

# Memory

To understand at all how human beings operate, it is necessary to consider how information, knowledge, and past experiences are stored and retrieved for use. Thus, memory is of crucial importance as a psychological process

# Three Processes

- **Acquisition** or **Encoding**

Information is processed and encoded into the nervous system as a *memory trace*

- **Retention**

Information is stored for later use

- **Retrieval**

- Information is found and brought to consciousness for use

- Two types

- Recall

- Recognition

- Note that memory can fail in any of the three processes

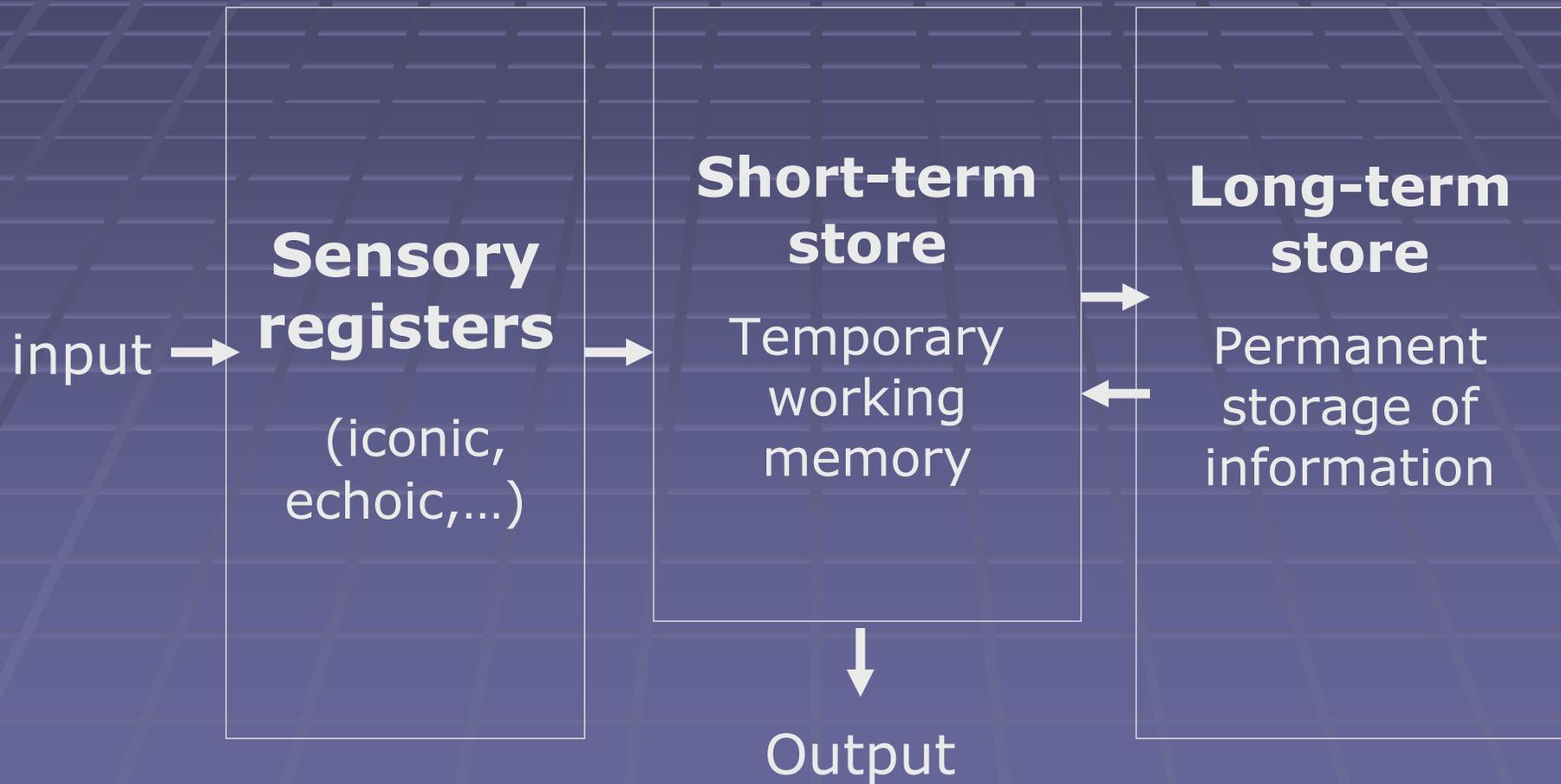
# Three Memory Stages

Many investigators believe that information placed in memory passes through three successive memory systems that hold information for varying lengths of time

- *Sensory registers*
- *Short-term memory (STM)*
- *Long-term memory (LTM)*

A good example of this approach is Atkinson & Shiffrin's Modal Model of Memory

# Atkinson and Shiffrin's Modal Model of Memory



# Sensory Registers

- The initial stage of memory seems to involve several sensory registers which have these characteristics:
  - Large capacity
  - Hold information in relatively unprocessed form
  - Only hold information for a very short time: a few seconds (echo) or a fraction of a second (icon)

# George Sperling's Experiments

- Sperling's experiments provided some of the classic evidence regarding characteristics of the visual sensory register (the *icon*)
- He presented subjects with a very brief (50 ms) exposure to a matrix of letters

# Sperling (1960) Sensory Memory Experiments

## Whole Report Procedure

Display

50 milliseconds

Report

as many as  
possible

F	G	E	P
D	W	T	O
M	K	V	Q

# Sperling (1960) Sensory Memory Experiments

## Whole Report Procedure

### Result

4 – 5 letters recalled  
on average

participants claim to  
see all letters

total size of display  
irrelevant

F	G	E	P
D	W	T	O
M	K	V	Q

# Sperling (1960) Sensory Memory Experiments

## Partial Report Procedure

Display

50 milliseconds

Signal target row  
after display

Report from target  
row

F	G	E	P
D	W	T	O
M	K	V	Q

# Sperling (1960) Sensory Memory Experiments

## Partial Report Procedure

Signal target row  
after display  
Report from target  
row




# Sperling (1960) Sensory Memory Experiments

## Partial Report Procedure

Result

3 out of possible 4



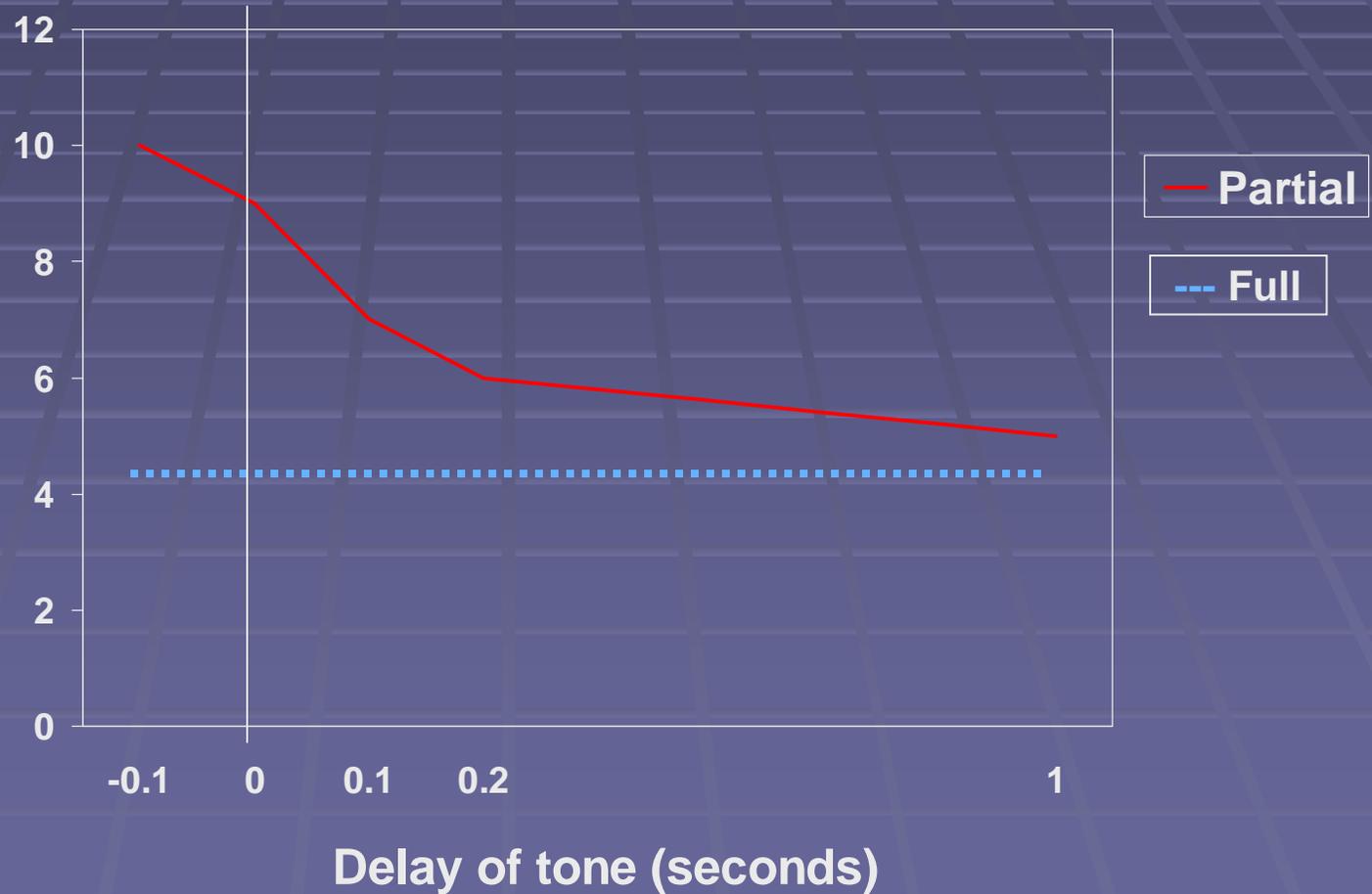
F	G	E	P
D	W	T	O
M	K	V	Q

Conclusion

9 out of 12 available

# Results from Sperling's Experiments

Number of letters recalled



# Sperling's Reasoning

- If a person's earlier performance in the whole report procedure indicated that they only perceived approximately 4 or 5 letters (<50%) then people should be able to name in the partial report procedure only about 50% of the letters correctly
- Actually, they were able to report a much higher percentage
- Furthermore the longer the delay between stimulus and tone the lower the percentage until after about 1 second it was back to about 50%
- Sperling concluded that there must be a nearly total storage register for visual information that lasts for only a very short time (second or so)—a sort of visual image that the subject can almost read information from, but which decays very rapidly
- That register is usually called the *icon*

# Other Sensory Register Findings

- Other experiments on other sensory modalities, such as audition, have found evidence for similar sensory registers (e.g., the *echo*)
- The echo differs from the icon in that it lasts longer (approximately 4 seconds as opposed to 1 second)
- Most investigators believe that sensory registers hold essentially unanalyzed or unprocessed information, i.e., the information is not recognized as a letter or vowel, etc. Only after further processing are such characteristics recognized
- Note also the phenomenon of *eidetic imagery*

# Eidetic Imagery

- Eidetic imagery is the ability to retain an accurate, detailed visual image of a complex scene or pattern (sometimes popularly known as photographic memory) or the ability, possessed by a minority of people, to 'see' an image that is an exact copy of the original sensory experience.
- We can test to see if you possess eidetic imagery. Study the picture for 30 seconds.



**8.1 Test picture for study of eidetic imagery** This picture from *Alice in Wonderland* was shown for half a minute to elementary schoolchildren, a few of whom seemed to have an eidetic image of it. (Illustration by Marjorie Torrey)

# Eidetic Imagery Test

- Can you count the number of stripes on the cat's tail? The number of flowers on the highest stem? If you possess eidetic imagery you should be able to answer such questions.
- Very few children (< 5%) are capable of eidetic imagery, and the percentage is even smaller in adults. It has been suggested that the difference between adults and children occurs because children have less developed verbal and semantic systems, and so rely more on imagery.
- Such examples of “photographic memory” are often associated with “savants” (people who are severely limited in most abilities but have extraordinary ability in a limited domain) rather than memory experts, whose skills usually lies in organizing their memories rather than eidetic images.
- Normal cognition is associated with the ability to extract important details while ignoring most of what is perceived. This abstraction is adaptive as it avoids overloading the limited capacity of thought.

# An Adult Eidetiker

- The most famous adult 'eidetiker' was a woman named "Elizabeth," who was studied and written about by Charles F. Stromeyer in 1970. She was an artist and teacher at Harvard who could mentally project detailed and exact images onto her canvas and was even able to move her eyes about to inspect the image while the image stayed still. She could also reproduce poems in a foreign language years after having seen the original printed page.
- In Stromeyer's tests on her abilities, "Elizabeth" was presented with a 10,000-dot stereogram pattern to one eye for a specified length of time and then was asked to superimpose her eidetic image onto another pattern presented to her other eye. She was able to perform this task with great ease and could see depth and figures in these patterns. Non-eidetikers need a stereoscope to perform this feat.
- "Elizabeth" was also capable of projecting her eidetic images onto other images, often obscuring the actual image. Her eidetic images were capable of after-images and movement after-effects just like that of actual visual stimulus, and she is even reported to have been able to see a 10-second section of a movie in complete eidetic detail.
- Her only constraint was that she had to move her eyes to scan an eidetic image and generally would create the image in sections rather than as a whole. Also, "Elizabeth's images did not just fade, but instead would dim and break apart piece by piece. In any case, "Elizabeth" is the only one of her kind. Since the publication of Stromeyer's paper, no other adult eidetiker of her caliber has been found.

# Short-Term and Long-Term Memory

- Many psychologists have adopted the theory that there are basically two memory systems (over and above the sensory registers): *short-term memory (STM)* and *long-term memory (LTM)*
- The two memory stores differ in
  - Duration of experience
  - Capacity
  - Processing

# Characteristics of STM

- Information that is attended to arrives in a temporary store called *short-term* or *working memory*. The more recent term "working memory" is intended to convey the idea that information here is available for further processing. In general information in working memory is information you are conscious of and can work with.
- **Duration**: Events in STM are experienced as presently occurring or being perceived, e.g., after the last word in a sentence, previous words are still being perceived as in the present. About 18 to 20 seconds (Peterson & Peterson, 1959)
- **Processing**: To hold information in STM, it is often encoded verbally, although other strategies may also be used such as visualization. These strategies make it possible to "rehearse" the information.
- **Capacity**: About 7 plus or minus 2 "chunks" of information (Miller, 1956)

# Characteristics of LTM

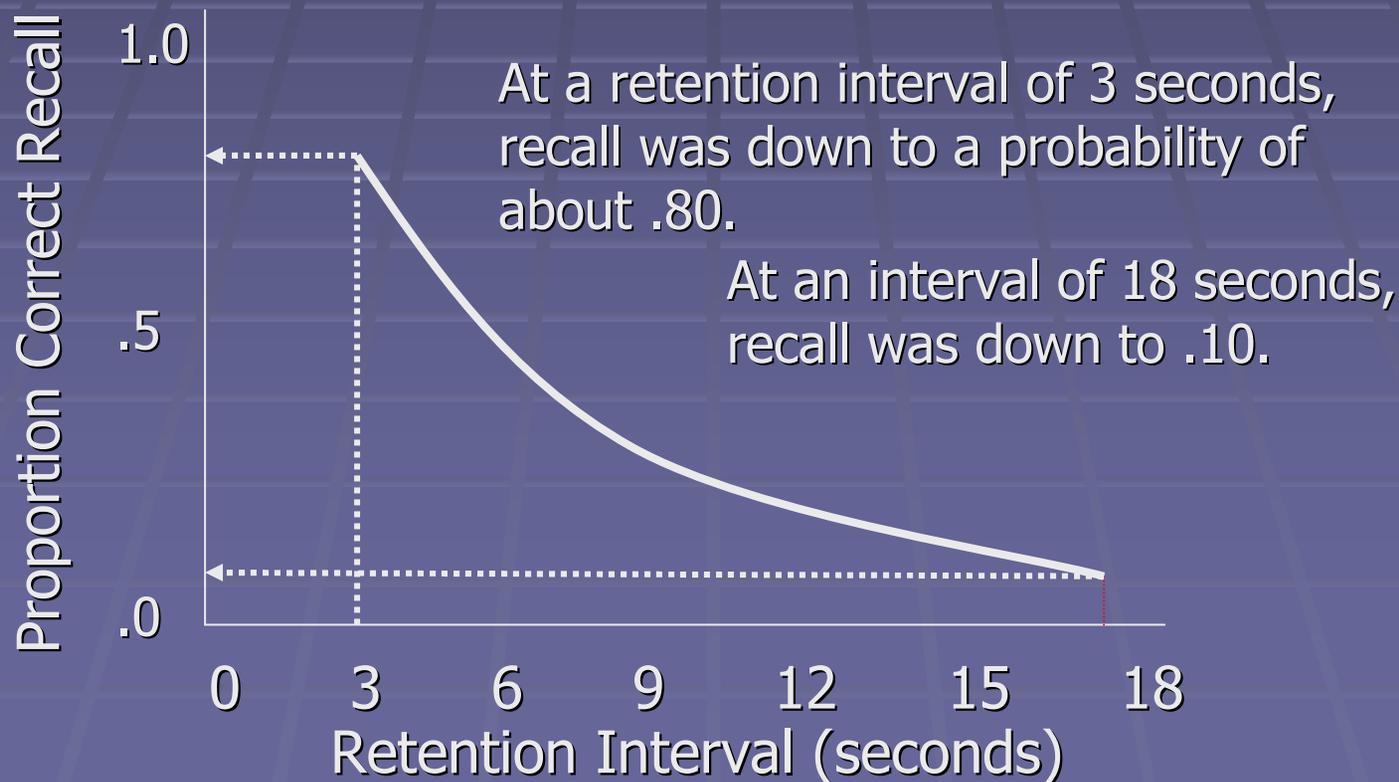
- *Long-term memory* is the relatively permanent memory store in which you hold information even when you are no longer attending to it. Information held in LTM is not represented as patterns of neural activity (as in STM), but rather as changes in brain wiring--in the "conductivity" of existing synapses, and in the formation new synapses and destruction of old ones. Storing information in LTM is analogous to a computer writing information out to its hard drive, or to a tape recorder writing patterns of magnetization onto tape to record music. The recording process is called *storage* and the "playback" process, *retrieval*. Here are some properties of LTM:
  - **Duration**: Up to a lifetime
  - **Processing**: Information is organized according to *meaning* and is associatively linked
  - **Capacity**: Virtually unlimited

# Processing Differences Between STM and LTM

- There are a number of experiments looking at the kinds of errors subjects make in memory experiments
  - In STM experiments subjects tend to make *acoustic* confusions, i.e., confusing words that *sound alike*, e.g., bat, cat, rat
  - In LTM experiments subjects tend to make *semantic* confusions, i.e., confusing words that have *similar meanings*, e.g., little, small, tiny

# Peterson & Peterson Studies

- Peterson & Peterson (1958) got their subjects to read series of three consonants (e.g., CJK). As soon as they had read them they had to start counting backwards in threes from a three-digit number they were given. This prevented them from rehearsing the material they were trying to remember. After a period of between 3 and 18 seconds, they were asked to recall the consonants. As the graph shows, recall drops off very sharply as the information decays without active attention. Forgetting may be due to either decay or interference, or both—probably both



# Free Recall Experiments

- Class demonstration – Free recall

# Serial Position Effects

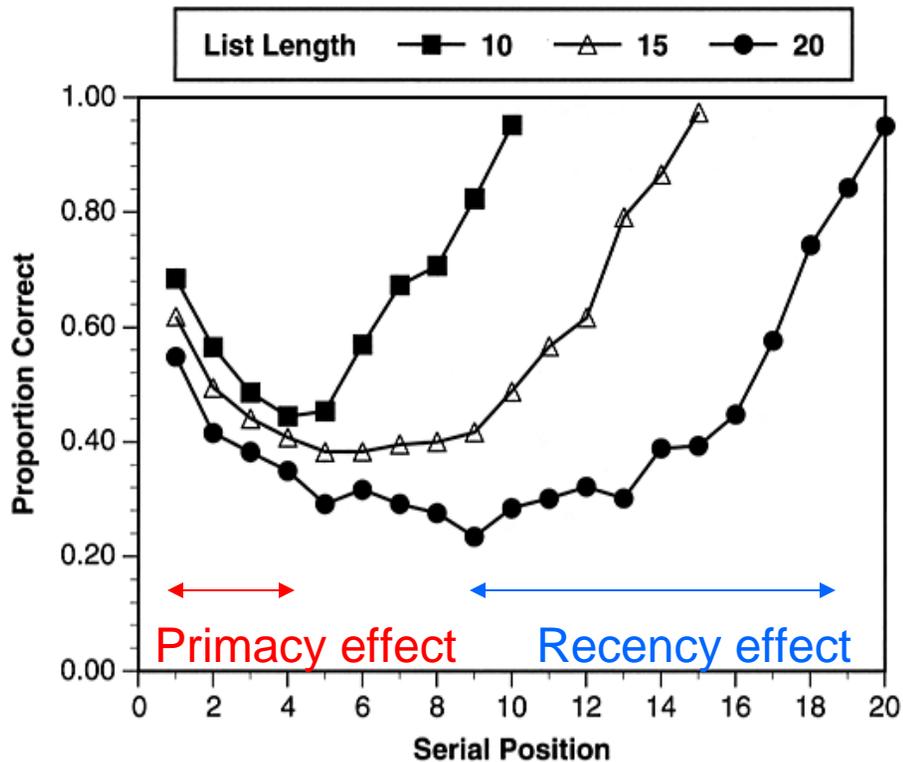
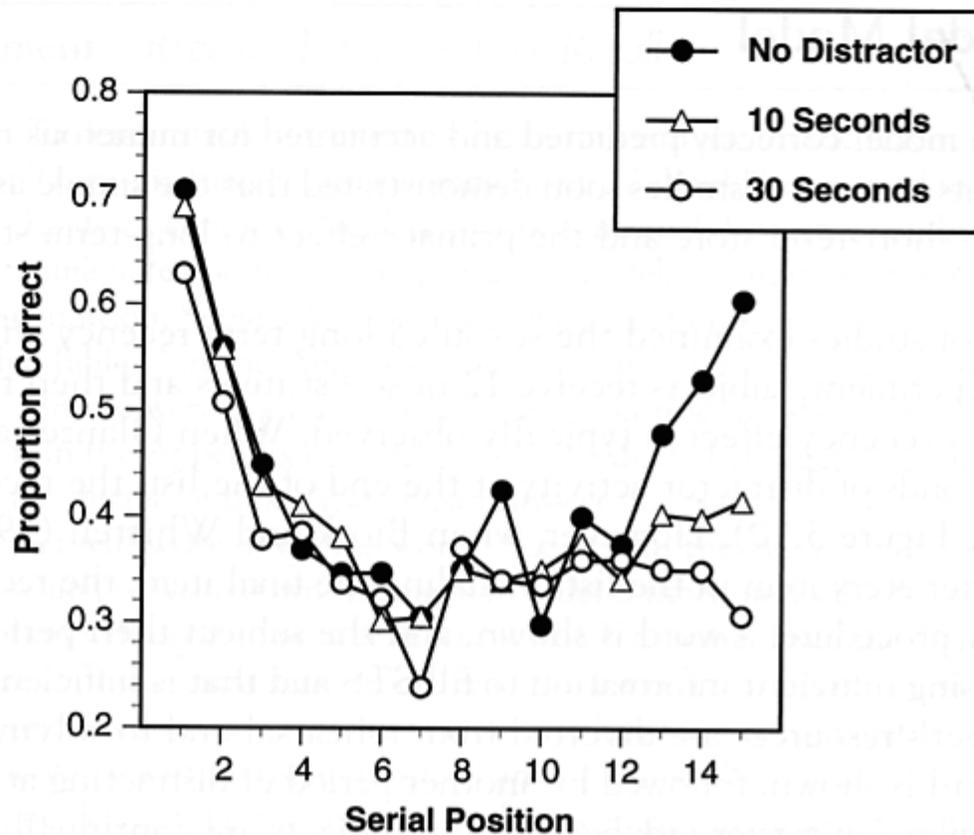


Figure 3.8 Serial positions curves showing the proportion of items recalled correctly in a free recall test as a function of input position for three different list lengths. SOURCE: Data from Murdock (1962).

- In free recall, more items are recalled from start and end of list
- First items recalled tend to be from the end of the study list
- Modal model explanation for the primacy effect:  
Early items can be rehearsed more often → more likely to be transferred to long-term memory
- Modal model explanation for the recency effect:  
Last items of list are still in short-term memory → they can be read out easily from short-term memory

# Other Results Supporting the STM-LTM Distinction



- Recency effect disappears with delay
- During delay, contents of STM seem to be lost

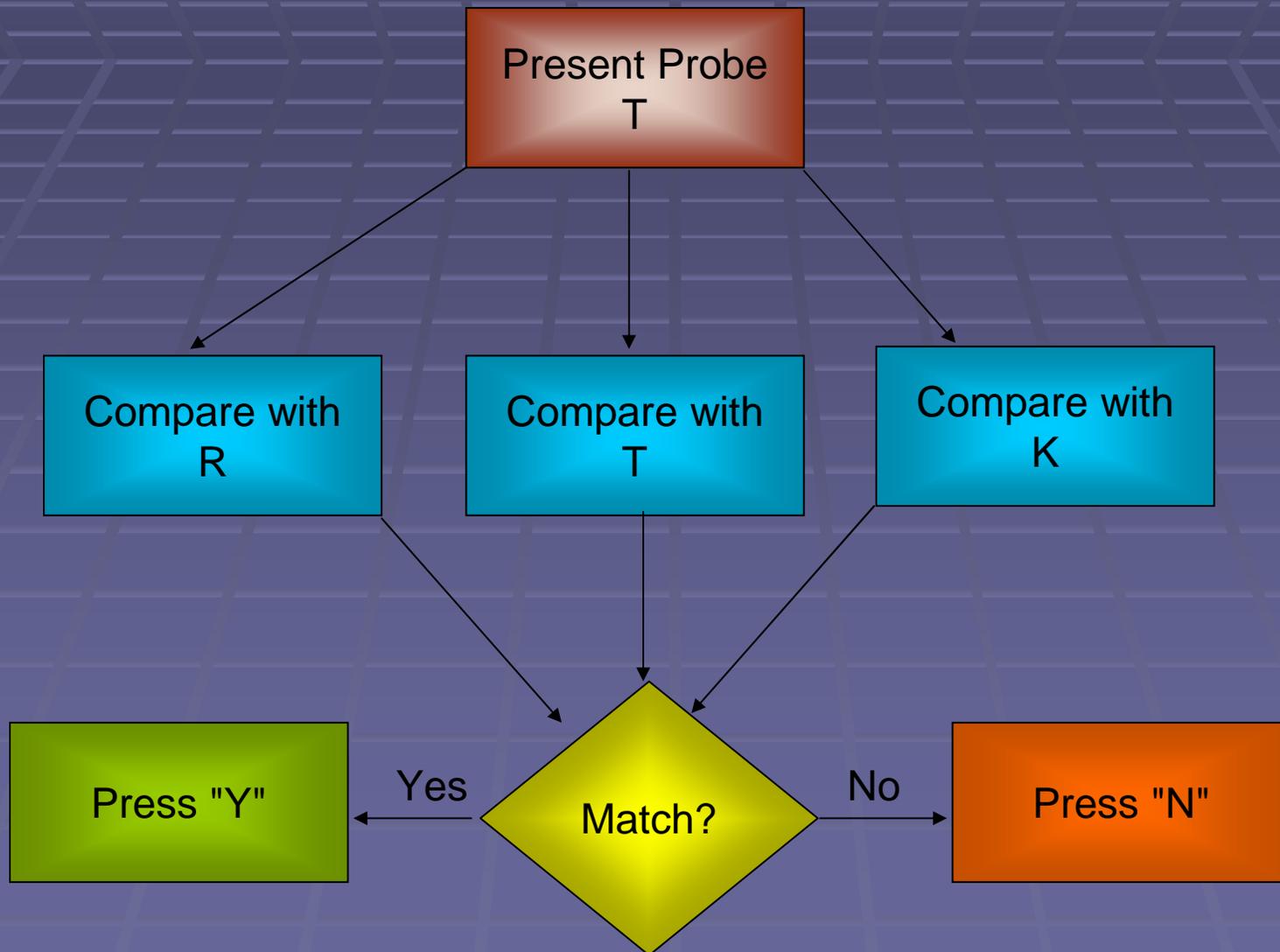
(Glanzer & Cunitz, 1966)

# Sternberg's Short Term Memory Search Paradigm

- How are items retrieved or searched for in STM?
- Subjects are presented with a short list of letters which could contain as many as 7 letters, then presented with a single stimulus (probe) letter and asked to indicate whether the target was one of the letters on the list
- To do this, S's must compare the probe with each item in the target list and see if there is a match
- Do S's compare the probe with all the target letters at once (in parallel) or with each letter sequentially (serially)?

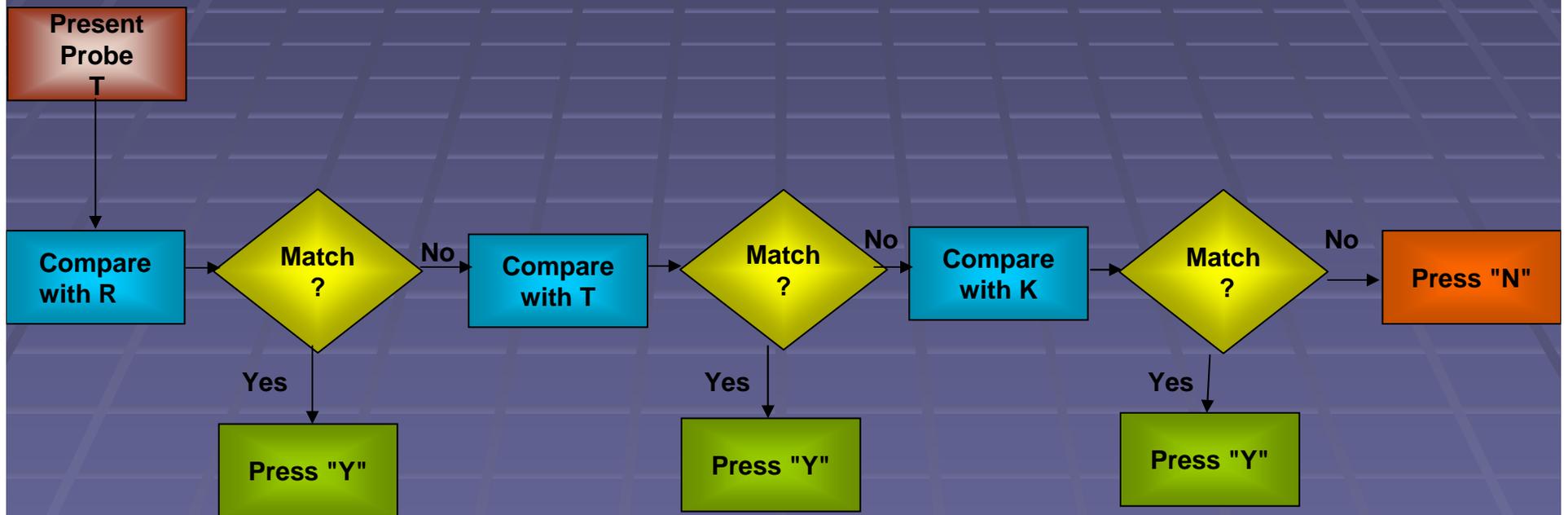
Target Set (set size 3):  
R T K

# Parallel Model



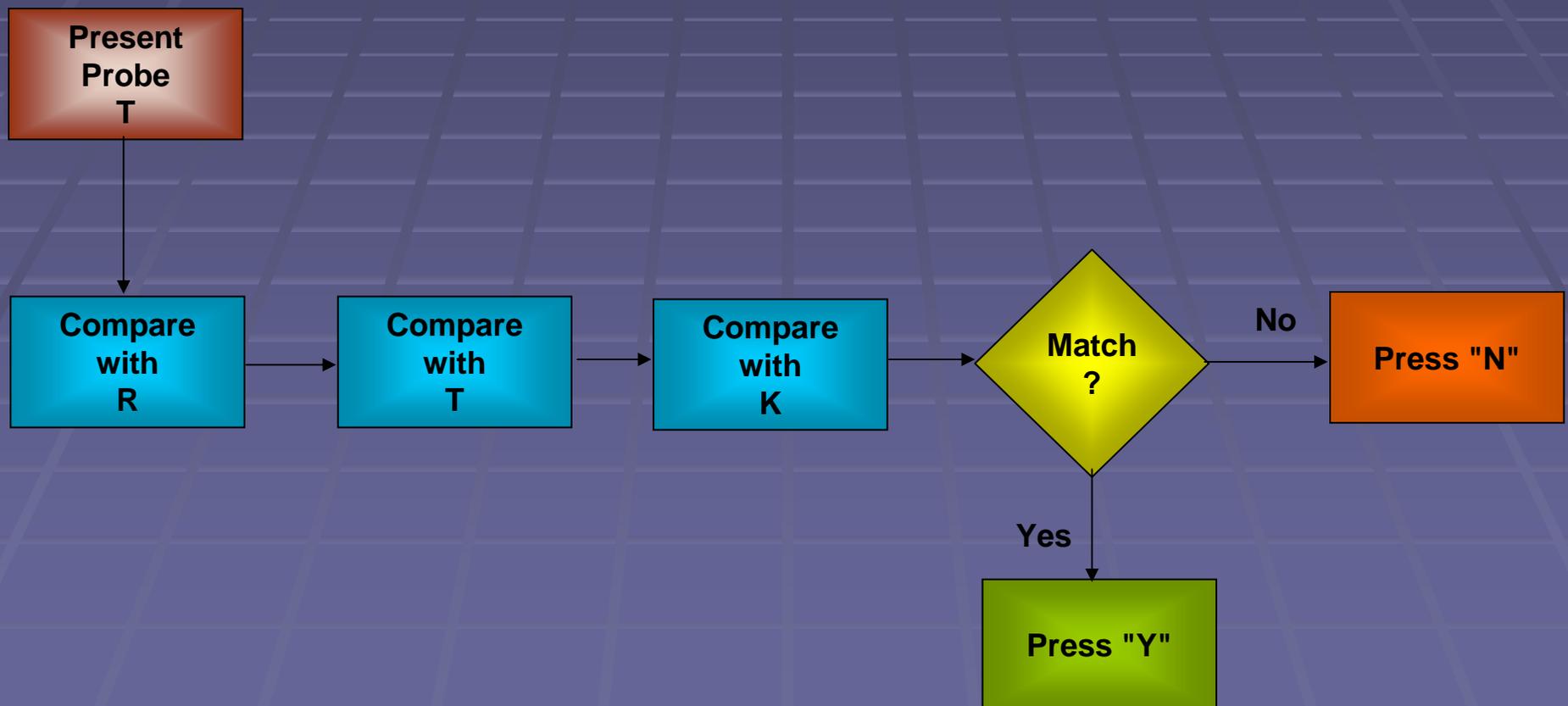
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# Serial Self-Terminating Model



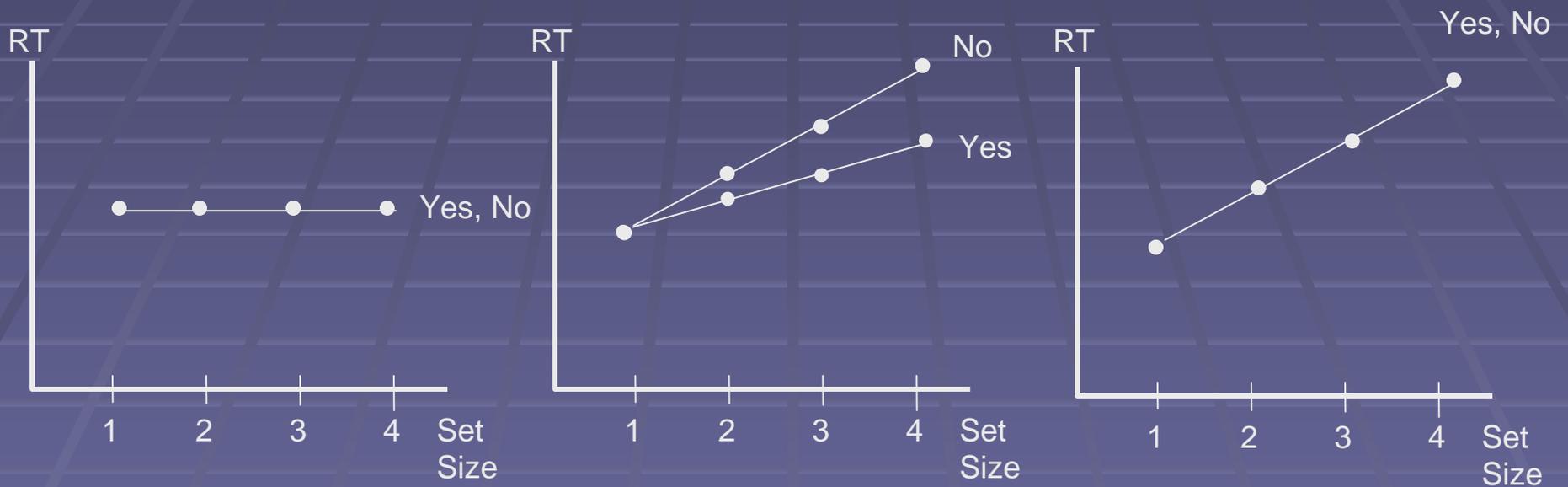
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# Serial Exhaustive Model



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# Model Predictions for RT's



Parallel Model Predictions

Serial Self-Terminating Model Predictions

Serial Exhaustive Model Predictions

# Sternberg Paradigm Results & Implications

- Actual results show upward sloping line with a slope of about 35 milliseconds (ms), supporting the serial exhaustive model and indicating that it takes about 35 ms to compare the probe letter with each additional letter in the target list (i.e., speed of comparisons in STM is about 25-30 comparisons/second)
- Note that the exhaustive process is counterintuitive; introspection is not a good guide to what's going on with memory processes
- This kind of experiment illustrates a type of experiment commonly carried out in cognitive psychology
- Note the use of simple RT to diagnose subtle distinctions in memory processes
- The computer program metaphor is also a very common approach to studying memory and other cognitive processes

# Retrograde & Anterograde Amnesia

- The distinction between STM and LTM is also suggested by the well known phenomena of *retrograde* and *anterograde* amnesia
- *Anterograde* (forward) *amnesia*: Due to lesion in the hippocampal area or Korsakoff's syndrome (in alcoholics). Subject has very good memory of events prior to lesion and an intact STM, but is unable to transfer new information from STM into LTM so that the new information is completely lost as soon as it leaves STM
- *Retrograde* (backward) *amnesia*: After some kind of injury the subject loses memory for some period prior to the accident. Gradually, memory may return, usually earliest memories first, but memory for events just prior to the accident are totally wiped out

# Trace Consolidation

- Some theorists have argued for the *trace consolidation* hypothesis to explain how items get transferred from STM to LTM
- Consolidation is the process whereby a new memory trace undergoes a gradual chemical change that fixes it firmly in memory
- For this consolidation to take place, the trace must remain undisturbed for awhile
- In fact, some evidence suggests that much of this process takes place during sleep
- Injuries could prevent consolidation by disturbing the unconsolidated trace (in retrograde amnesia) or by destroying the mechanism for consolidation (associated with the hippocampus) entirely (in anterograde amnesia)

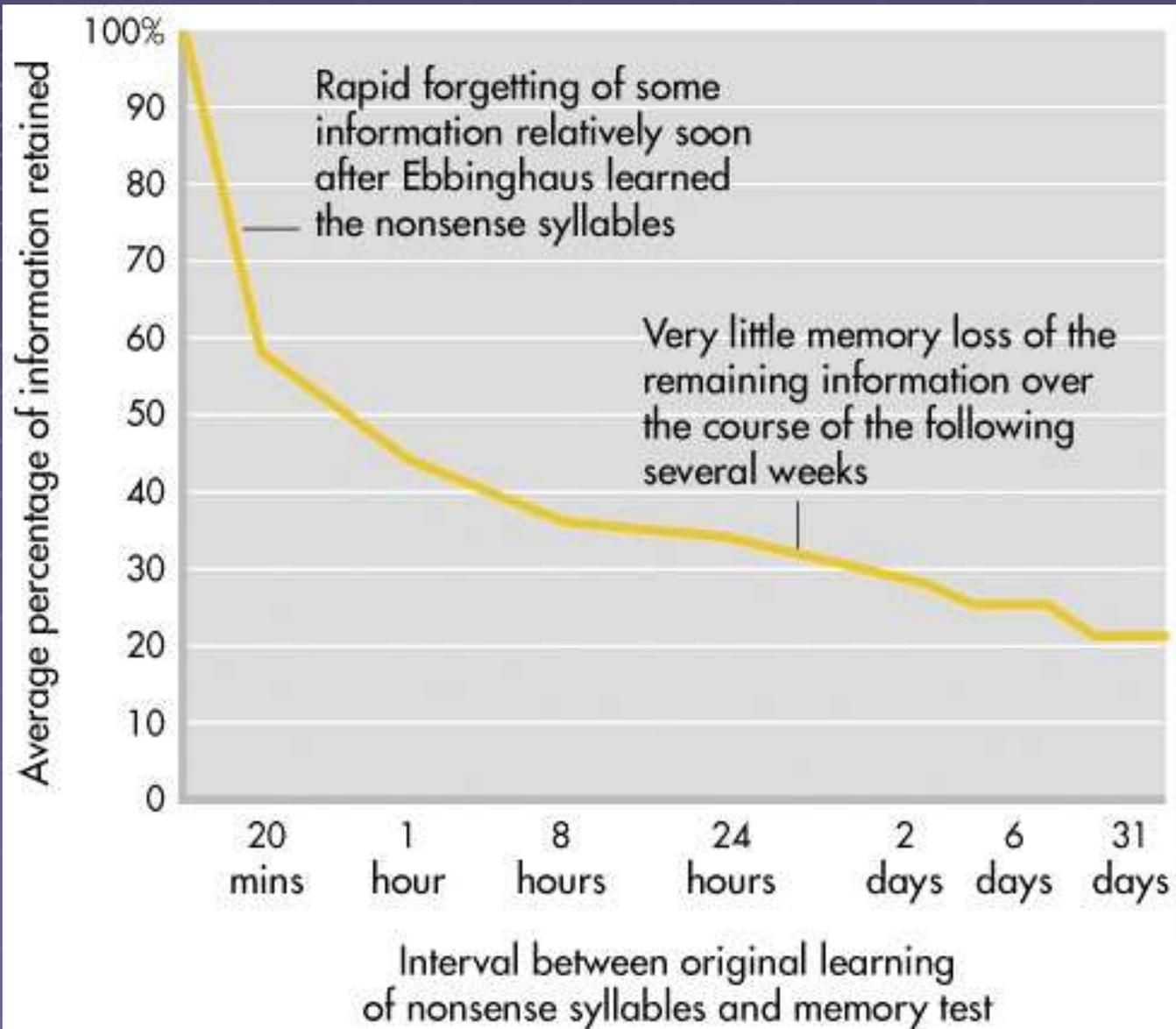
# Memory and Association

- Much early work and even much current work on memory is closely tied to *associationist* ideas (Aristotle, Locke, Berkeley)
- Associationists see the notion of connection or link or association between ideas or events as a crucial component in explaining memory
- Things paired together frequently become associated or linked with one another so that when one is presented as a stimulus the other is evoked

# Early Memory Research

- Ebbinghaus in 1885 conducted some of the first experimental studies on memory
  - He used himself as a subject required himself to learn (successfully recite) 420 lists of 16 nonsense syllables (e.g., *jik*) each (chosen since they were assumed to have no prior associations)
  - He found:
    - Repetition facilitates memory
    - Memory declines as a function of time (and most rapidly immediately after learning - forgetting curve)
    - 'Savings' – reduction in trials needed to relearn a list
    - Discovered the serial position effect (items at beginning and end of a list are more readily recalled)
  - His work is an example of the application of associationist ideas to studying memory, and his well known *forgetting curve* has stood the test of time

# Ebbinghaus Forgetting Curve



# Organization and Memory

- The associationist approach may be contrasted with the Gestalt or organizationist analysis of memory, which argues that organization of material is key to understanding how memory works
- Both approaches have contributed much to understanding memory
- Example: Classroom paired associates recall task

# Organization & Chunking

- Using imagery helps memory because it organizes information
- Things that are well organized are much more easily remembered
- Example: Consider the following sequence
  - FBIC IAIB MTWA
  - Is it easier to remember that sequence or the following?
  - FBI CIA IBM TWA
- When people can organize the material into units or *chunks* the chunks can be remembered as though they were individual items

# Chunking

- Chunks may be words or phrases or any higher order units that tend to be recalled or forgotten as units
- Example: Gordon Bower carried out a well known study in which subjects' task was to associate several pictures, e.g., a flag, a doll, and a chair
- When S's were shown flag, doll & chair pictures along side one another they were much less likely to remember the association between the three than when they were shown a picture of the doll holding the flag sitting on the chair
- Things get stored in LTM by *active organization* of the material, sometimes even to the point that the material is substantially changed by the organizational structure imposed on it
- Best way to remember material you've read or learned in a course is to organize it—understand its natural organization or impose your own organization on it, make an outline, etc.

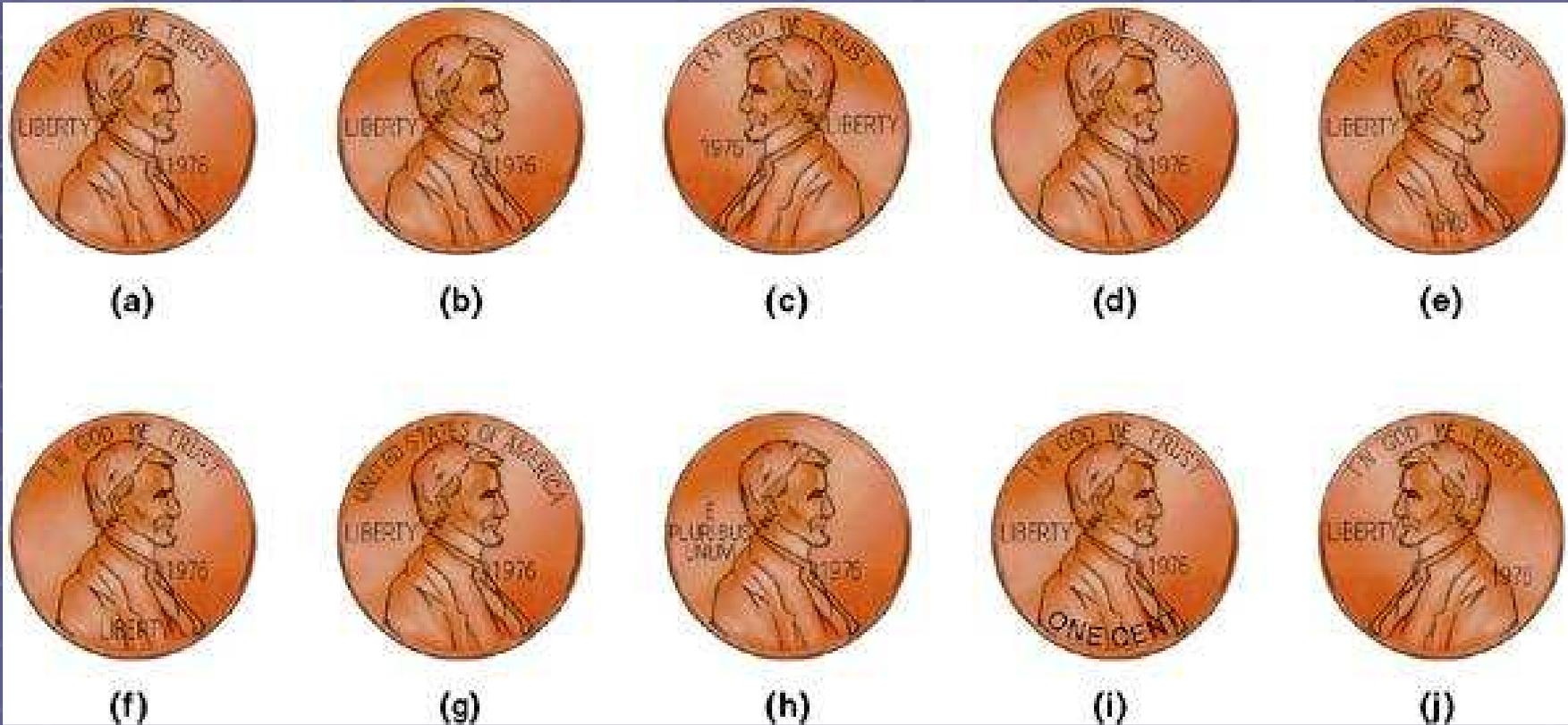
# Mnemonic Devices

- Mnemonic devices developed over the centuries have been used organization to aid memory
- Method of loci (Cicero): Visualize each item to be remembered in some separate spatial location, e.g., in different rooms of your house, then mentally go through the house and 'see' what's in each room
- Peg method: First memorize a simple rhyme like 'One-bun, two-shoe, three-tree, etc.' These serve as 'mental pegs.' The subject then forms a mental image of the appropriate object, say, 'shoe,' and the to-be-remembered item in some unusual combination
- Mnemonic acronyms are very powerful and rely on chunking
  - Roy G. Biv – colors of the spectrum
  - EGBDF – lines of the treble clef
  - ACEG – spaces of the bass clef
  - etc.

# Forgetting from LTM

- It's important to note that failure to remember or misremembering could occur as a result of failure at any one of the stages of memory: acquisition (encoding), retention, or retrieval
  - Information might not get encoded into LTM
  - Something might happen to the memory over time
  - One might simply be unable to retrieve it

# Which is the real penny?



The fact that people have a good deal of difficulty picking out the right picture despite loads of experience with pennies is probably a result of encoding failure

# Five Hypotheses to Explain Forgetting

- Trace decay
- Interference
- Trace transformation
- Repression
- Loss of access or retrieval failure

# Trace Decay

- This is the idea that memory traces tend to fade away over time just as unused muscles tend to atrophy
- This cannot be the whole explanation because many studies show that what happens in the interval between encoding and recall matters a lot
- *Example:* Trace decay theory would imply that after learning a word list, whether one slept or engaged in activity for, say, 4 hours would not affect recall of the list because trace decay is only time-dependent. However, recall is much better after 4 hours of sleep than after 4 hours of activity, suggesting that something other than trace decay accounts for the difference

# Interference

- Any information learned may interfere with—and be interfered with by—everything else you learn
  - *Retroactive interference*: New learning interferes with the recall of old information
  - *Proactive interference*: Prior learning interferes with the learning or acquisition of new information
- Also, the more similar the new material is to the old, the more interference
- There is much evidence to support interference as important in forgetting, but the theory doesn't account for the forgetting of highly novel material over time

# Trace Transformation

- The fact that memory is an active organizing process means that information that is stored may be distorted or transformed over time in some way so that it is no longer faithful to the original
- Examples
  - Loftus' work on eyewitness testimony
  - Bartlett's classic studies on remembering

# Eyewitness Testimony

- Actively researched since turn of century. Much recent work done by Loftus and colleagues
- The results of this research can have big implications for legal systems; there are several journals dedicated to issues concerning psychology and the law
- In eyewitness research subjects typically view pictures, or a video, or even an enacted 'crime,' and their memory for details of the the event are subsequently assessed

# Effect of Misleading Questions

- Loftus (1975): Subjects viewed film of car accident
- Group A was asked, “How fast was the car going when it passed the barn?”
- Group B was asked, “How fast was the car going?”
- Question: “Did you actually see a barn in the film?”
  - >20% of Group A respond “Yes”
  - < 3% of Group B respond “Yes”
- Misleading post-event information can lead to false memories

# Subtle Differences in Wording of Questions Can Affect Memory

- Loftus & Palmer (1974)
  - Ss watched film of crash.
  - Some Ss given questionnaire asking, “How fast were the cars going when they smashed into each other?”
  - Others were asked, “How fast were the cars going when they hit each other?”

1 Week Later, Ss were asked:  
Did you see any broken Glass?

	Smash	Hit
Yes	16	7
No	34	43

# Bartlett's 'War of the Ghosts'

For one experiment, Bartlett presented his subjects (adults) with a story and had them recall it later.

## *"The War of Ghosts"*

*One night two young men from Egulac went down to the river to hunt seals and while they were there it became foggy and calm. Then they heard war-cries, and they thought: "Maybe this is a war-party." They escaped to the shore, and hid behind a log. Now canoes came up, and they heard the noise of paddles, and saw one canoe coming up to them. There were five men in the canoe, and they said: "What do you think? We wish to take you along. We are going up the river to make war on the people."*

*One of the young men said, "I have no arrows."*

*"Arrows are in the canoe," they said.*

*"I will not go along. I might be killed. My relatives do not know where I have gone. But you," he said, turning to the other, "may go with them."*

*So one of the young men went, but the other returned home.*

*And the warriors went on up the river to a town on the other side of Kalama. The people came down to the water and they began to fight, and many were killed. But presently the young man heard one of the warriors say, "Quick, let us go home: that Indian has been hit." Now he thought: "Oh, they are ghosts." He did not feel sick, but they said he had been shot.*

*So the canoes went back to Egulac and the young man went ashore to his house and made a fire. And he told everybody and said: "Behold I accompanied the ghosts, and we went to fight. Many of our fellows were killed, and many of those who attacked us were killed. They said I was hit, and I did not feel sick."*

*He told it all, and then he became quiet. When the sun rose he fell down. Something black came out of his mouth. His face became contorted. The people jumped up and cried.*

*He was dead.*

# Bartlett's Results

- Bartlett found that different subjects recalled the passage in their own characteristic way. He also detected a number of consistent tendencies:
  - The passages always became shorter, tended to become more coherent, and to fit in more closely with the subject's own viewpoint
  - The subject often selected certain features of the passage and used these to anchor the whole story
  - detail was often changed so as to become more familiar
- Bartlett also observed that in the process of remembering a passage, the first thing the subject tends to recall is his attitude towards it
- What you remember is driven to some extent by your emotional commitment and response to the event

# Bottom Line

- Bartlett's and Loftus' work show that the active organizing character of the memory process can often produce changes in the information that is stored so that it is no longer faithful to the original

# Repression

- The idea underlying repression is that forgetting is not an automatic process over which the individual has no control
- Freud argued that things that are very disturbing to us or threatening are likely to be driven out of consciousness
- Repression protects us from unacceptable or painful information
- There is a good deal of controversy surrounding the claim by some psychotherapists that therapy enables some subjects to 'recover' repressed memories of childhood abuse
- The main problem is that a number of studies have shown that it is quite easy to produce false memories
- This is a current topic of much debate

# Loss of Access or Retrieval Failure

- Changes in retrieval cues over time make it difficult for information to be retrieved
- Example: Certain childhood memories have been mostly forgotten, but when an appropriate retrieval cue is presented, e.g., an old diary or photo album, a huge flood of old memories become available
- Note: Each theory of forgetting can account for some aspects of forgetting, but not all