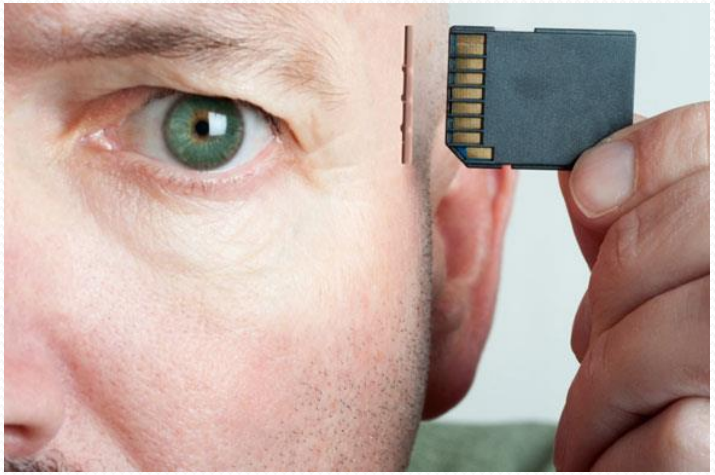
Memory and Language

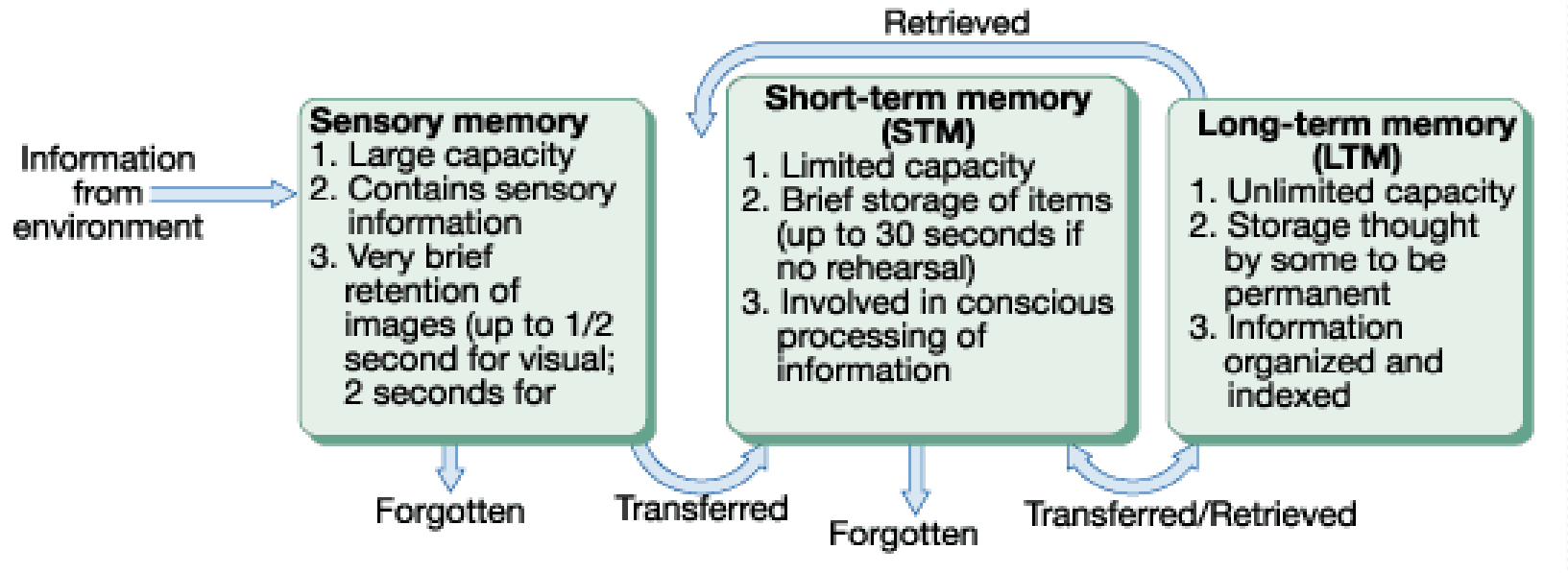
November 10, 2021

Memory

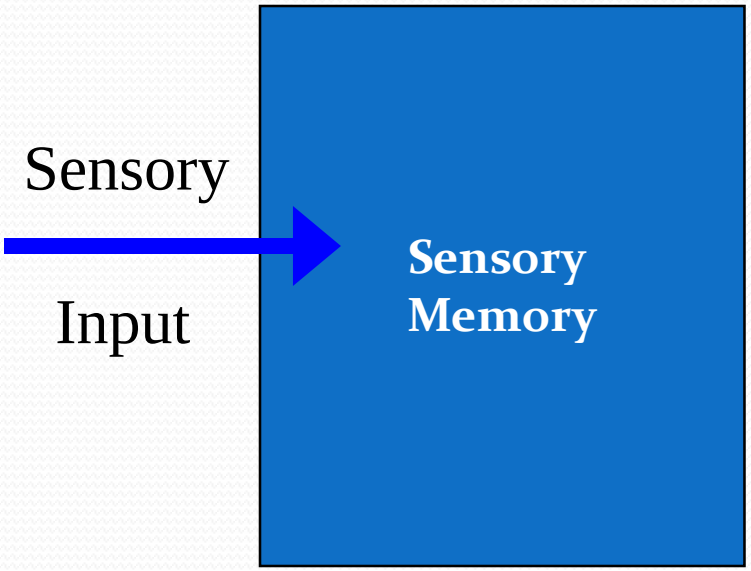
- Process by which information is:
  - Acquired
    - Encoding
  - Stored in the brain
    - Storage
  - Later retrieved
    - Retrieval
  - Eventually (possibly) forgotten



Three-Box Model of Memory

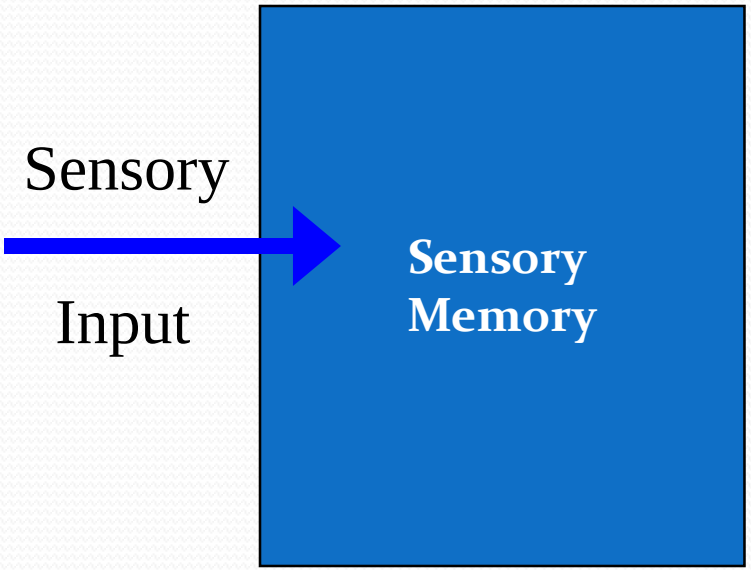


Sensory Memory



- Function - holds information long enough to be processed for basic physical characteristics
- Capacity - large
  - can hold many items at once
- Duration - very brief retention of images
  - .3 sec for visual info
  - 2 sec for auditory info

Sensory Memory



- Divided into two subtypes:
  - iconic memory - visual information
  - echoic memory - auditory information
- Visual or iconic memory was discovered by Sperling in 1960

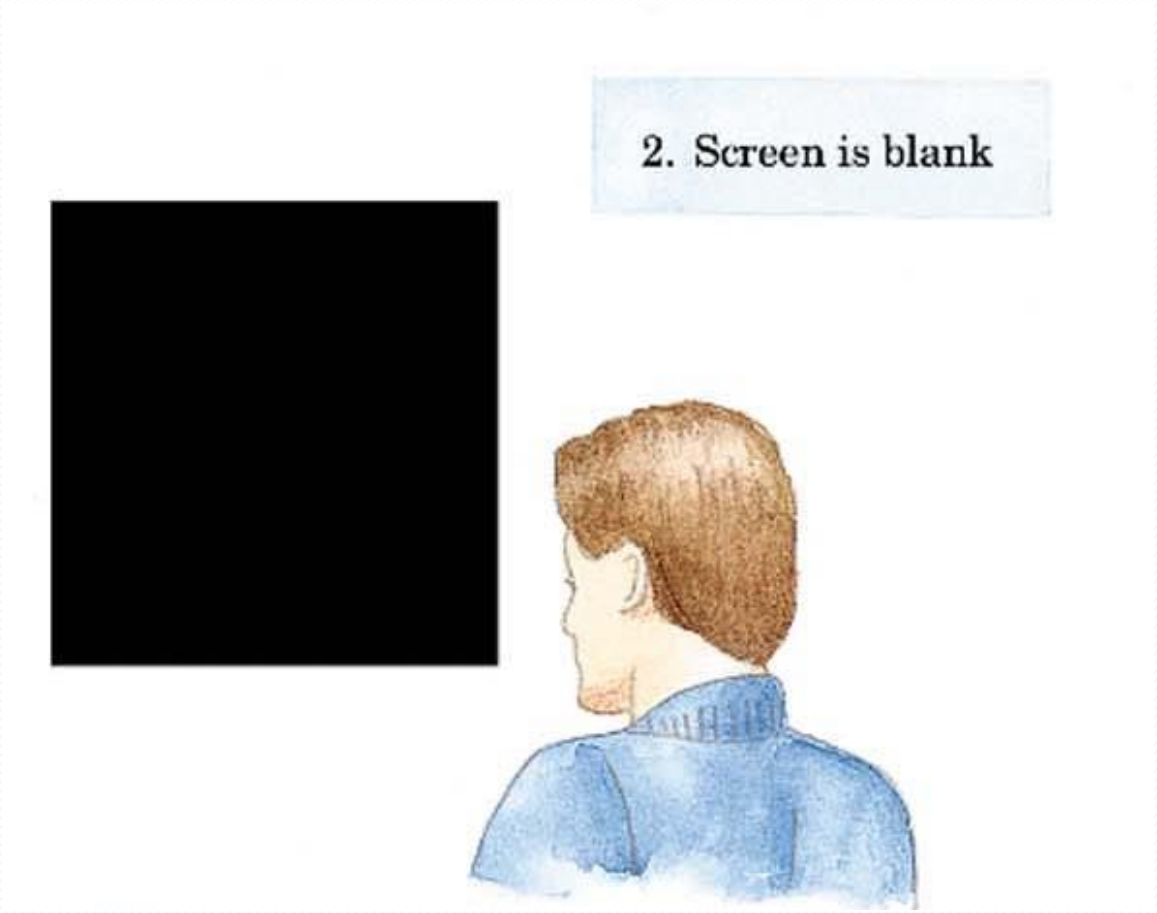
Sperling's Experiment

- Presented matrix of letters for 1/20 seconds
- Whole-report procedure
  - Participants are asked to report all the items of a display
- Partial-report procedure
  - Participants are cued to report only some of the items in a display

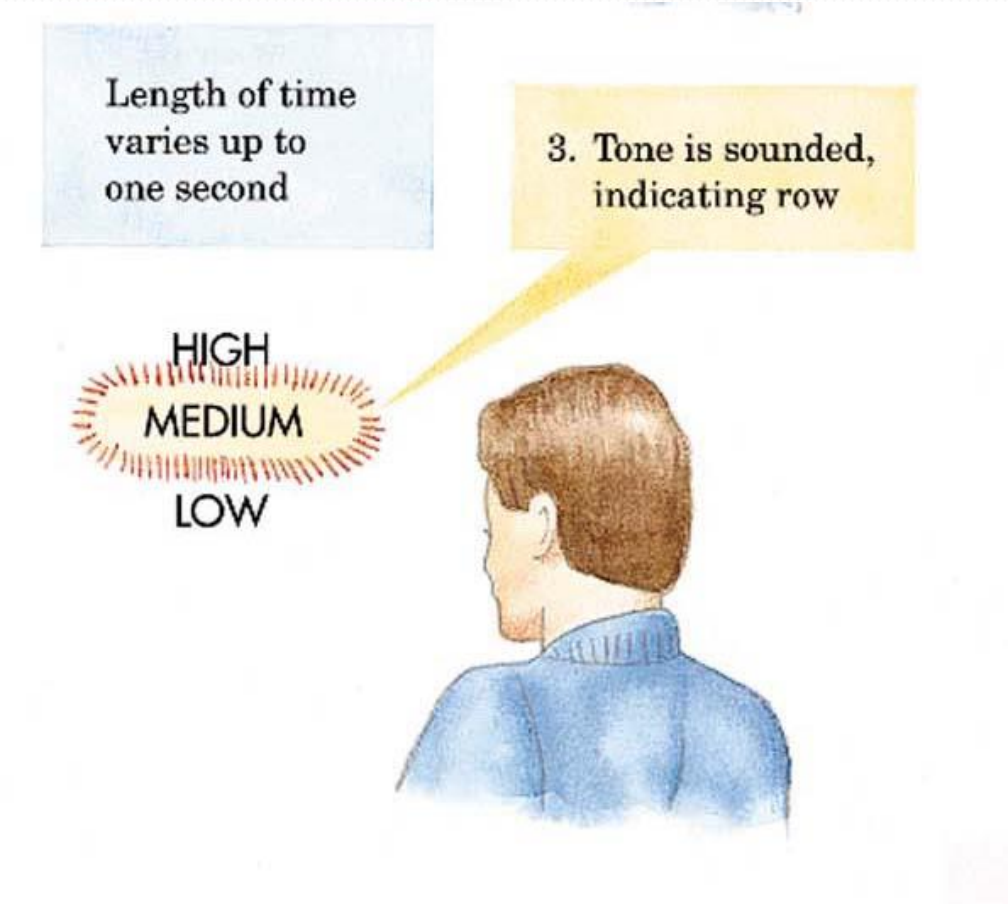
Sperling's Iconic Memory Experiment

1. Letters are displayed on a screen for 1/20 of a second

Sperling's Iconic Memory Experiment



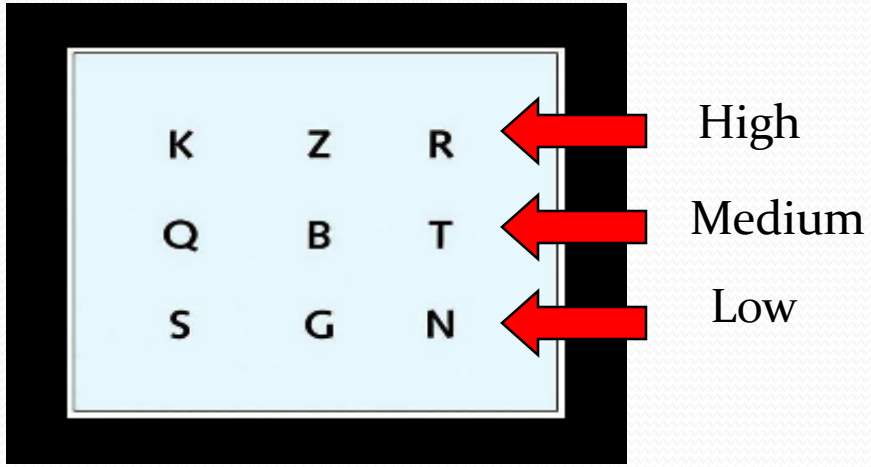
Sperling's Iconic Memory Experiment

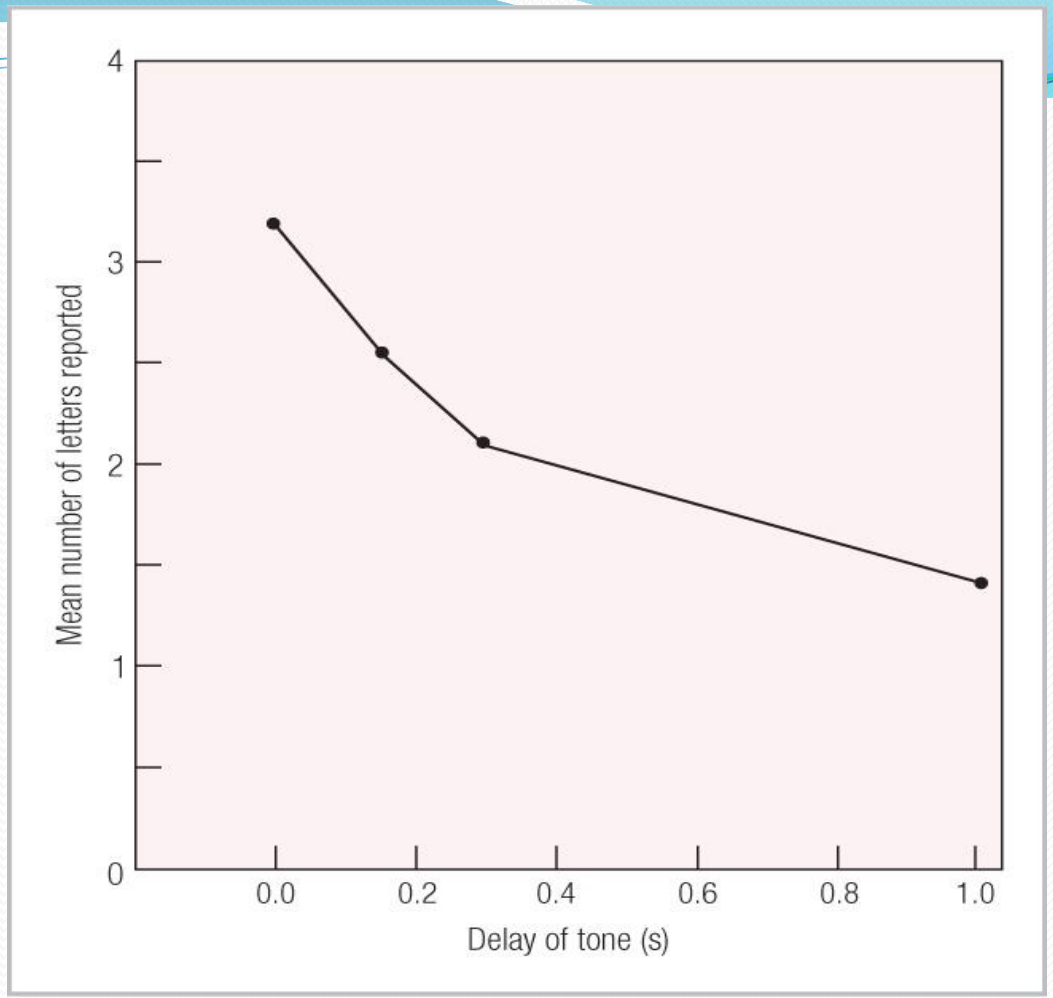


Sperling's Iconic Memory Experiment

Sperling's Experiment

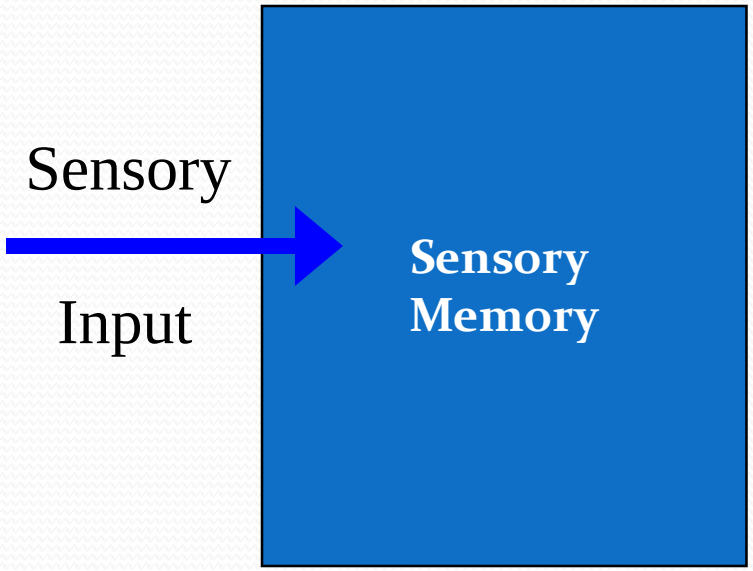
- Sounded low, medium or high tone immediately after matrix disappeared
  - Tone signaled 1 row to report
  - Recall was almost perfect
- Memory for images fades after 1/3 seconds or so, making report of entire display hard to do





Results from Sperling's experiment demonstrating the existence of a brief visual sensory store. Participants were shown arrays consisting of three rows of four letters. After the display was turned off, they were cued by a tone, either immediately or after a delay, to recall a particular one of the three rows. The results show that the number of items reported decreased as the delay in the cuing tone increased.

Sensory Memory

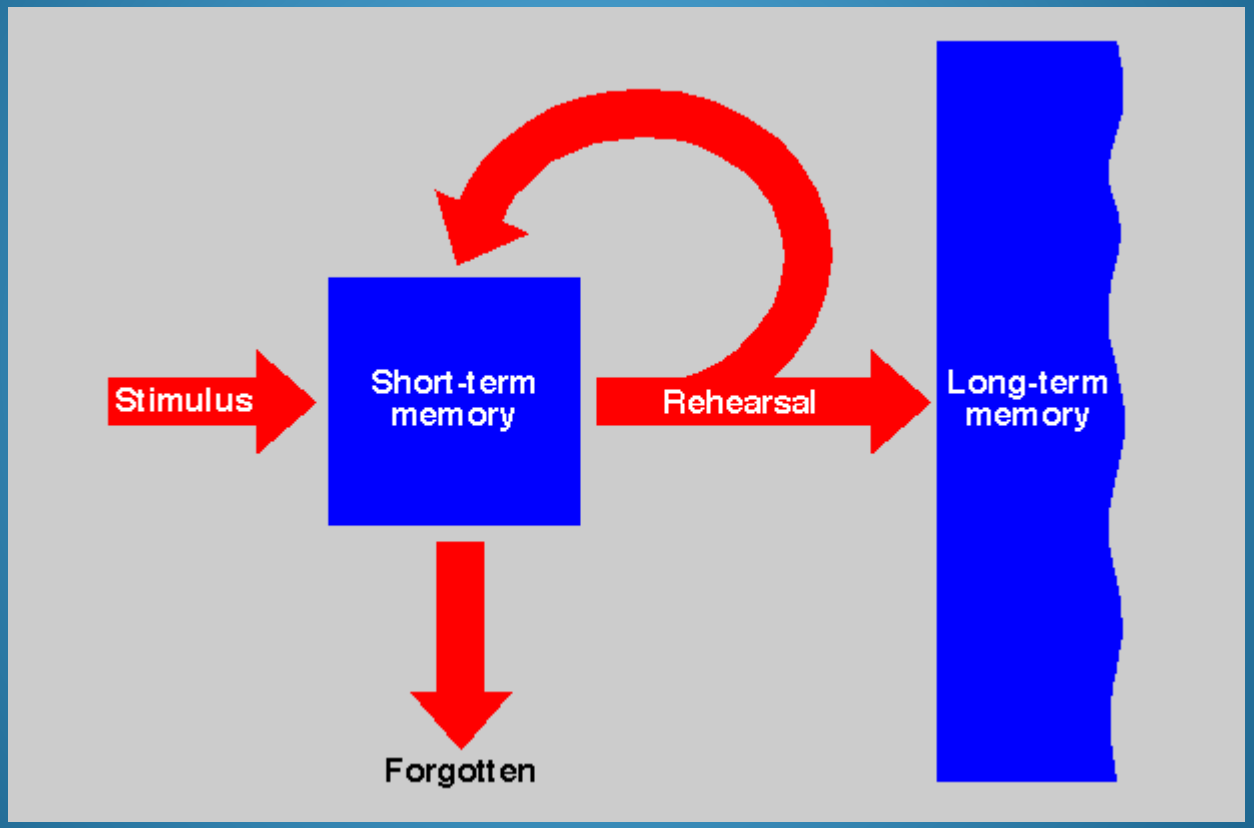


- Sensory memory forms automatically, without attention or interpretation
- Attention is needed to transfer information to short-term memory

Short-Term Memory (STM)

- A proposed intermediate system in which information has to reside on its journey from sensory memory to long-term memory

Atkinson and Shiffrin (1968) Model



Proposes that as information is rehearsed in a limited-capacity STM, it is deposited in long-term memory

Memory span

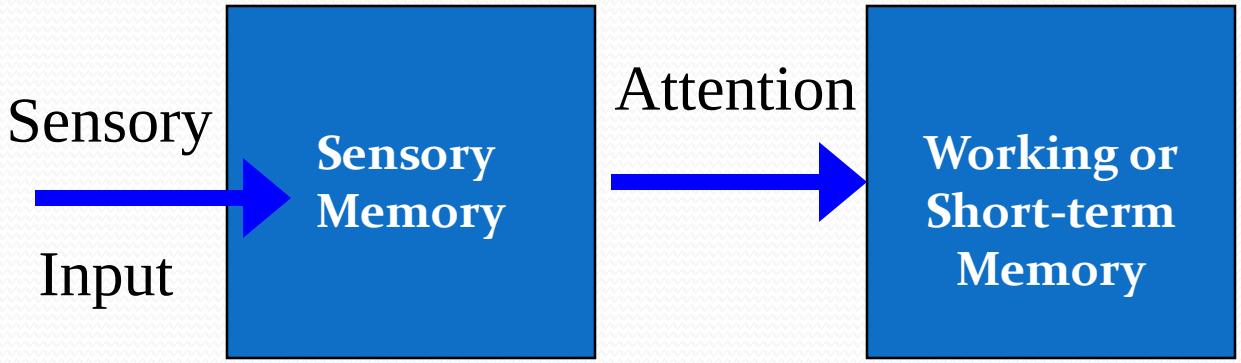
- The number of elements one can immediately repeat back
  - Typical short-term memory span is about seven items of information (i.e., words)
    - George Miller (1957)
    - Shepard and Teghtsoonian (1961)
      - Information cannot be kept in STM indefinitely

George Miller

“The magical number seven, plus or minus two: Some limits on our capacity for processing information” (1956)

Working Memory

- Function - conscious processing of information
  - where information is actively worked on
- Capacity - limited (holds 7 +/- 2 items)
- Duration - brief storage (about 30 seconds)
- Code - often based on sound or speech even with visual inputs

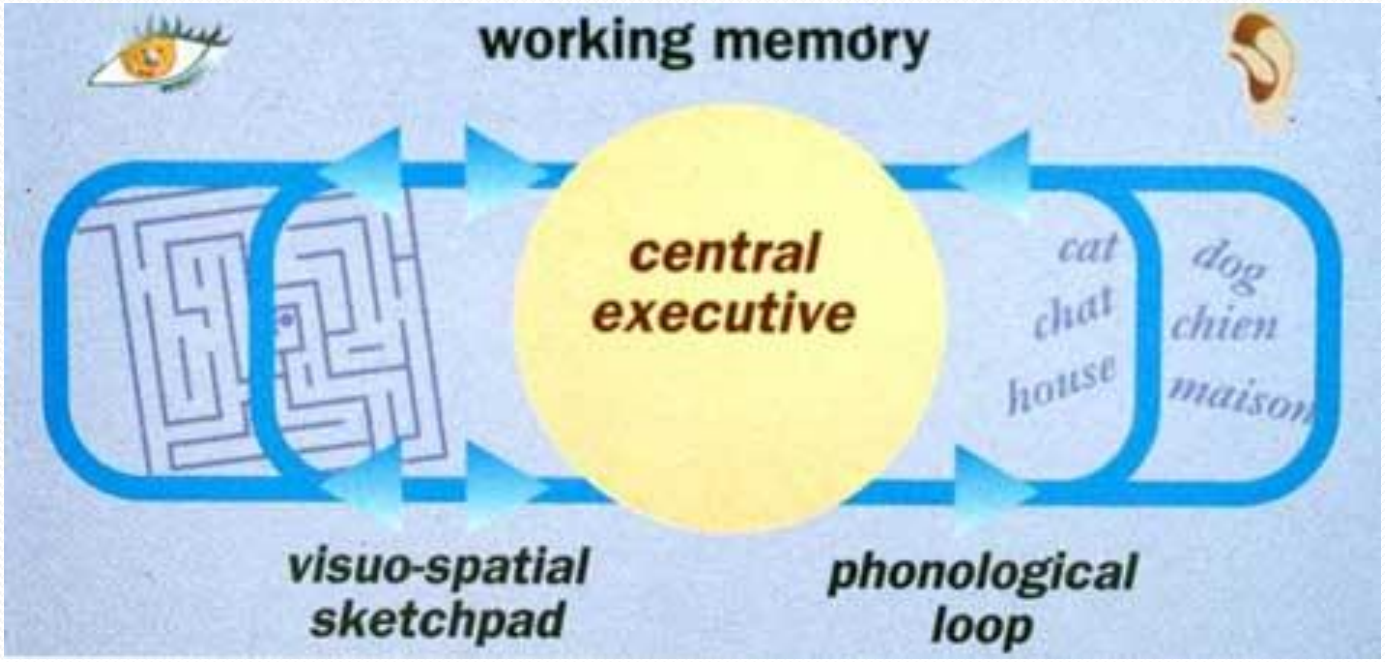


Working Memory

Holds the Information Needed to Perform a task

Memory system that provides temporary storage for information that is currently being used in some conscious capacity (Baddeley, 1986)

- Function - conscious processing of information
  - where information is actively worked on
- Capacity - limited (holds 7 +/- 2 items)
- Duration - brief storage (about 30 seconds)
- Code - often based on sound or speech even with visual inputs



Baddeley's theory of working memory in which a central executive coordinates a set of slave systems.

Working Memory

- The Central Executive
  - An attentional control mechanism for working memory
    - Coordinating between the various subsystems
    - Temporary activation of long-term memory
    - Shifting between tasks or retrieval strategies
    - Relying on the frontal lobe, mainly in the left hemisphere
  - Use of language clearly relies on the central executive

Working Memory

- The visuospatial sketchpad
  - Integrating spatial, visual, and kinesthetic information
- Phonological loop
  - Articulatory loop
    - ‘Inner voice’ used during rehearsal of verbal information
    - Able to maintain about 1.5 to 2 sec worth of material in the loop
  - Phonological store
    - An ‘inner ear’ that hears the inner voice and stores the information in phonological form

Word length effect

- wit, sum, harm, bay, top
- University,opportunity,aluminum,constitutional,auditorium

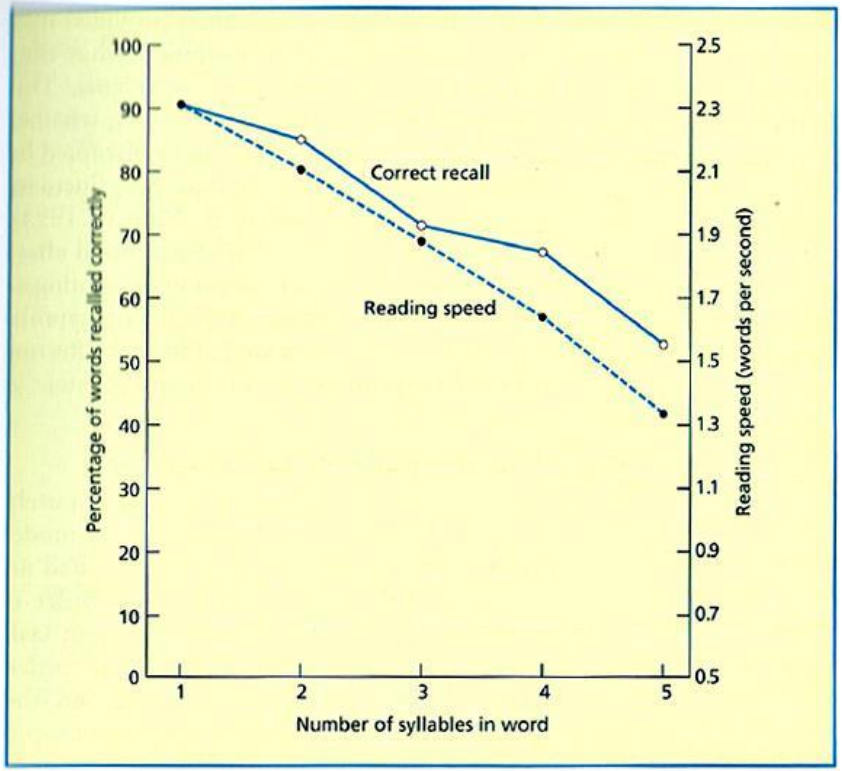


Figure 2.5 The relationship between word length, reading rate, and recall. Long words take longer to rehearse and also produce lower memory spans. From Baddeley, Thomson, and Buchanan (1975).

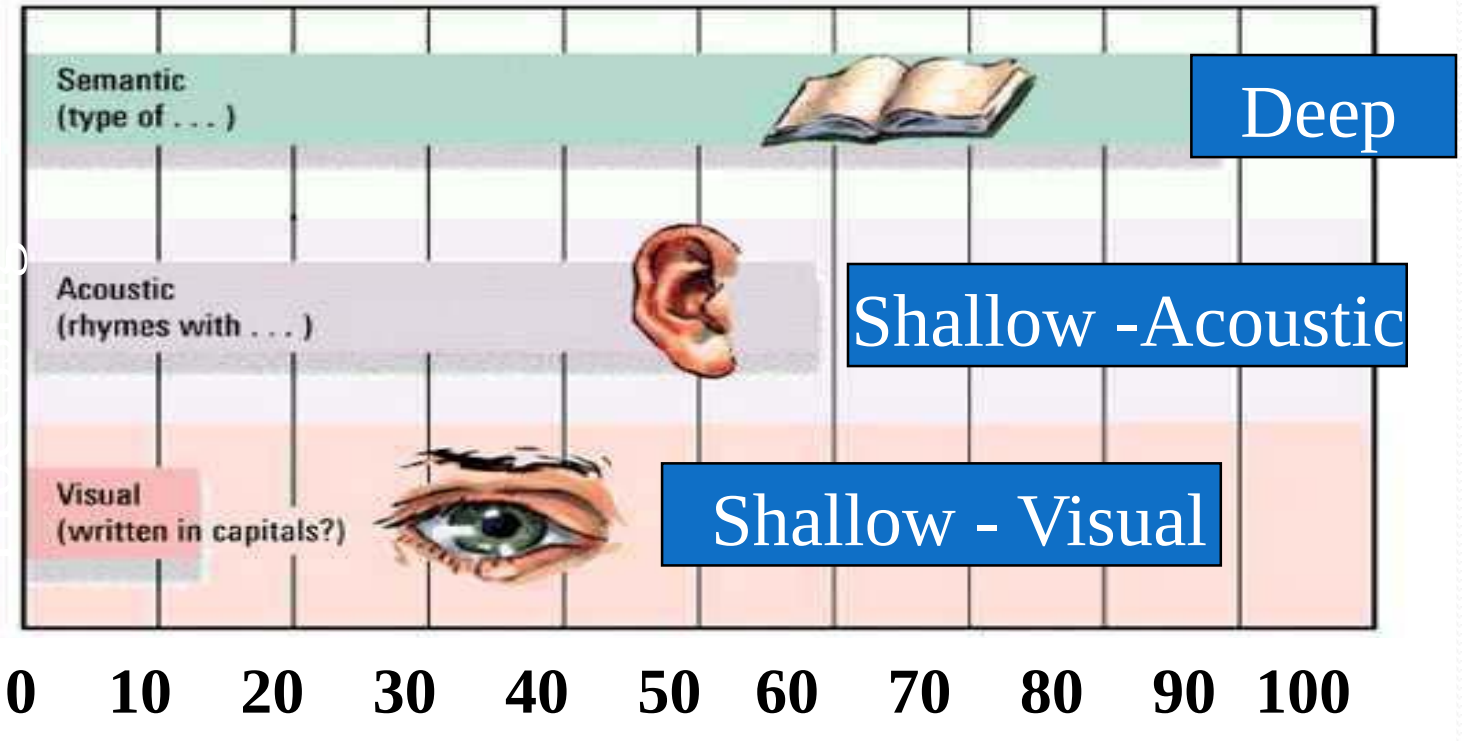
Working Memory

Phonological similarity effect

- "G, C, B, T, V, P" vs. "F, L, K, S, Y, G."
- Performance is usually _____ when the items sound similar than when the items sound different.
- The phonological store retains speech-based memory for a brief period of time and unless material is rehearsed, it usually decays within 2 seconds.
- The articulatory control process, which is responsible for translating visual information into speech-based codes, as well as transfering it to the phonological store.

Processing depth

- Elaboration leads to better recall than shallow processing



Working Memory measures

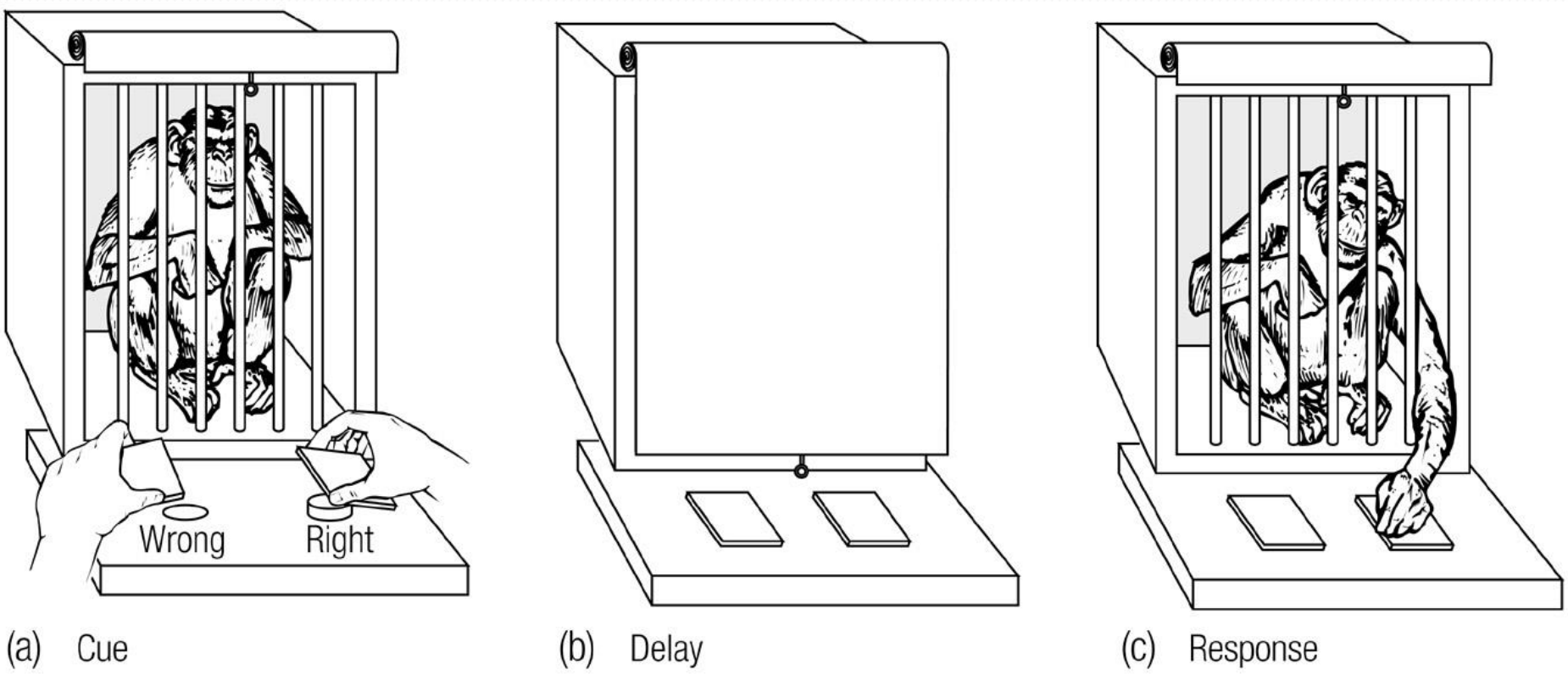
- Digit span(Wechsler, 1974)
  - Forward digit span (Botwinick & Storandt, 1974)
  - Backward digit span (Gathercole & Alloway, 2008)
  - Letter-number sequencing (Wechsler, 1997)
- Nonword repetition(Obrien et al., 2006)
- Wisconsin Card Sorting Test (WCST) (Miyake et al., 2000)
- Tower of Hanoi (TOH)/London (Korkman, Kirk, & Kemp, 1998)
- Random number generation (RNG) (Baddeley, 1998)
- Operation span (Miyake et al., 2000)
- Dual task (Papagno et al., 1991)
- N-back (Smith & Jonides, 1999)
- Delayed-recognition (Jha & McCarthy, 2000)

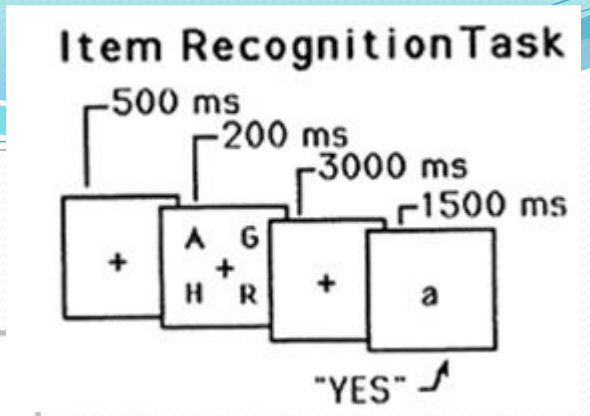
Working Memory

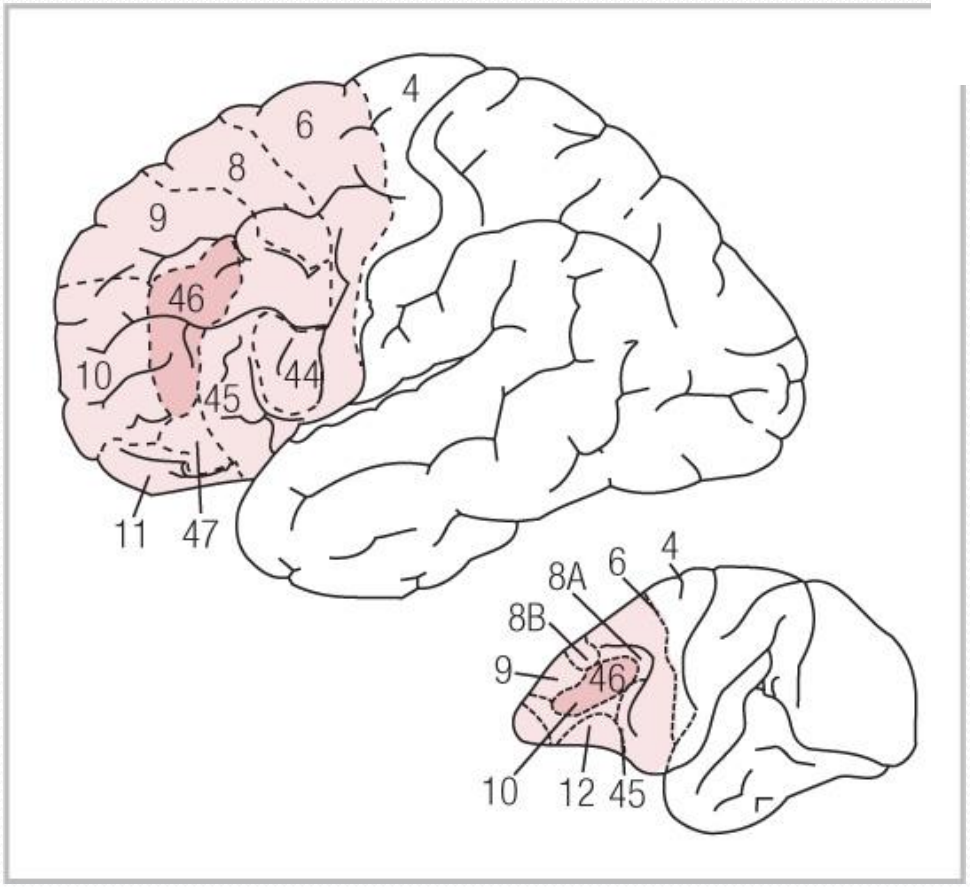
The Frontal Cortex and Primate Working Memory

- **Delayed match-to-sample tasks with monkeys (Goldman-Rakic, 1992)**
  - Monkeys with lesions in the frontal cortex cannot perform this working memory task.
  - Human infants cannot perform similar tasks successfully until their frontal cortices have somewhat matured (around 1 year)

An illustration of the delayed match-to-sample task







Lateral views of the cerebral cortex of a human (top) and of a monkey (bottom). Area 46 is the region shown in darker color.

Working Memory - Neuropsychology

- Auditory-Verbal maintenance deficit following Left Supramarginal / Inferior Parietal lesions, eg KF (Warrington & Shallice, 1969)

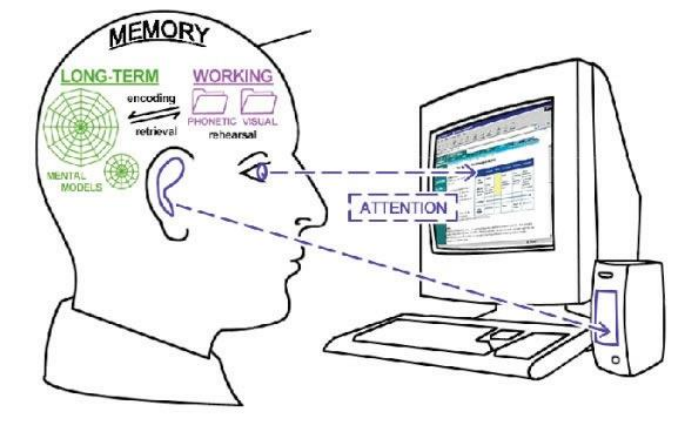
- Visual-spatial maintenance deficit following Right Inferior Parietal lesion, eg ELD (Hanley et al 1991)

- Frontal patients impaired on manipulating information in Working Memory on tasks such as card sorting (Milner, 1963) and selection-without-repetition (Petrides & Milner, 1982)

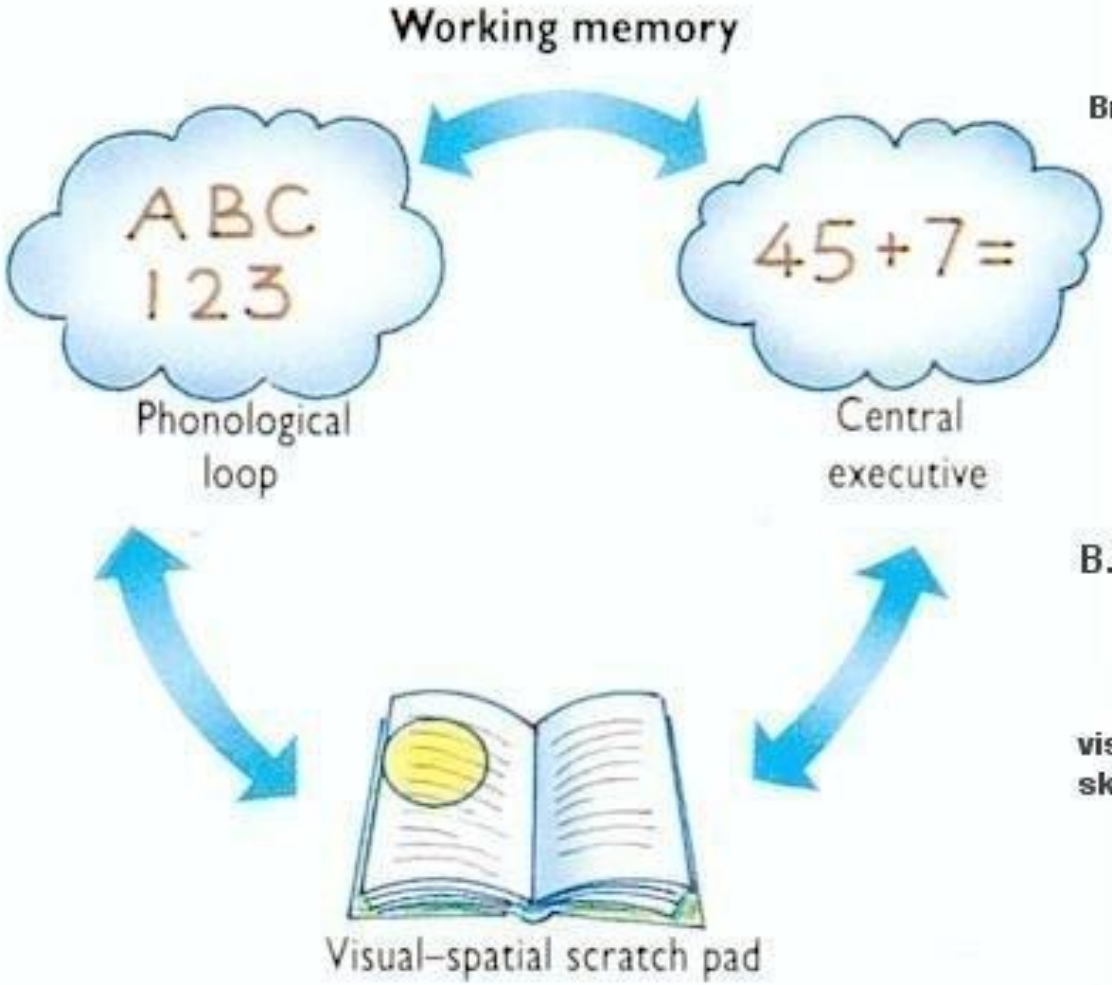
- Age-related Working Memory deficits following frontal-striatal decline (Gabrieli, 1996)

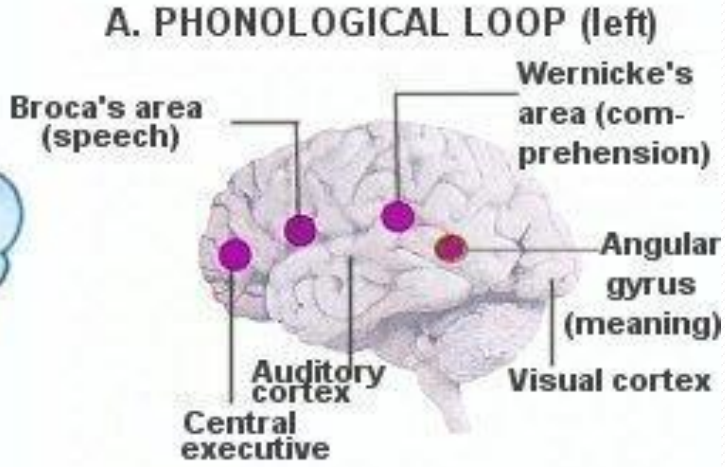
Modality-specific, passive stores in posterior parietal/temporal cortex
Common executive processes in frontal cortex

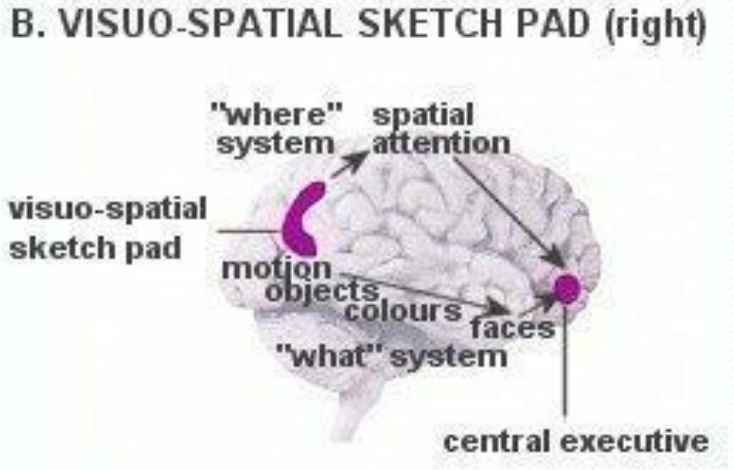
Neural Correlates of Working Memory



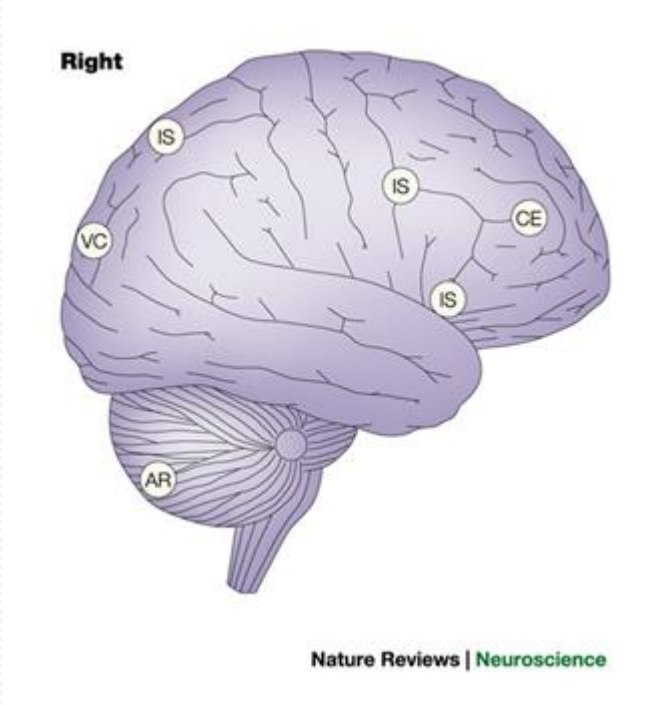
- The phonological loop – Speech
  - Left hemisphere: frontal and parietal regions
- The visuo-spatial sketchpad – Nonspeech
  - Right hemisphere
- The central executive – Domain general
  - Frontal lobe and ACC (anterior cingulate cortex)

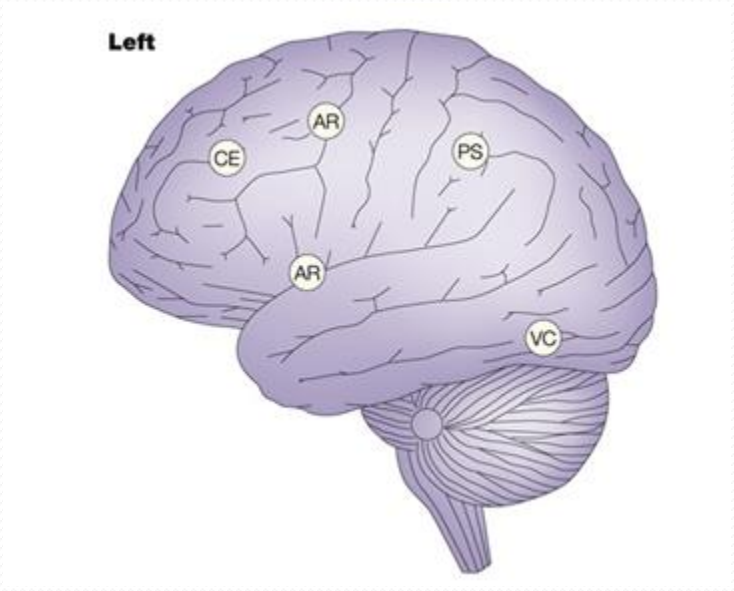

Working memory
ABC
123
45+7=
Phonological loop
Central executive
Visual–spatial scratch pad


A. PHONOLOGICAL LOOP (left)
Broca's area (speech)
Wernicke's area (com-prehension)
Angular gyrus (meaning)
Auditory cortex
Visual cortex
Central executive


B. VISUO-SPATIAL SKETCH PAD (right)
"where" system
spatial attention
visuo-spatial sketch pad
motion
objects
colours
faces
"what" system
central executive

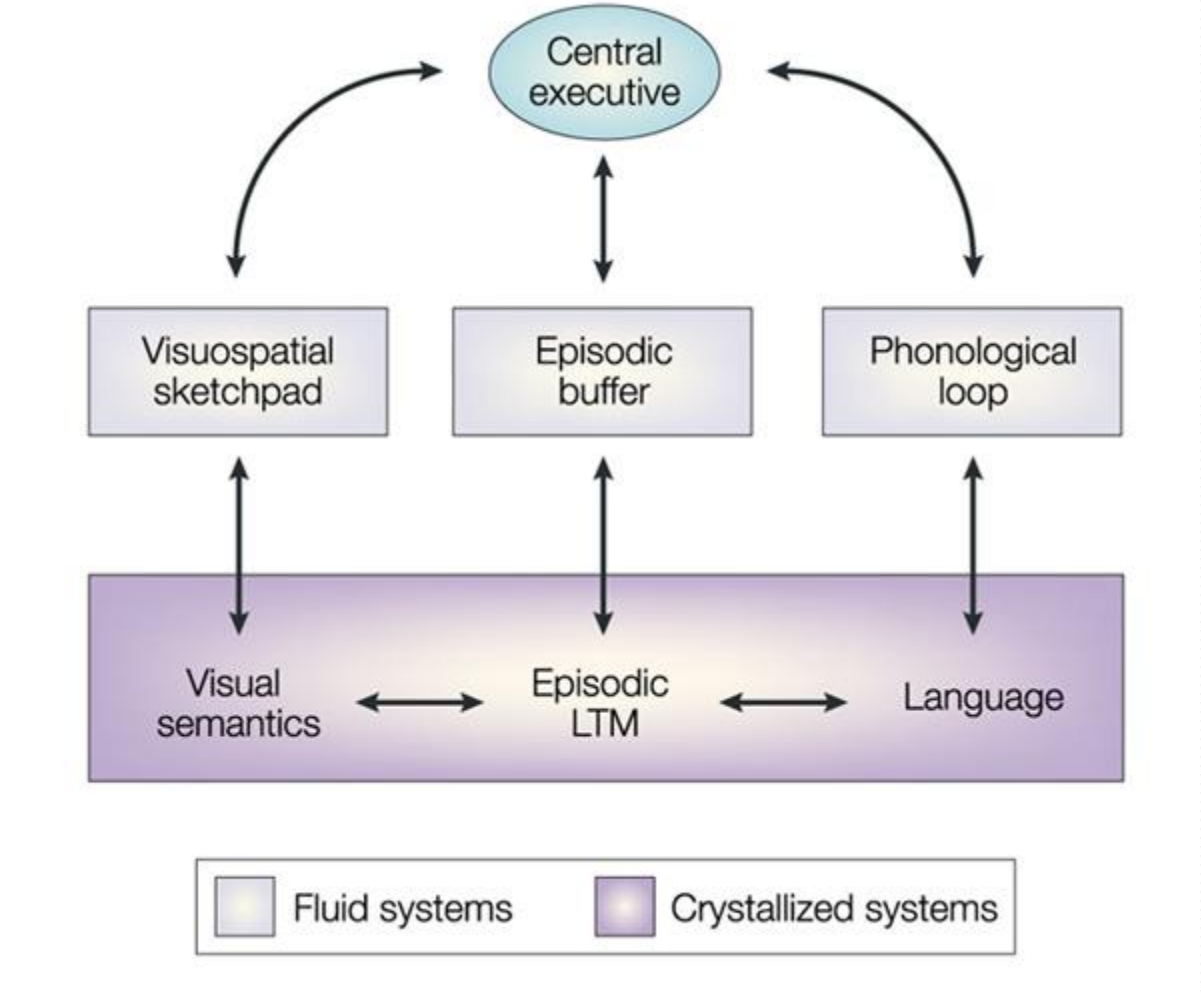
Baddeley, 2003





Working Memory

Baddeley's Theory of Working Memory (2003)



Memory aids

- Chunking
- Hierarchical organization
- Rehearsal

Chunking

- Grouping small bits of information into larger units of information
  - expands working memory load

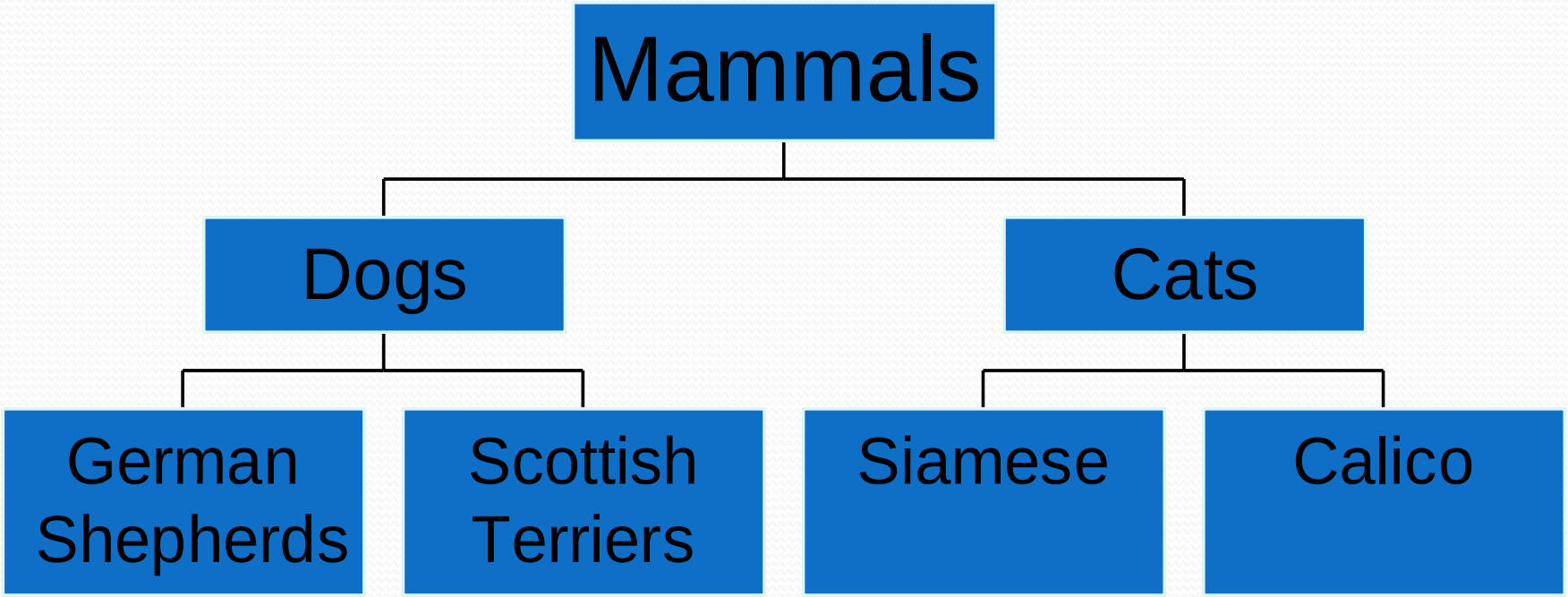
- Which is easier to remember?
  - 4 8 3 7 9 2 5 1 6

  - 483 792 516

Hierarchical Organization

- Related items clustered together to form categories
- Related categories clustered to form higher-order categories
- Remember list items better if list presented in categories
  - poorer recall if presented randomly
- Even if list items are random, people still organize info in some logical pattern

Hierarchical Organization

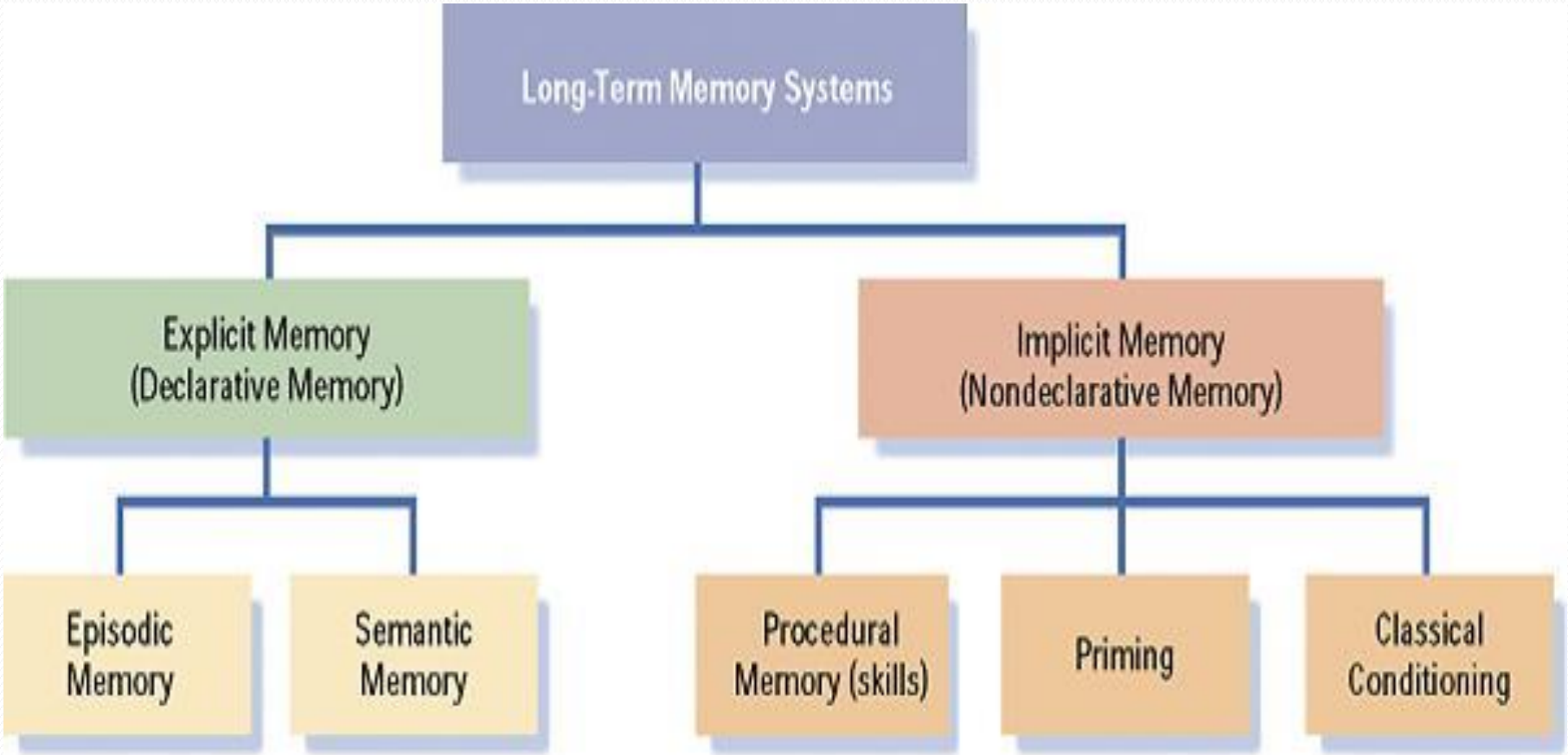


Amnesia

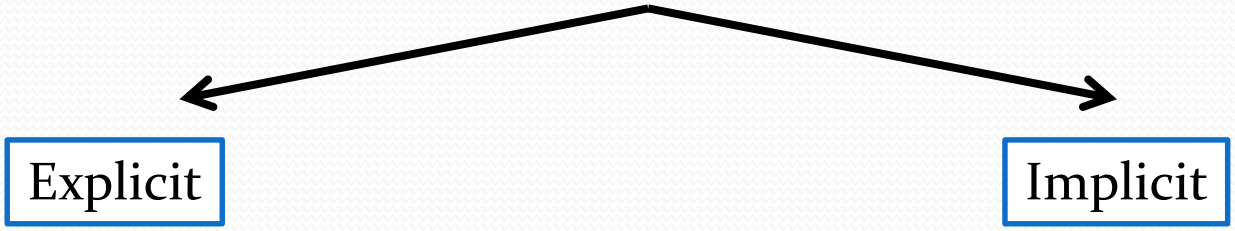
- Retrograde Amnesia
  - Loss of past memory
- Anterograde Amnesia
  - Can't form new memories

Anterograde Amnesia

Long-Term Memory

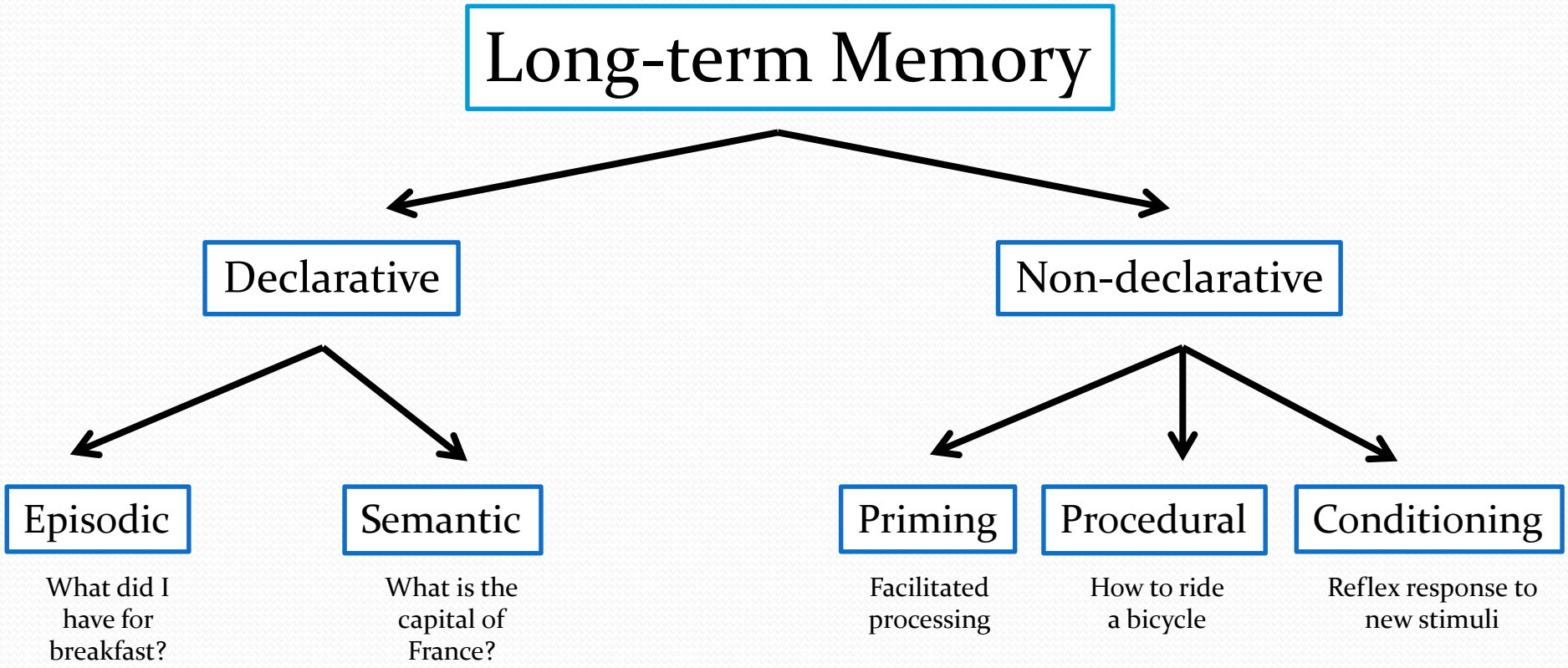


Long-Term Memory



- Available to conscious retrieval
- Can be declared (propositional)
- Examples
  - "What did I eat for breakfast?" (episodic)
  - "What is the capital of Spain?" (semantic)
  - "What did I just say?" (working)

- Experience-induced change in behaviour
- Cannot be declared (procedural)
- Examples
  - Subliminal advertising? (priming)
  - How to ride a bicycle (skills)
  - Phobias (conditioning)


Long-term Memory
Declarative
Non-declarative
Episodic
Semantic
Priming
Procedural
Conditioning
What did I have for breakfast?
What is the capital of France?
Facilitated processing
How to ride a bicycle
Reflex response to new stimuli

Explicit Memory

- Also known as declarative or conscious memory
- Properties:
  - memory consciously recalled or declared
  - Can use to directly respond to a question
- Two subtypes of explicit memory

Episodic Memory

- Memory tied to your own personal experiences
- Examples:
  - what did you have for dinner?
  - do you like to eat caramel apples?
- Why are these explicit memories?
- Because you can actively declare your answers to these questions

Semantic Memory

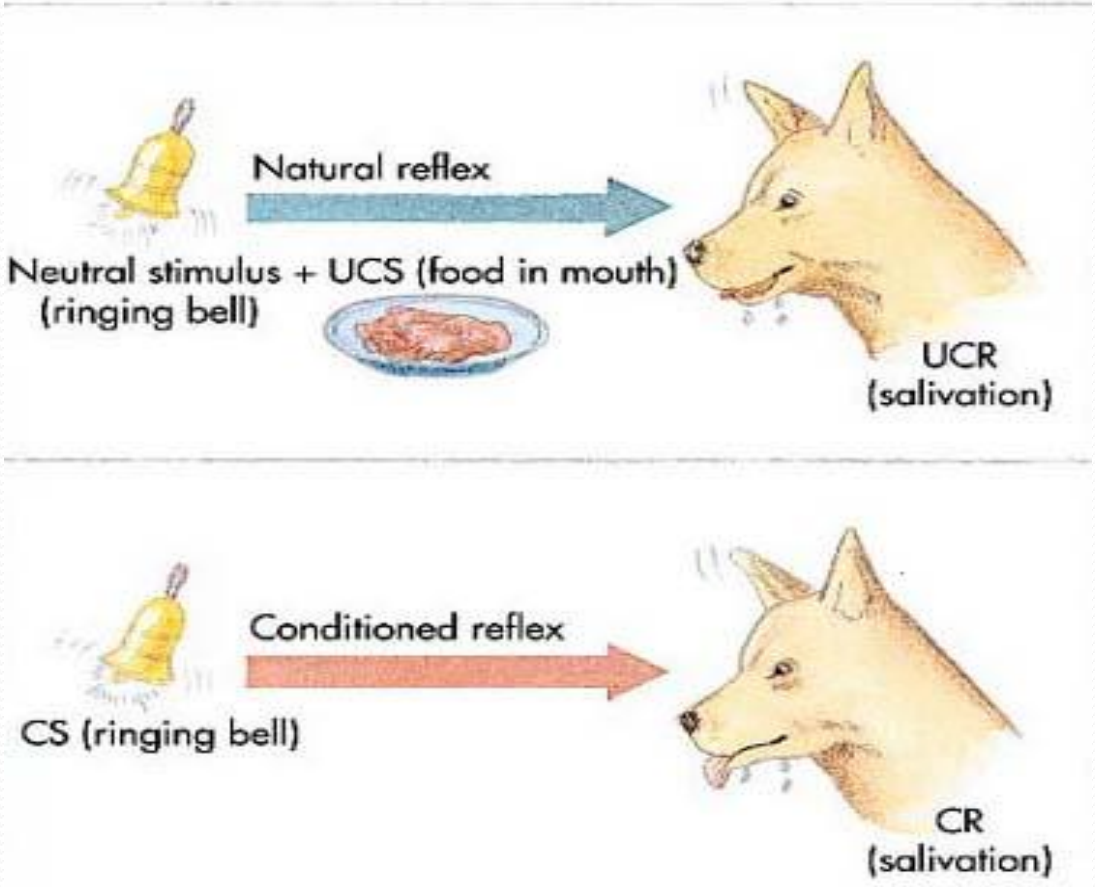
- Memory not tied to personal events
- General facts and definitions about the world
- Examples:
  - who was George Washington?
  - what is a cloud?
  - what is the climate at the north pole?
- These are explicit memories because you can describe what you know about them.
- Unlike episodic memories, your knowledge does NOT include your personal experience
  - i.e., You may never have been to the north pole but do know about it.

Implicit Memory

- Also known as nondeclarative memory
- Influences your thoughts or behavior, but does not enter consciousness
- Three subtypes

Classical Conditioning

- Studied earlier
- Implicit because it is automatically retrieved



Priming

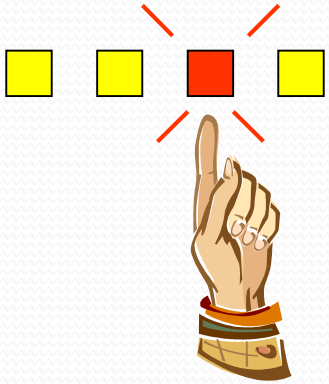
- Priming is influence of one memory on another
- priming is implicit because it does not depend on awareness and is automatic
- Here is a demonstration

- Unscramble the following words:
- O R E S
- L T E P A
- K T A L S
- TSME
- L O B S O M S
- ELAF

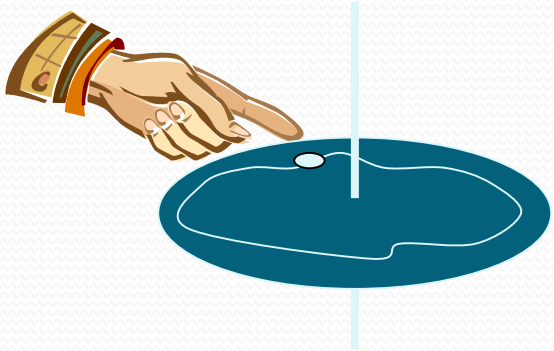
Procedural Memory

- Memory that enables you to perform specific learned skills or habitual responses
- Examples:
  - Riding a bike
  - How to speak grammatically
  - Tying your shoe laces
- Why are these procedural memories implicit?
  - Can't readily describe their contents
    - try describing how to tie your shoes
  - They are automatically retrieved when appropriate

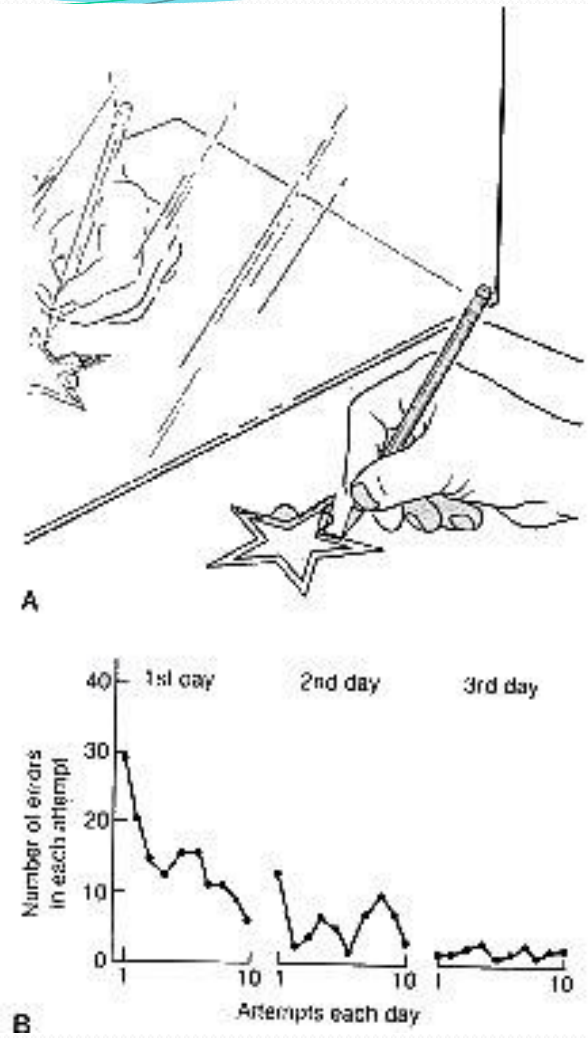
Procedural Memory



Serial Reaction Task
(e.g. Hazeltine et al., 1997)



Rotary–Pursuit
(e.g. Gabrieli et al., 1997)



Mirror Tracing
(e.g. Corkin, 1968)

Procedural - Neuropsychology

- Amnesic patients show intact:
  - Rotary Pursuit (Corkin 1968)
  - Serial Reaction Task (Nissen & Bullemer 1987)
- Alzheimer's patients show intact:
  - Rotary Pursuit (Gabrieli et al 1993)
  - Mirror Tracing (Heindel et al 1989)
- Parkinson's patients impaired on:
  - Rotary Pursuit (Heindel et al 1989)
  - Serial Reaction Task (Ferraro et al 1993)
- Huntington's patients impaired on:
  - Rotary Pursuit (Gabrieli et al 1997)
  - Serial Reaction Task (Willingham & Koroshetz 1993)

  but not:
  - Mirror Tracing (Gabrieli et al 1997)
- Cerebellar lesions impair Mirror Tracing (Sanes et al 1990)

Procedural - Neuroimaging

- Rotary Pursuit learning correlates with activity in Primary and Secondary Motor Cortex (Grafton et al 1992)
- Serial Reaction Task correlates with activity in Primary and Secondary Motor Cortex, and Basal Ganglia (Hazeltine et al 1997)
- Two hypotheses:

1. Learning repetitive sequence involves Basal Ganglia-Thalamic-Motor Cortical loop
   Learning new visual-motor mappings involves Cerebellar-Motor Cortical loop

2. Open-loop learning (minimal feedback): Basal Ganglia-Thalamic-Motor Cortical loop
   Closed-loop learning (continual feedback): Cerebellar-Motor Cortical loop

- Rotary Pursuit and Serial Reaction Task involve open-loop motor learning with little visual feedback (impaired by Basal Ganglia lesions)
- Mirror Tracing involves much visual feedback (impaired by Cerebellar lesions)

Need to examine nonvisual feedback

Episodic Memory - Neuroimaging

- MTL activations during episodic encoding (Tulving et al 1996) and retrieval (Schacter et al. 1996)

  Anterior-Posterior dissociation? (Lepage et al. 1998; Schacter et al. 1999)

- Left Frontal during Encoding (Shallice et al., 1994), right during Retrieval

  "HERA: Hemispheric Encoding Retrieval Asymmetry" (Tulving et al., 1994)

- Posterior cingulate / Precuneus (Fletcher et al., 1996)
- Left lateral inferior parietal cortex (Henson et al., 1999)

  Network of Frontal - Medial Temporal – Posterior areas all involved:

  Frontal areas control encoding and retrieval of memories?

  Posterior association areas store components of memories?

  Medial Temporal regions (temporarily) bind different components?

- Finer spatial resolution (fMRI) beginning to dissociate MTL regions, eg Hippocampus / Perirhinal for "Recollection / familiarity"? (Aggleton & Brown, 1999)

Semantic Memory - Neuroimaging

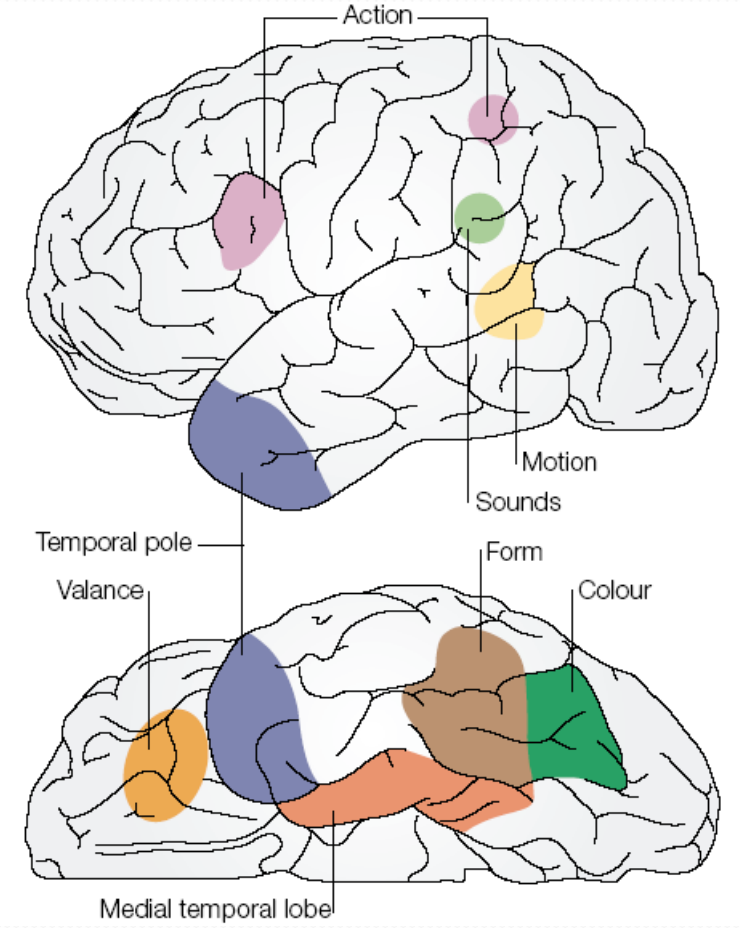
- Common activation in Left Inferior Frontal, Inferior Temporal, Angular gyrus and Temporal pole for semantic judgments to words and pictures (Vandenberghe et al 1996)

- Left Inferior Temporal activations for animal and tool naming, Temporal Pole for people naming (Damasio et al., 1996)

- Left Inferior Temporal activation for category- versus letter-fluency (Mummery et al 1996)

- Left Middle Temporal and Premotor activations for tool vs animal naming, Left Middle Occipital for animal vs tool naming (Martin et al 1996)

Distributed representations, with activations reflecting object's interaction with world? E.g., tool naming activates motor regions



McClelland and Rogers, 2003

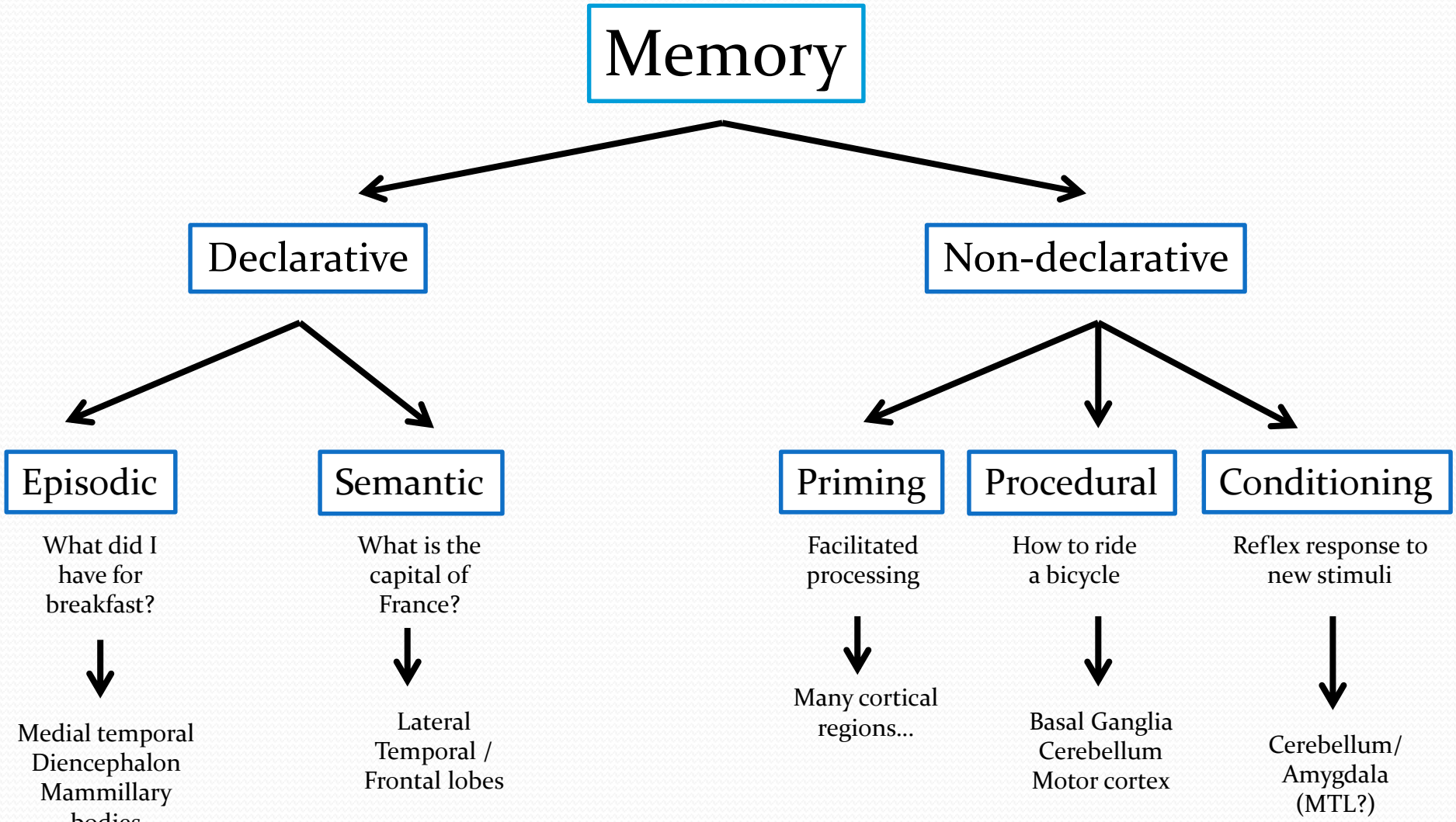
Basic Neuroanatomy of Memory

A) **Subcortical structures**

- Basal ganglia and cerebellum – Procedural memory. Caudate nucleus involved particularly with habit formation (unconscious learning)
- Thalamus – Temporal sequencing information. Also supplementary role to medial temporal lobes in new learning
- Basal forebrain – The binding together of different modal components in episodic memory

B. **Cortical structures**

- Hippocampus – Acquisition of new factual knowledge
- Primary association cortex – Visual, auditory and somatosensory data
- Non-medial temporal – Retrieval of previously learned material e.g. autobiographical info, names, faces
- Ventromedial frontal lobes – Memory traces linking facts and emotion
- Dorsolateral frontal lobes – Recency and frequency memory. Working memory


Memory
Declarative
Non-declarative
Episodic
Semantic
Priming
Procedural
Conditioning
What did I have for breakfast?
What is the capital of France?
Facilitated processing
How to ride a bicycle
Reflex response to new stimuli
Medial temporal
Diencephalon
Mammillary bodies
Frontal lobe
Lateral
Temporal /
Frontal lobes
Many cortical regions...
Basal Ganglia
Cerebellum
Motor cortex
Cerebellum/
Amygdala
(MTL?)