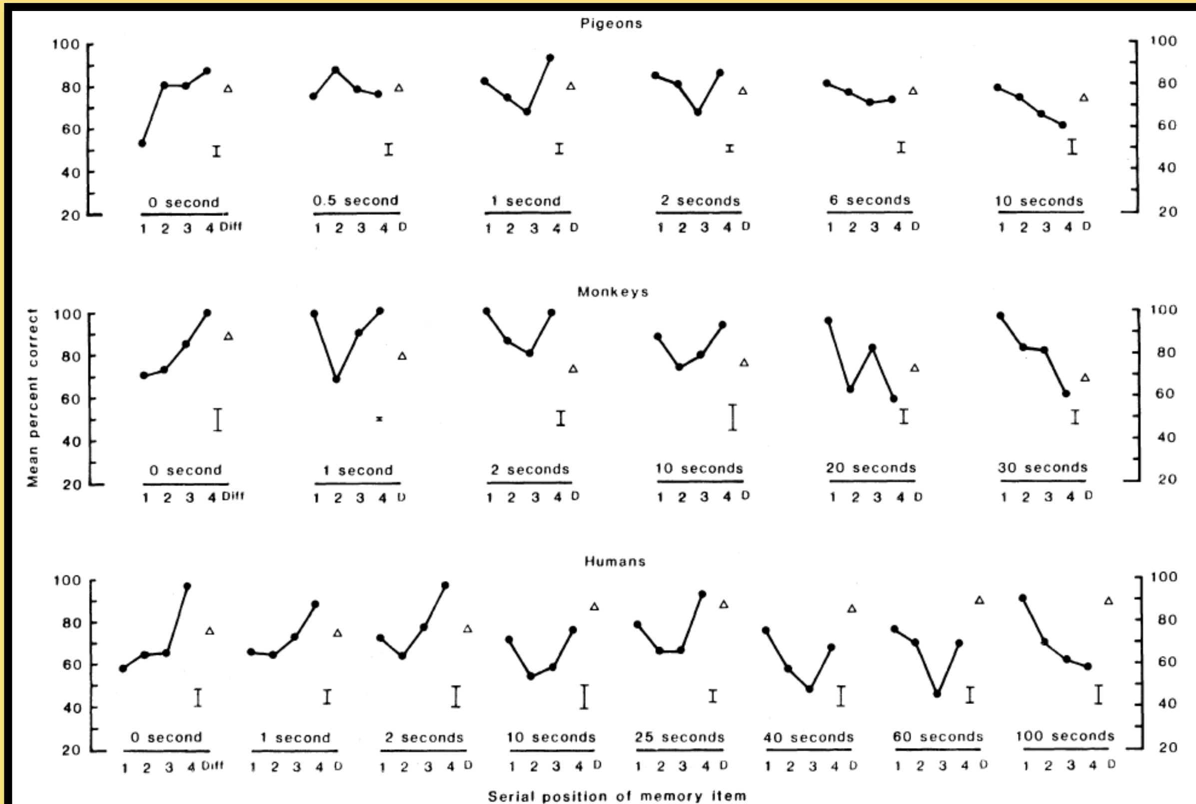


Fig. 1. Mean memory performance for four-item serial lists at different probe delays (retention intervals), the interval between the last list item (labeled 4) and the probe test item. The bar shown for each serial-position function is the average standard error of the mean for the four serial positions ("same" trials). Open triangles show performance on "different" trials where the probe item matched none of the four list items.

VISUOSPATIAL SKETCHPAD

Monkey moves sample object for reward.
(a)

Screen obscures monkey's view during delay.
(b)

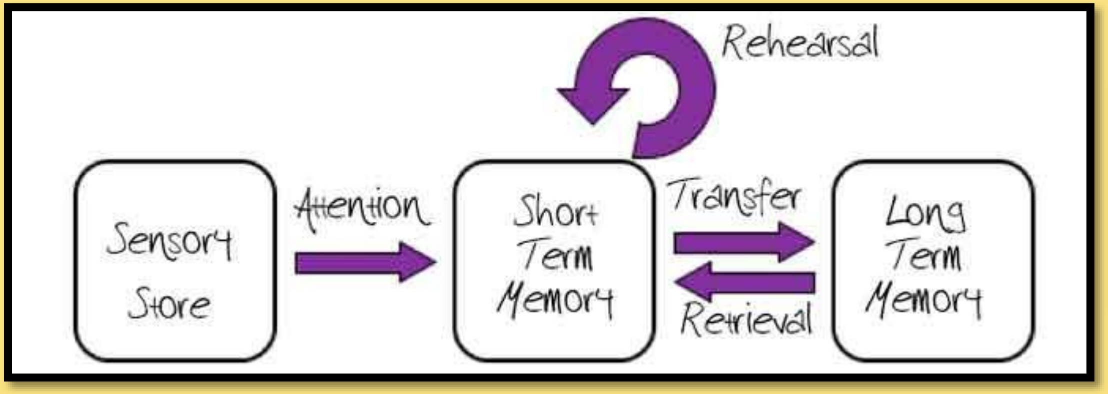
Monkey must choose novel nonmatch object for next reward.
(c)

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

- Delayed nonmatching to sample task:
  - Novel object shown
  - Delay
  - Choose the nonmatching object
- Requires visual memory of object to be held in mind during short delay—a function of the visuospatial sketchpad

Place vs State models of Memory

- Multi-Store



- Unitary-Store

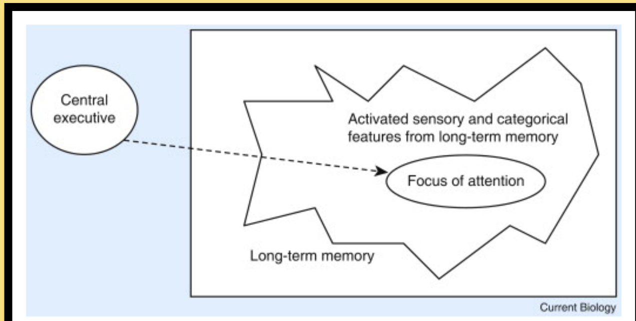
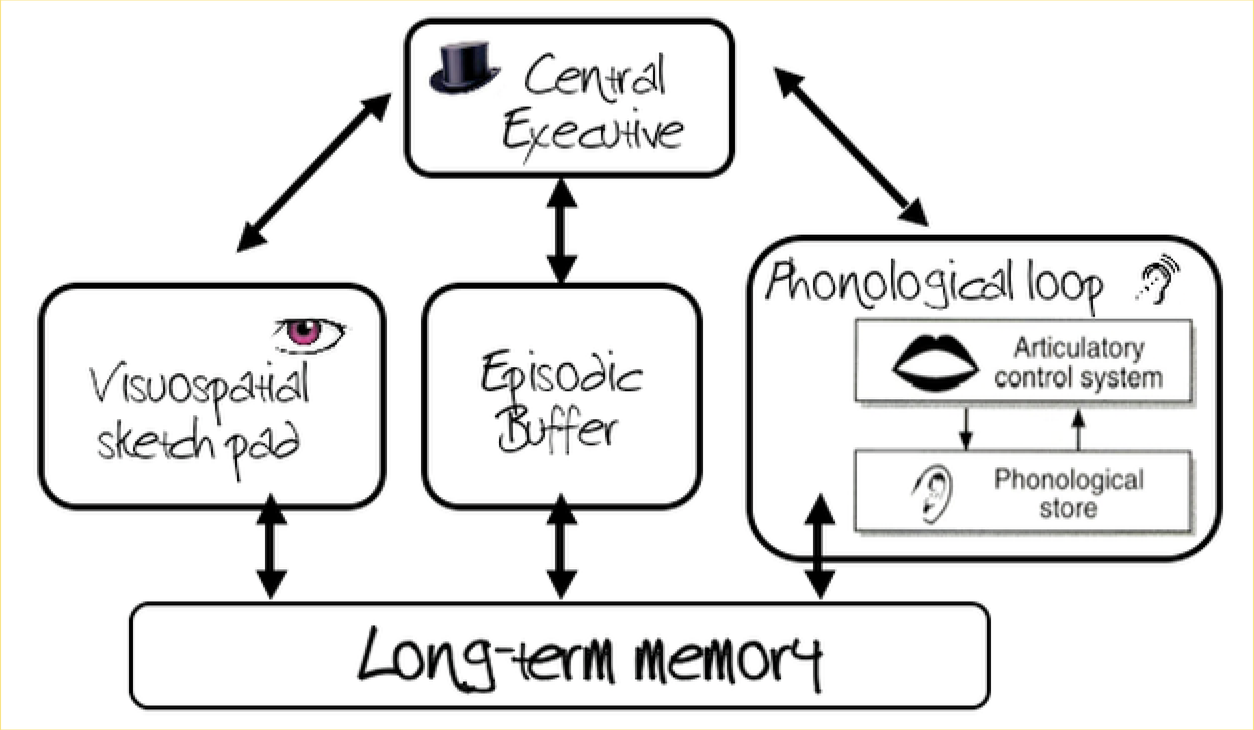


Figure 5. Cowan's Model of Working Memory

Place vs State models of Memory



Cognitive (Executive) Control and the Central Executive

- *Manipulating the contents of STM*

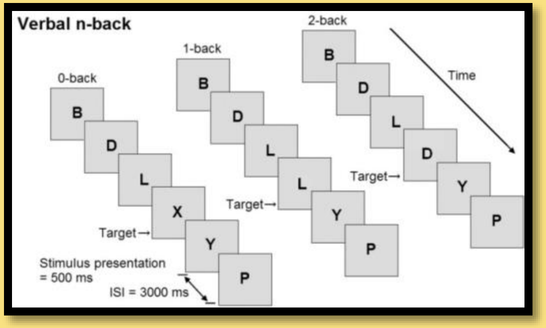
Table 9.2 Cognitive control through the manipulation of working memory

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

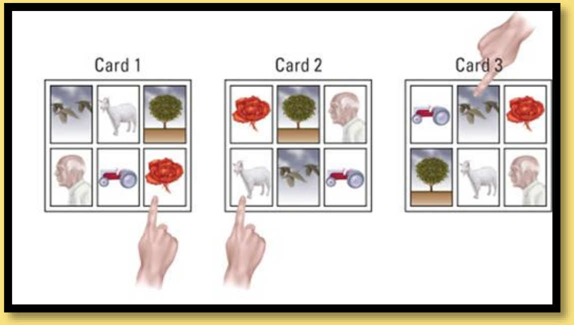
TABLE 9.2

EXECUTIVE FUNCTION: UPDATING

- N-back Task
  - *Update contents of WM to keep up with task.*



- Self-Ordered Tasks
  - *Mental "To Do" Lists*



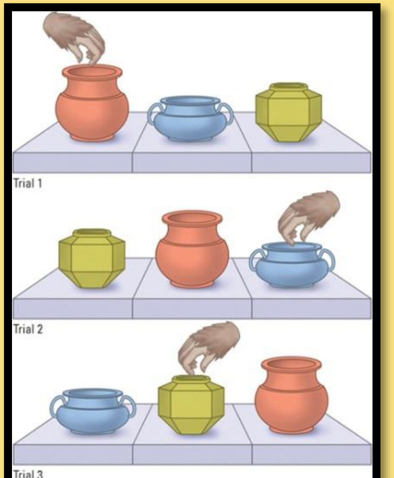
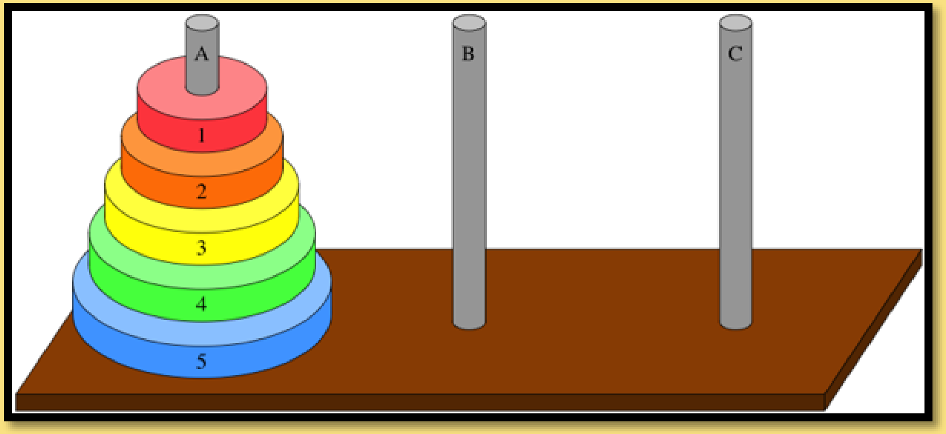


FIGURE 9.7
Mark A. Gluck/Eduardo Mercado/Catherine E. Myers, *Learning and Memory From Brain to Behavior*, 3e, © 2016 Worth Publishers

Executive Function: Setting Goals and Planning

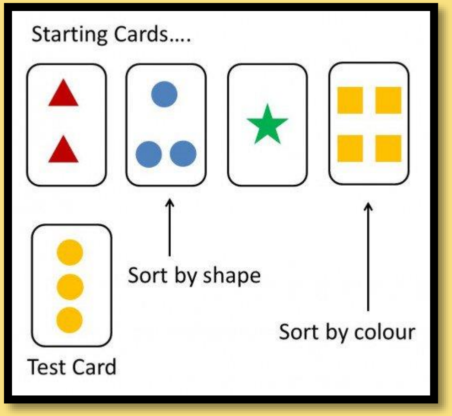
- Edouard Lucas and the Tower of Hanoi Legend
  - 64 gold disks @ 1 per second = 580 bn years!

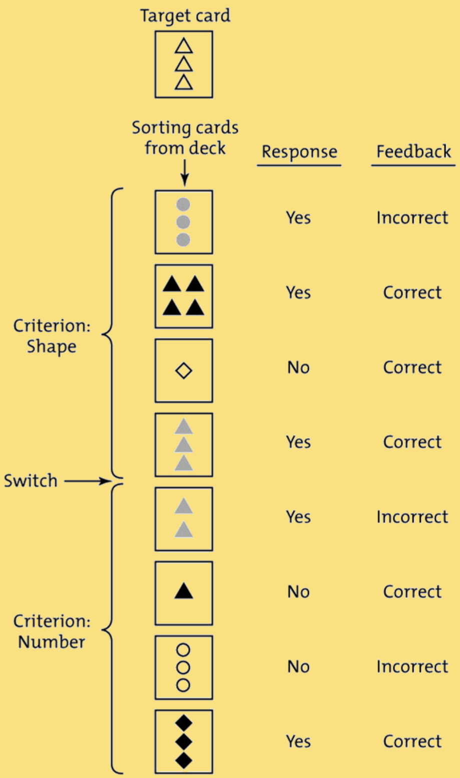


  - Setting subgoals, tracking completed and remaining goals, planning next goal…

Executive Function: Task Switching

- Wisconsin Card Sorting Test (WCST)





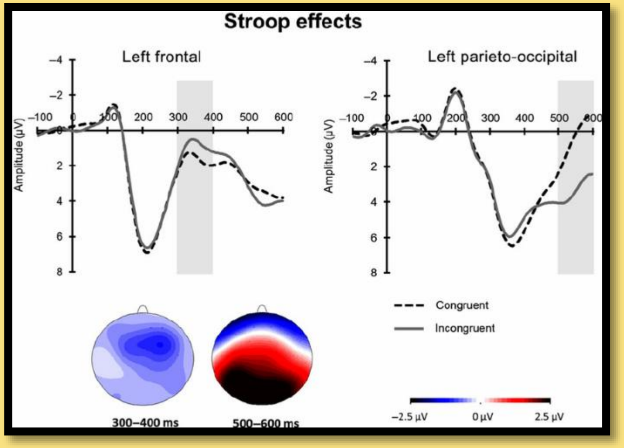
- *Sorting rule changes without warning*
  - *Maintaining and then switching a rule*
  - Frontal patients and perseveration (Roberts et al., 1996)

Executive Function: Stimulus Selection & Response Inhibition

- Driving and Crossing Roads in England and Australia

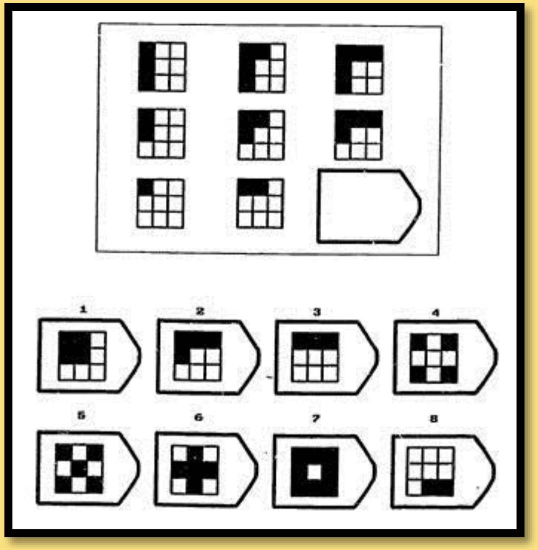
- Stroop Task (Stroop, 1935)

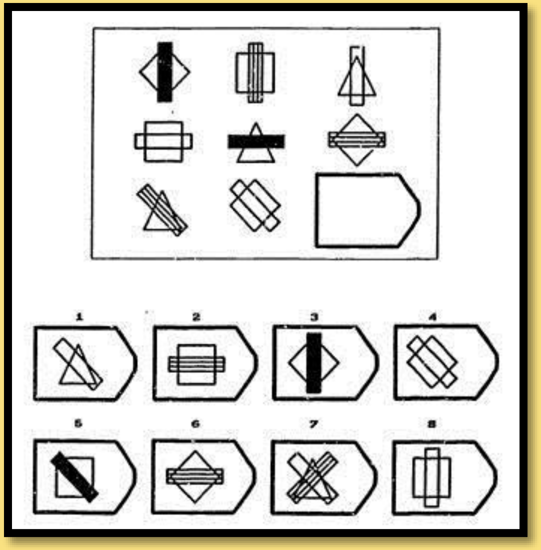
1 control	2 compatible	3 incompatible
dog	red	red
chair	yellow	yellow
boat	green	green
window	blue	blue
block	red	red
fan	blue	blue
wheel	yellow	yellow
tray	green	green
bottle	blue	blue
fence	red	red

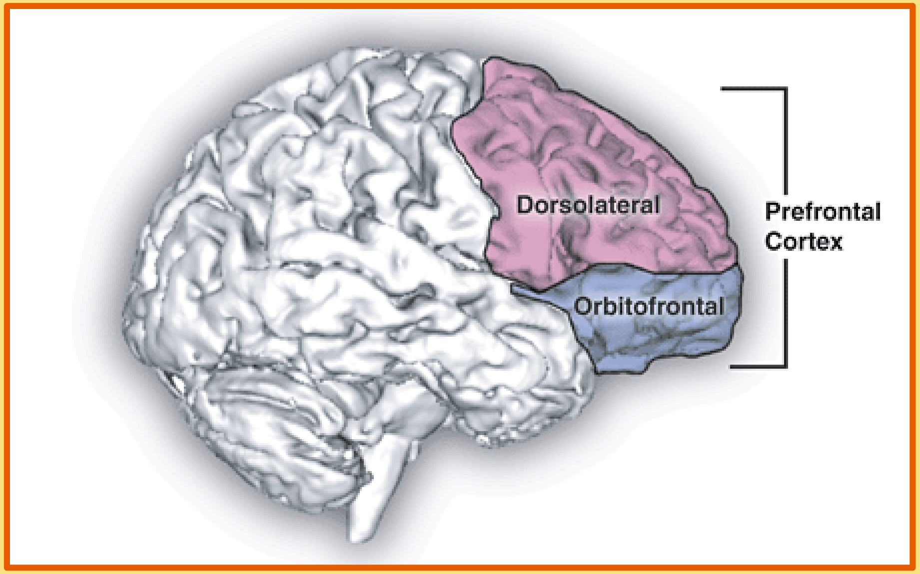


Executive Function and Intelligence

- Daneman & Carpenter
  - Correlations between WM (Delayed Recall) and…
    - Verbal SAT
    - Raven's Progressive Matrices (Mensa)







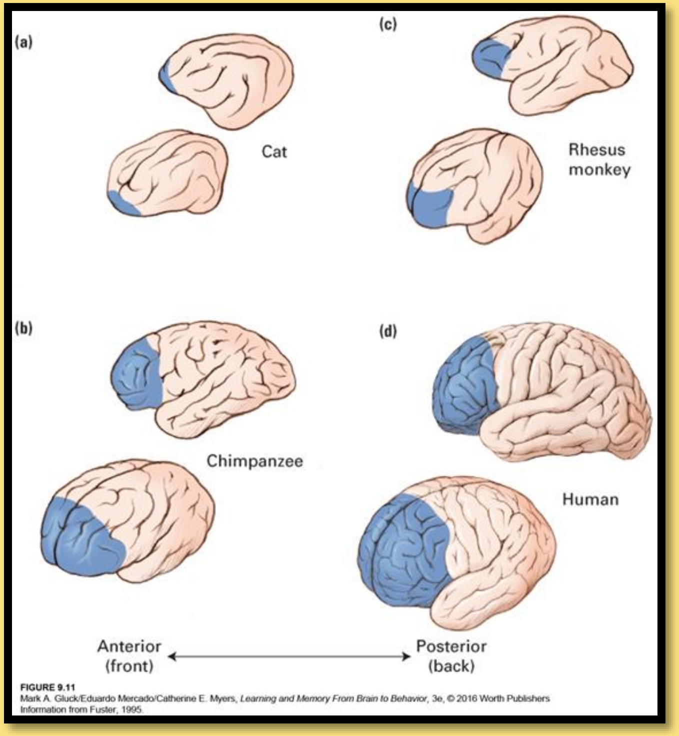
Neurological Basis of WM

Prefrontal Cortex (PFC)

The Case for the Prefrontal Cortex

- 300 World War II Vets (Pfiefer, 1922)

- Wilder Penfield's Sister
  - Disexecutive Syndrome
    - Disrupted ability to think/plan
  - Baddeley's (1986) patient RJ
    - Bilateral Frontal Lesions
    - Tower of London & String Cutting
  - N-back, Span, Delayed Recall, WCST



The Case for the Prefrontal Cortex

- Jacobsen et al. (1937): Bilateral PFC Lesions
  - Delayed Response Task

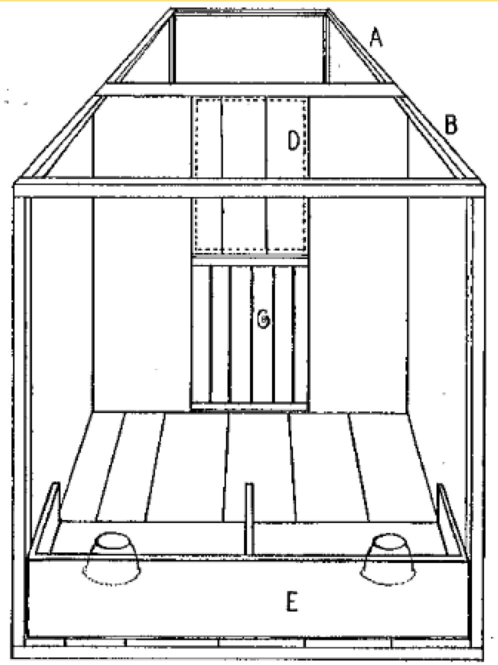


Fig. 1. Floor Plan of Experimental Cage

A and *B* denote the delay and reaction compartments; *G* is a portcullis grille, and *D* an opaque door. The tray and cups, *E*, used for the delayed response are shown in position. The problem boxes and visual discrimination apparatus are substituted for the delayed response equipment.

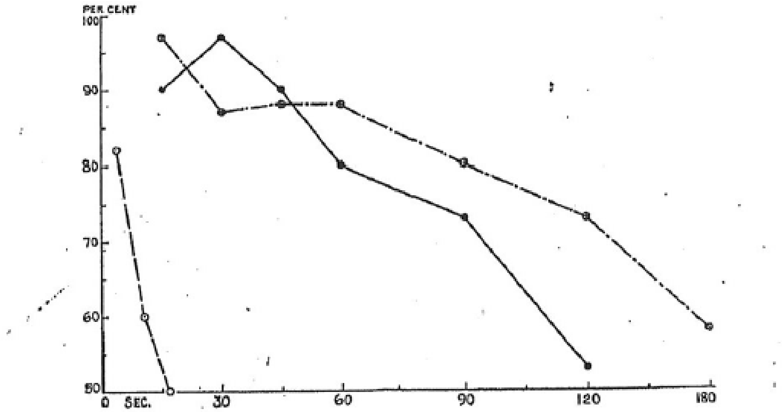
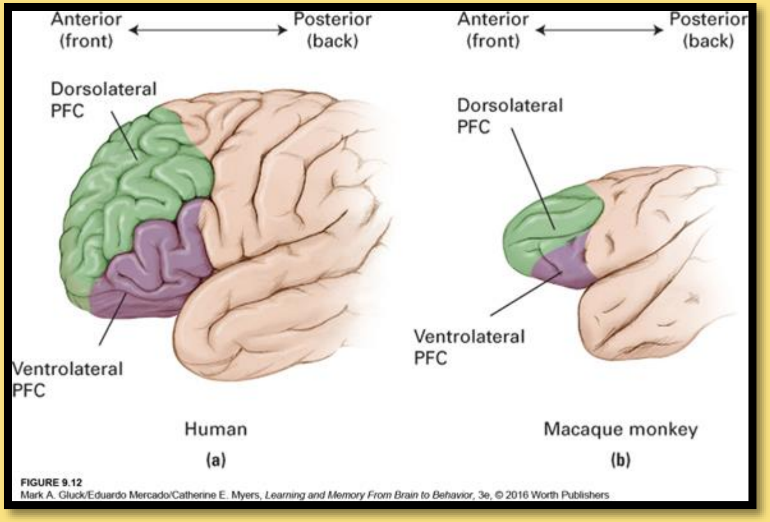
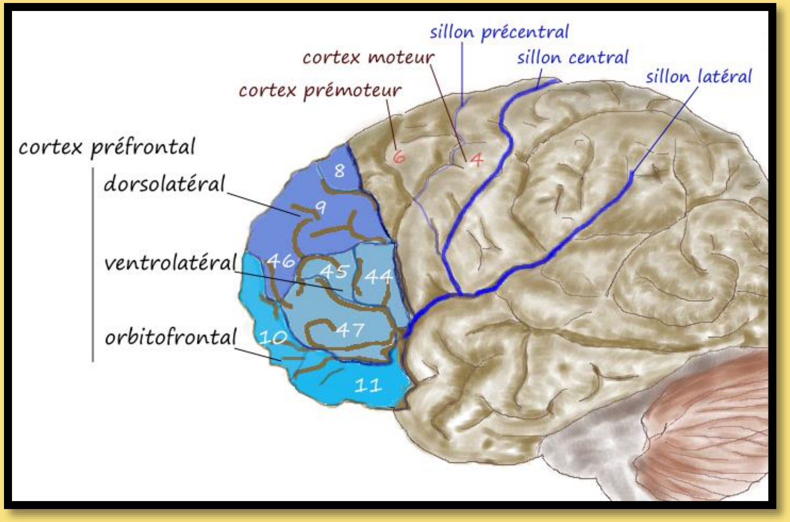


Chart 2.—Training record in tests of delayed response for a baboon, Papio papio (frontal series, no. 9), which underwent complete extirpation of the left prefrontal area and ablation of the anterior portion of the right prefrontal area. The broken line with hollow circles indicates the results obtained in the tests after the incomplete bilateral extirpation.

Dividing the Prefrontal Cortex

- Orbital, Medial, and Lateral PFC
  - Lateral ➔ Dorsolateral (DLPFC)
    Ventrolateral (VLPFC)






Delay Cells

- Fuster (1995)
  - Delay cells in DLPFC
  - “holding in mind”
- Goldman-Rakic (1995)
  - Occular motor delayed response task
    - Sensory and Motor Response Info
  - DLPFC lesions
- Miller (2000)
  - Maintain activity, despite distractions, until needed

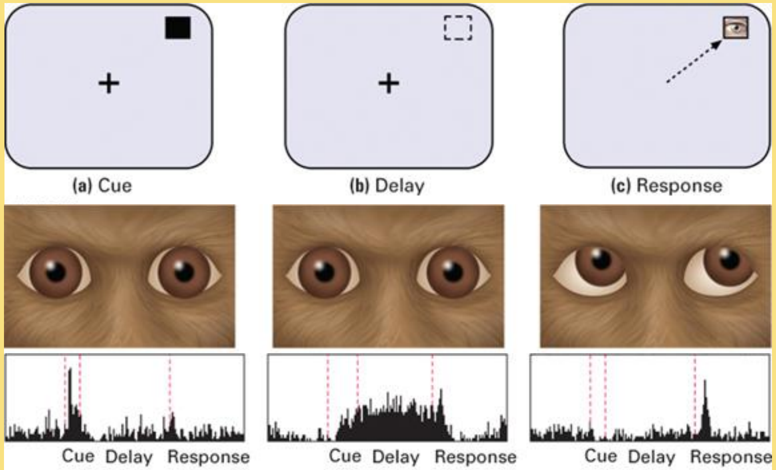
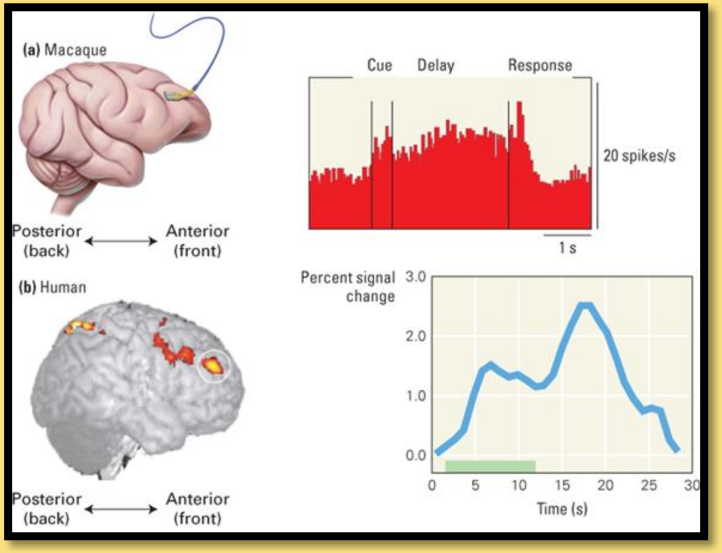


FIGURE 9.13
Mark A. Gluck/Eduardo Mercado/Catherine E. Myers, *Learning and Memory From Brain to Behavior*, 3e, © 2016 Worth Publishers
Data from Funahashi, Bruce, & Goldman-Rakic, 1989.



Baddeley's Model and Brain Anatomy

- DLPFC lesions impair monitoring, not maintaining
  - Self-Ordered Delayed Response Tasks (Petrides, 1995)

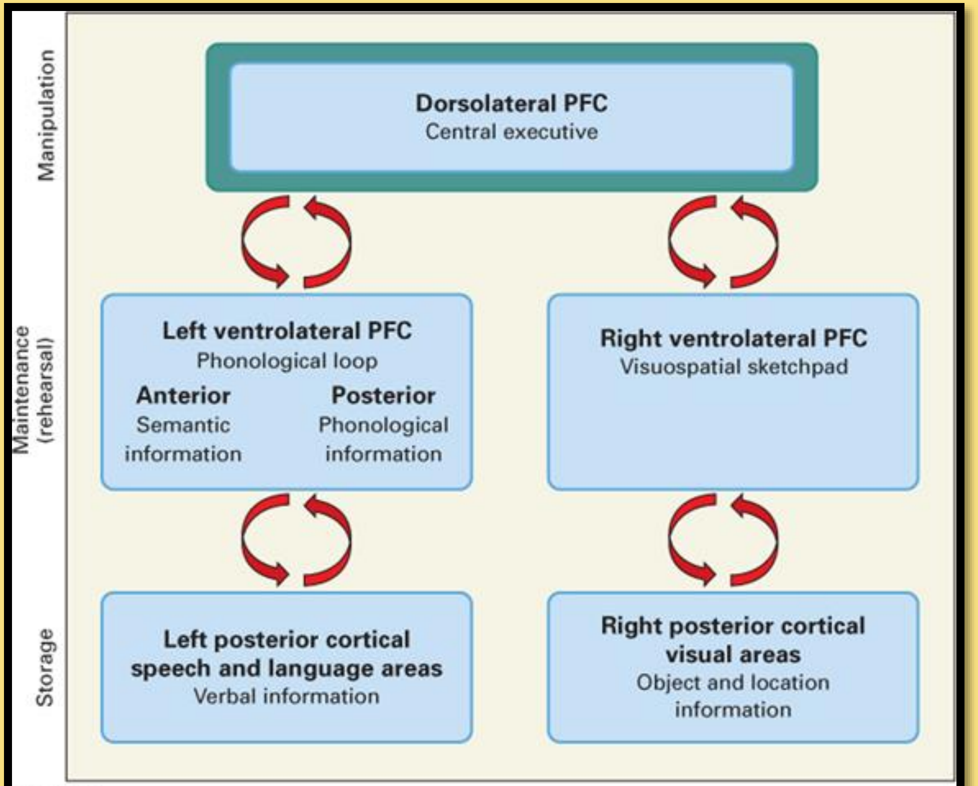


FIGURE 9.16
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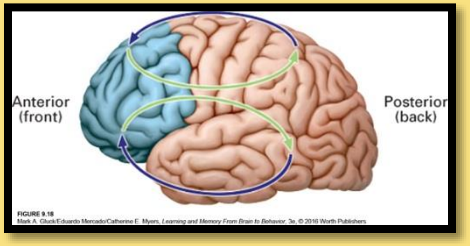
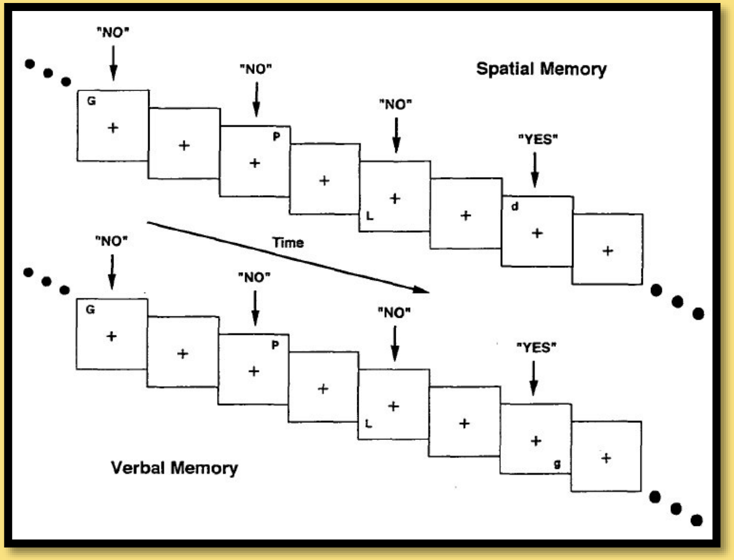
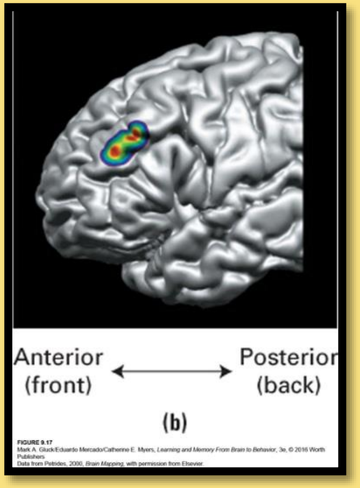
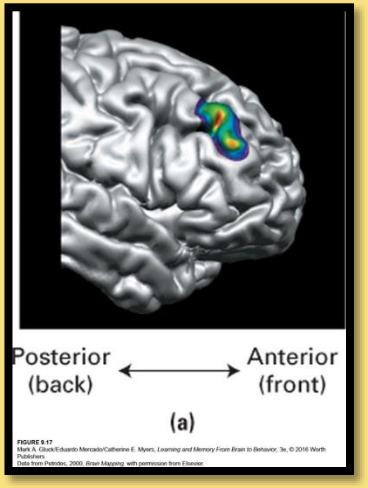
It's a Big DLPFC After All



- Phonological Loop and Visuospatial Sketchpad
  - *n*-back task (Spatial vs. Verbal)
    - (Smith et al., 1996)
    - Left is Specialized and Right is not?

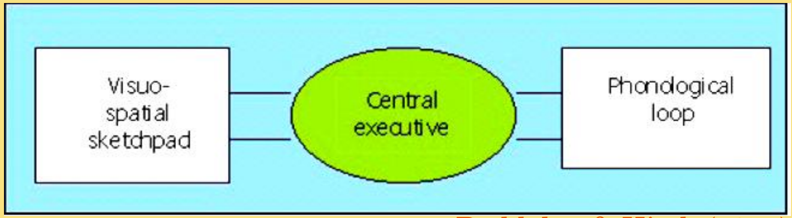






- Reconciliation of Baddeley's Model and Unitary Store?

SMITH ET AL.'S (1996) *N*-BACK TASKS



Baddeley & Hitch (1974)

Right Hemisphere

Left Hemisphere
(Broca's area?)

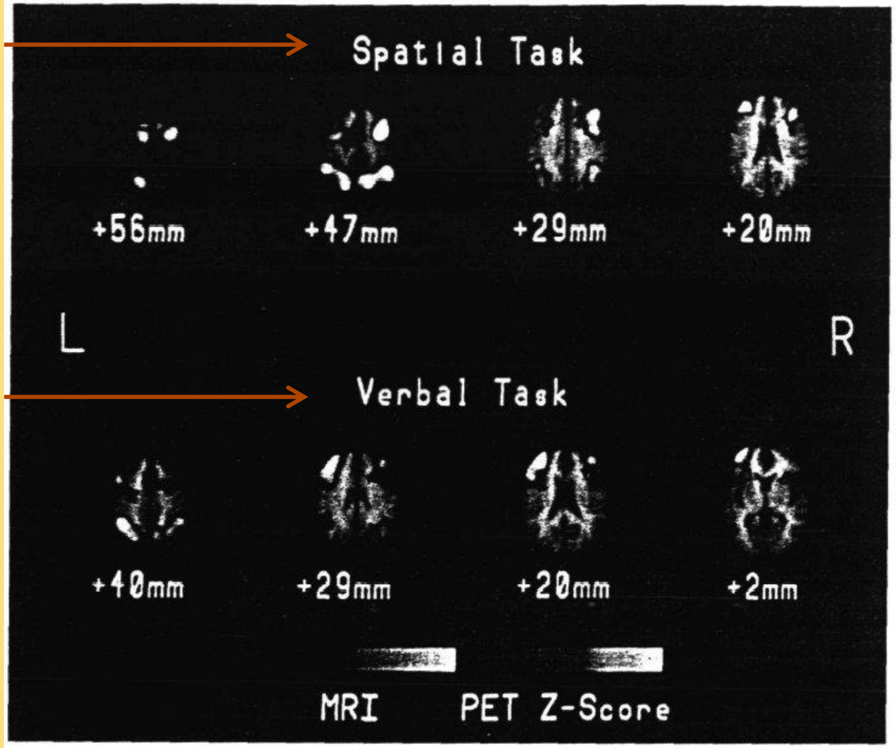
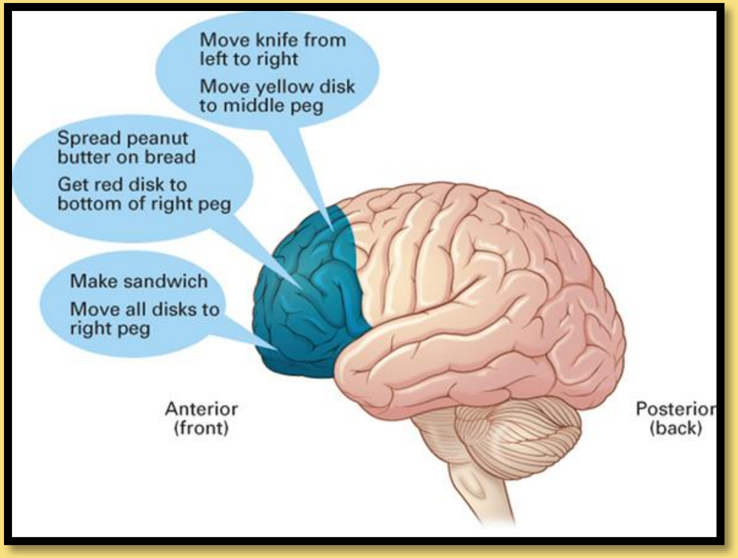


Figure 4. PET images of statistically significant activation sites in the spatial memory condition (*top*) and the verbal memory condition (*bottom*). Each image is superimposed on an MRI image of a composite brain. Note that in the verbal memory task the activation is greater in the left than the right hemisphere, whereas in the spatial memory task the activation is greater in the right hemisphere in key regions (see text). Stereotaxic coordinates of all significant foci of activation are given in Table 1 (Experiment 2).

Smith, Jonides, & Koeppe (1996)

Goal Abstraction

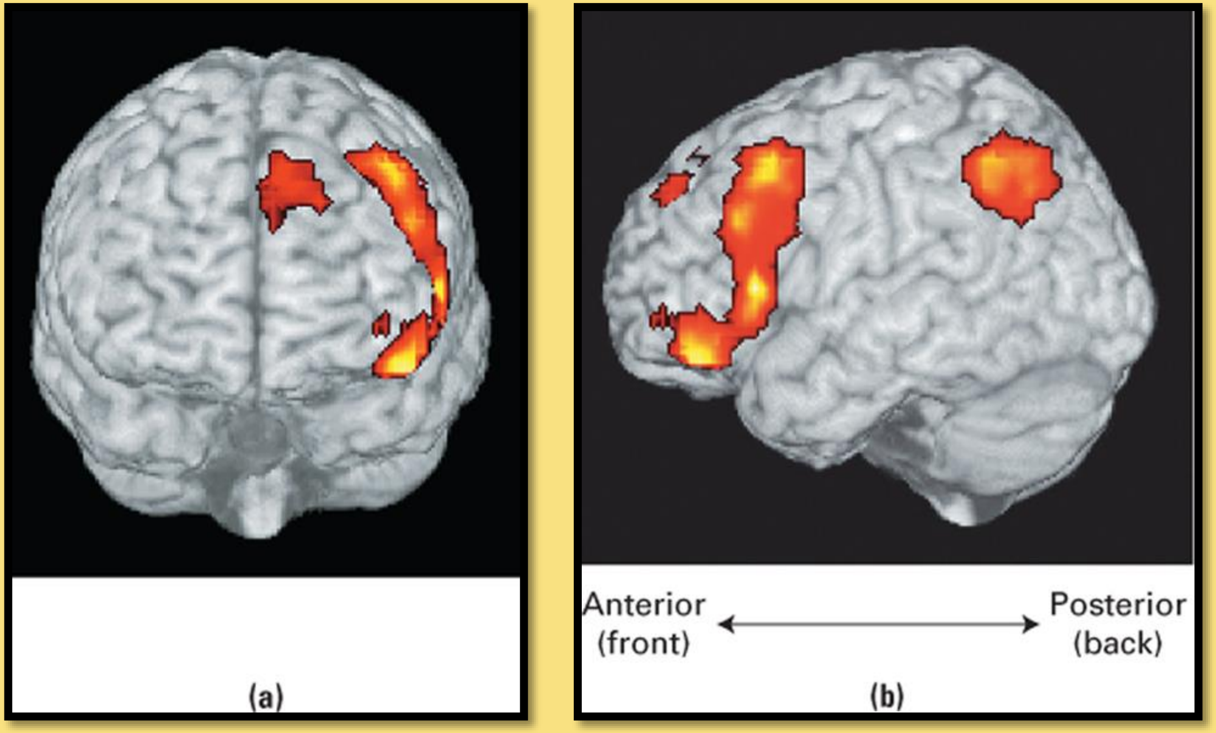
- *Making PBJ Sandwiches*
  - *Broad Abstraction Starts at the Front*



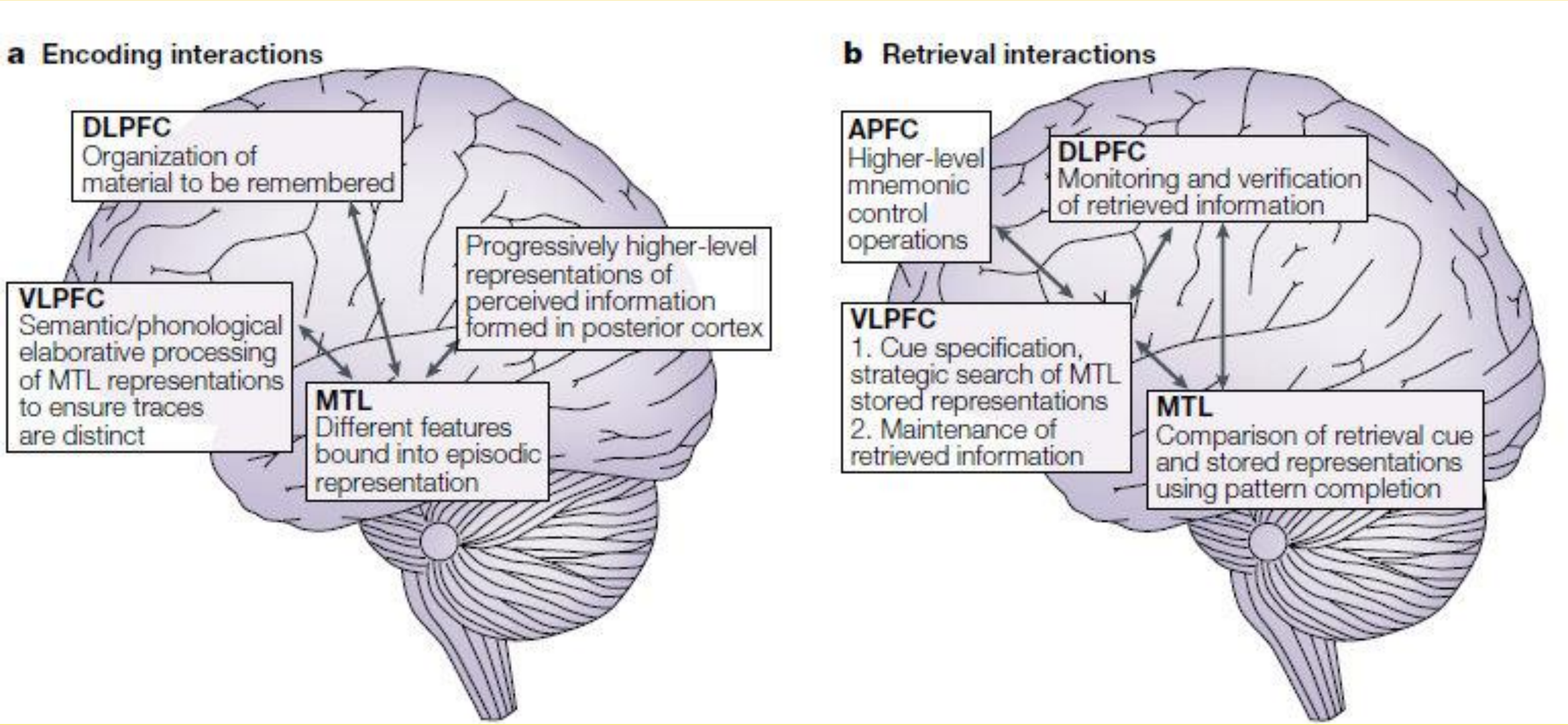
  - *"Make your own breakfast this morning"*
    - Developmental changes in frontal lobes support abstract planning (Shaw et al., 2008)

USING PFC TO CONTROL LTM

- Frontal Patients and Observing Activity in Controls
  - Meta-Memory (underconfident JOL; TOT)
  - Source Memory (Dobbins et al., 2002)

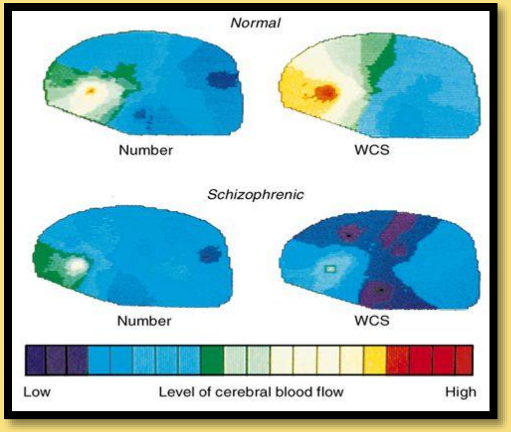


PFC-Hippocampus Interactions

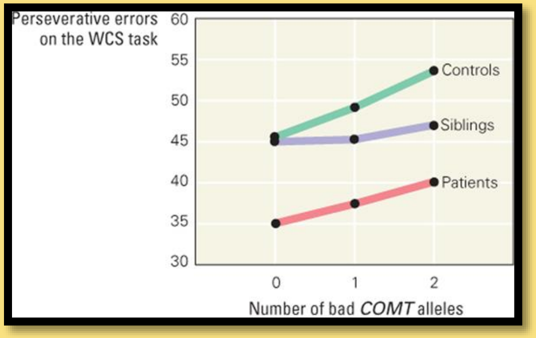


SCHIZOPHRENIA AND THE PFC

- Weinberger et al. (1996)
  - WCST and DLPFC in Schizophrenic and Control



  - Activity in DLPFC lower in Sz. during N-back (Barch et al., 2002)
  - Post-mortem neural pathologies
  - COMT gene
    - Degrading dopamine



Attention Deficit/Hyperactivity Disorder (ADHD)

- At least 5% children diagnosed*
- Decreased PFC activity and weaker connections in PFC
  - Is the problem in the PFC or elsewhere (basal ganglia)?