1.7 Memory

Syllabus: *Encoding and remembering; Short term memory, Long term memory, Sensory memory, Iconic memory, Echoic memory: The Multistore model, levels of processing; Organization and Mnemonic techniques to improve memory; Theories of forgetting: decay, interference and retrieval failure: Metamemory; Amnesia: Anterograde and retrograde.*

Previous Year Questions

2016

Q. What do you understand by Amnesia ? Illustrate the types of Amnesia with reference to H.M.'s brain operation. 10 marks [2016]

Q. Give a critical appraisal of interference theory of forgetting & show how the process of retrieval inhibition influences forgetting. 20 marks [2016]

Q. Explain the phenomena of implicit & explicit memories. Also, critically evaluate Tulving's model of long term memory. 20 marks [2016]

2015

Q. Bring out the disruption in retrieval processes due to anxiety, context & repression. 10 marks [2015]

Q. Citing studies on amnesia show how the explicit & implicit memory systems are separate. 20 marks [2015]

Q. How far do you agree with the contention that research findings on infant memory can present novel approaches toward analyzing adult memories ? Corroborate your answer with examples. 15 marks [2015]

2014

Q. Distinguish between single-process theory & dual process theory of short term memory. 20 marks [2014]

Q. What is the role of constructive & reconstructive processes in human memory ? Explain. 15 marks [2014]

2013

Q. What factors contribute to the encoding of information into long term memory ? 10 marks [2013]

Q. Describe & evaluate the modal model for short term memory. 20 marks [2013] *{Hint : Atkinson & Shriffin model is called the modal model}*

2012

Q. What is McCrary Hunter invariance hypothesis? Discuss the shape and characteristics of serial position error curve in terms of invariance hypothesis. 20 marks [2012]

Q. Compare Sterling's experiment with that of Neisser's experiments in the study of sensory memory. What did these two experiments prove ? 20 marks [2012]

2011

Q. On what grounds are STM & LTM distinguished ? 10 marks [2011]

Q. How the principles of encoding help enhancing the use of mnemonic devices. ? 10 marks [2011]

Q. How does the level of processing model differ from the multi-store & working memory models ? Explain . 30 marks [2011]

Q. What are the techniques & devices used in improving memory to ensure better academic achievements ? Discuss. 30 marks [2011]

2010

Q. Explain anterograde amnesia with special reference to the classical case of HM. 10 marks [2010]

Q. Discuss the levels of processing framework of memory & the relevant supporting research evidence. 30 marks [2010]

Q. How would you process information for maintaining it for long term usage. 10 marks [2010]

Q. How do task similarity and modality influence dual-task performance ? 30 marks [2010]

2009

Q. Discuss various characteristics of probability learning. Prepare an experimental design of probability learning following "Bernoulli Sequence". When is the beahviour of the subject labelled as 'gambler's fallacy'. 60 marks [2009]

Q. Prepare an experimental design following Sperling's technique to study iconic memory. What does the experiment prove ? 30 marks [2009]

2008

Q. Describe the various techniques used in improving memory. Discuss their merits & demerits for teaching students in undergraduate courses. 60 marks [2008]

Q. Representational knowledge can be ivestigated neurocognitively through the studies of amnesia. Elaborate this statement. 60 marks [2008]

Q. What is the meant by ‘echoic memory’ How long does this memory last? Discuss with experimental evidence. 20 marks [2008]

Q. The level at which an information is processed has a bearing on recall of that particular information. Discuss in the light of experimental studies. 20 marks [2008]

Encoding & Remembering

Earliest research in memory psychology–**Hermann Ebbinghaus (1885)-** used himself as a subject & tried to memorize & recall **nonsense syllables** (e.g. teg, bom etc.). His findings have been important. These are

- forgetting occurs rapidly initially but later slows down
- *distributed practice (*learning spread over time) is superior than *massed practice* (all at once)

Alfred Binet (who developed intelligence tests too) also did some early work on memory. He chose to focus on memory for meaningful written passages as opposed to Ebinghaus's nonsense syllables.

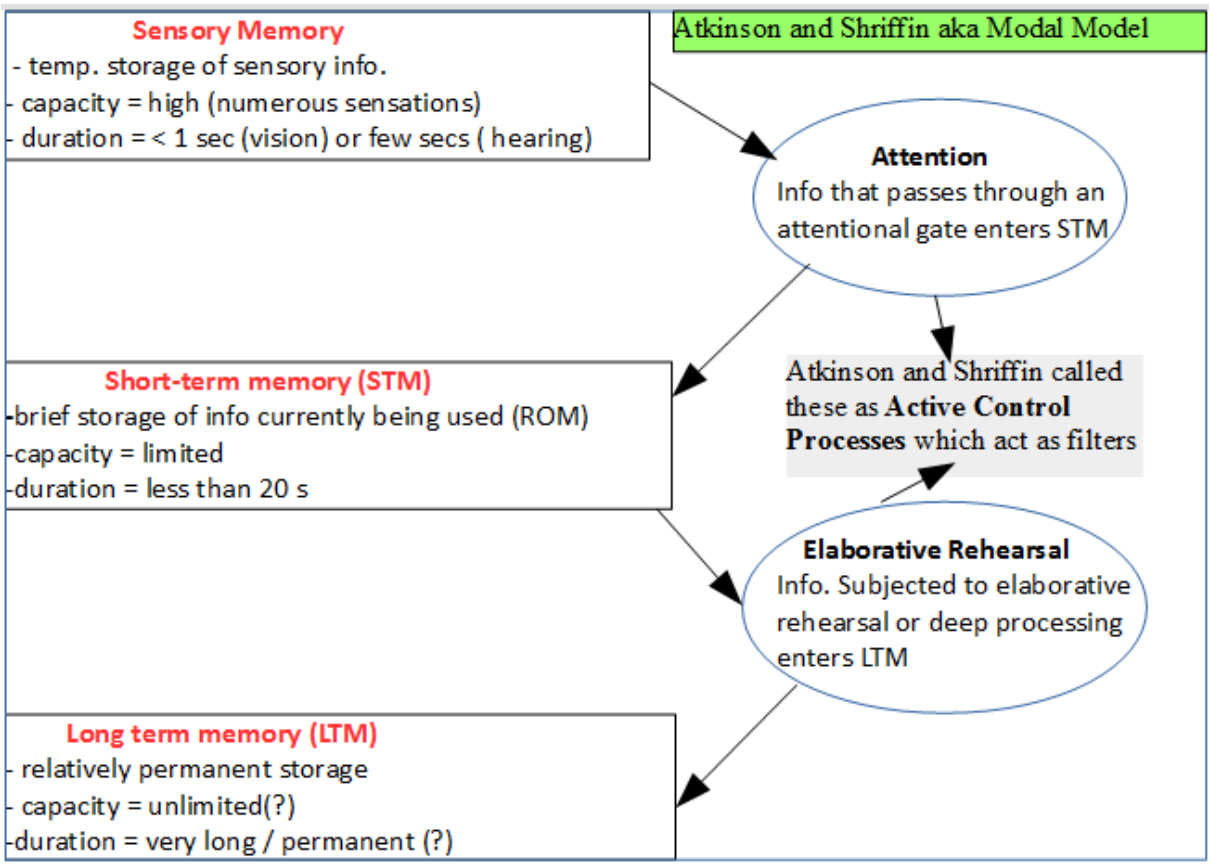
1.7.2 Models & theories on human memory
Why do we need models in psychology or any other field of science ? For

- Accurate description
- Explanation
- to organize a huge repository of empirical data (e.g. vk. gupta & his comminution models)
- to facilitate future researchers formulate predictions that can be used in further studies

Atkinson & Shriffin Modelaka**Modal Model**aka**Multistore Model of memory(1968)**

A & S noted that 3 basic mechanisms, (much like PCs) through which our memory works are :

- **Encoding** = Process through which information is converted into a form that can be entered into our memory.
- **Storage**
- **Retrieval**



- Psychologists now refer STM as **working memory.**
- **Selective Attention** = Our ability to pay attention to only some aspects of the world while largely ignoring others. It plays a crucial role as a active control process.
- **Maintenance Rehearsal** = Merely repeating information silently to ourselves does not necessarily transfer the info form STM to LTM. We need to engage in some sort of cognitive effort called **Elaborative Rehearsal** in order to accomplish it. e.g. thinking about the info's meaning & relating it to other items in LTM.

Evaluation of the A&S /Modal Model
Pros :

- Thus, A&S model aka Modal model linked the study of human memory firmly to **Information Processing Perspective,** which is an imp part of all cognitive psych today.
- The ideas of encoding , storage & retrieval have been corroborated by various research findings.
- Most imp. breakthrough of this model was that it proposed that we possess different kinds of memories.

Cons :

- Recent advances in memory research + underst&ing of how our brain functions, suggest that analogy of computers' memory for human memory is limited & oversmplified ; presents only a rudimentary view.

Neural Network Models : Parellel Processing of Information

- A/c to Neutral Network models of memory, through large numbers of simultaneously (**parallel processing**) operating processing units i.e. collections of interconnected neurons (modules), widely scattered physically in our brains, each dedicated to specific aspect of a task, we are able to accompolish even complex tasks efficiently & quickly. The more complex is the task, greater are the number of modules called into operation.
- For instance , a/c to one neural network model by **McClelland & Rumelhart (1981)**, we possess processors for 26 different letters, 16 letter features & >1k words. So when we encounter a string of letters such as *elephant,* these neurons are activated in parallel - all at the same time. The letter unit recognizes letters, & the word unit recognizes the combination of letters ; all of this occurs simultaneously at a lightening speed.
- This is in contrast to the working of the computers which are *serial devices* & work on 'one step at a time' principle, which can result in slower performance, especially for complex tasks.
- These models also propose that info in memory is not located in a specific place in the brain, rather it is represented by
    - patterns of activation spread over many processing units
    - strength of activation across these various units
- **Lindsay & Reed's spider-web analogy (1995) :** Neural networks are like the web of a spider with millions of interconnecting strands. The tighter the strands, the stronger the interconnection. Incoming info "pulls" on certain strands, thus activating other units; just as a fly that lands on a spider's web sends vibrations along the strands to other locations.

Types of Memories / Kinds of info stored in memory
There is a considerable debate among psychologists today whether we have diff. types of memories or just a single memory capable of handling many types of info.- procedural, factual, episodic etc.

1. **Working Memory (WM)**
It is kind of a "*work-bench*" of conciousness – a place where current info is held & processed. Previously it was used interchangeable with short term memory (STM) but in recent times psychologists have started distinguishing bettween the two in the sense that STM only concerns itself with temporary storage of info while working memory undertakes storage as well as the capacity to process/ transform the info.

Serial Position Curve (SPC)
It depicts the phenomenon of greater accuracy of recall of items at the beginning (**Primacy Effect**)& end (**Recency Effect**) of the list than the ones in the middle.

Explanation for SPC:
SPC can be explained on the basis of existence of two memory systems- one holding info for just a few secs & other which can hold it for a long time.

Receny Effect happens because items last on the list are still present in the *working memory* during the time of recall.

Primacy Effect occurs because the items in the beginning of the list have already entered the LTM.

The items in the middle vanish from the working memory & are also not present in LTM. *Bechaare !!*

How much can WM hold ? CHUNKING can help !

Research findings suggest that the limit of WM is **7±2 discrete items** also called **Miller's Magic Number** - George Miller's classic 1956 study found that the amount of info. which can be remembered on one exposure is between 5 and 9 items, depending on the info. Applying a range of +2 or -2, the number 7 became known as Miller's Magic Number, the number of items which can be held in Short-Term Memory at any one time.

However, the good news is that the amount of info retention in the working memory can be significantly enhanced by the process of ***chunking*** –grouping together several items as one single discrete item. For ex : remembering the list of letters BMISCTSTCSCC as IBM TCS CTS CSC – all initials of big software companies !

Baddeley's (1992) model of WM / Mutiple Component Model of WM

- Visuo-spatial sketchpad

- Phonological Loop
- Episodic Buffer (short term episodic memory) (added by Baddeley in 2000)
- Central Executive (The master)

The central executive is a flexible system responsible for the control and regulation of cognitive processes. It has the following functions:

1. binding information from a number of sources into coherent episodes
2. coordination of the other 3 slave systems
3. shifting between tasks or retrieval strategies
4. selective attention and inhibition

It can be thought of as a supervisory system that controls cognitive processes and intervenes when they go astray.

Evidence for Baddeley's multi-component model of WM :

a) **Neuroimaging :** Scans of people's brains while they work on various tasks show that spatial & phonological info are processed in separate areas.

b) additional findings indicate that visuospatial sketchpad region processes both visual & spatial info

c) **Concurrent Task Paradigm :** Attempts to prove the existence of the central executive. Participants work on two simultaneous tasks; for ex: adding digits (e.g., 13+18+19+25+43 = ?) & a second *distracting task* such as pushing numbered buttons in a sequence. The reasoning is that more is the distracting task similar to the primary task, more it will disturb the planning & control functions of the central executive & thus poorer the performance on the primary task will be. This is precisely what happens

d) **Dysexecutive Syndrome (DS) :** Persons who have suffered injuries in the frontal lobes – the presumed location of central executive are described as suffering from DS. Such persons are

- unable to make decisions
- get easily distracted
- show a tendency towards **perserveration** – continuing to pursue an inital goal instead of switching to other ones even when the first goal is met.

All these are taken as an evidence for the existence of a central executive which plays a key role in coordinating a wide range of mental processes.

Explicit Memory aka **Declerative memory : Memory for factual info**
Explicit /Declerative Memory = 2 types – Episodic & Semantic
a) **Episodic Memory :** Allows us to go back at a particular times & place & recall the info that was gathered back then. For ex : recalling list of numbers or words presented sometime back.
b) **Semantic Memory :** Holds info of a more general, abstract nature, which we don't remember acquiring at particular place /time. e.g. meaning of words, properties of objects, typical events in everyday life etc.

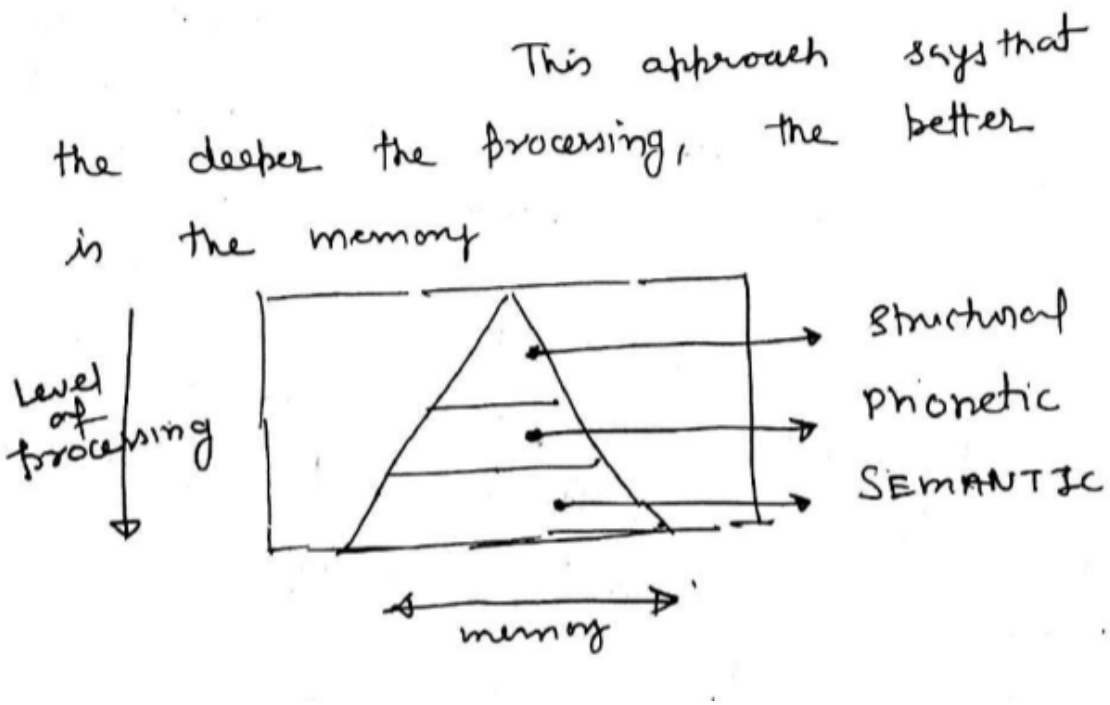
Factors affecting episodic memory :

1. Amount & Spacing (distribution in time) of practice

2. **Levels of processing view**: **Craik & Lockchart (1972)** presented this influential theory on memory. It suggests that more deeply the info is processsed, the more likely it is to be retained.

- Shallow processing : little mental effort ; repeating the word or making sensory judgements such as – do two words or letters look alike.
- Deeper level of processing : do two words rhyme

- Much deeper level of processing : do two words have the same meaning; does using the word in a particular sentence make sense.



Research Evidences

In a study, subjects were asked in a surprise test about three group of words. Earlier they were instructed to

1. Observe whether words consist of small or capital letters
2. Whether words rhyme or not
3. Meaning of the words

It was found that the level of retention was greatest in Case 3 > Case 2 > Case 1

Problems with levels of processing view :

- It is difficult to specify in advance exactly what constitutes a deep vs. a shallow level of processing
- it is not clear whether a person can read a word over & over again & not be aware of or think about its meaning.

Because of these confusions , it is difficult to speak about discrete levels of processing.

3. **Retrieval Clues** : stimuli that are associated with the info stored in memory. The more retrieval clues, the better our chances of remembering info in our episodic memory.

Retrieval clues theory is closely related to another topic called **Context-Dependent Memory (CDM) :** Material learned in one environment or context is easier to recall in a smilar context than in a very different one.

Godden & Baddeley (1975) experiment on CDM
Deep sea diver particpants were made to learn a list of words either on the beach or beneath 15ft of water. Later they were required to recall the info either in the same or different setting (beach or beneath water). The results gave clear support to the +ve impact of similar context (in this case, physical location) in recalling info.

Infact, further research suggests that physical presence is not necessary, even imagining the context or setting can aid in recall. (Smith, 1979)

State-Dependent Retrieval : External cues are not the only aid in remembering info; our internal states can also act as a 'context' for info recall. E.g. If some info is remembered while drinking coffee, (caffeine brings the body to a specific internal state of alertness); Drinking coffee would aid in info recall too.

Encoding Specificity Principle: The retrieval of learned info. is directly proportional to the extent of mathcing clues during learning & retrieval times.

Organization of info in semantic memory

There is a vast amount of info stored in our semantic memory. Categorization/organization of such large amount of info in our memory occurs in the following ways :

Concepts : Mental categories in which events, objects or ideas sharing similar some characteristics are grouped together. E.g : pizza, burger, biryani, noodles are all food items. Concepts in semantic memory exist in networks (**Semantic Networks**) reflecting the relationship b/w them. They are generally a hierarchy of concepts defined by certain properties such as food includes different cuisines like Chinese (is hot , has a typical taste), Continental (is plain & salty) , Indian (is spicy) , Fast food (served on street side & McDonalds etc.) etc. Indian food further includes south indian food (dosa , idli),north indian food (aaloo paratha, roti, litti chokha) ;North Indian food further includes Gujarati food (dhokla , fafra etc.) , Rajasthani food (Daal baati) , Bihari food (litti chokha) etc. & so on....

Prototypes : Abstract , idealized representations that capture an **overall average** or **typical notion** of members of a category. E.g. for a person who has lived in big cities all his life, the prototype of a village may be a place which is thinly populated, has kaccha (unmetalled) roads, with people working in agricultural fields.

Exemplar : An example of a category that an individual can readily bring to mind & also uses it for comparison purposes in deciding whether a new object belongs to that category or not. For ex: apple, mango etc.are exemplars for concept *fruits*.

Echoic and Iconic Memories

Echoic Memory : Echoic memory is one of the sensory memory registers; a component of sensory memory (SM) that is specific to retaining auditory information. The sensory memory for sounds that people have just perceived is the form of echoic memory. Unlike visual memory, in which our eyes can scan the stimuli over and over, the auditory stimuli cannot be scanned over and over. Overall, echoic memories are stored for slightly longer periods of time than iconic memories (visual memories). Auditory stimuli are received by the ear one at a time before they can be processed and understood. For instance, hearing the radio is very different from reading a magazine. A person can only hear the radio once at a given time, while the magazine can be read over and over again. It can be said that the echoic memory is like a "holding tank" concept, because a sound is unprocessed (or held back) until the following sound is heard, and only then can it be made meaningful. This particular sensory store is capable of storing large amounts of auditory information that is only retained for a short period of time (3–4 seconds). This echoic sound resonates in the mind and is replayed for this brief amount of time shortly after the presentation of auditory stimuli. Echoic memory encrypts only moderately primitive aspects of the stimuli, for example pitch, which specifies localization to the non-association brain regions.

Baddeley's model of working memory consists of the visuospatial sketchpad which is related to iconic memory, and a phonological loop which attends to auditory information processing in two ways. The first is a phonological store which has the capacity to retain information for 3–4 seconds before decay, which is a much longer duration than iconic memory (which is less than 1000ms). The second is a sub-vocal rehearsal process to keep refreshing the memory trace by the using one's "inner voice". However, this model fails to provide a detailed description of the relationship between the initial sensory input and ensuing memory processes.
A short-term memory model proposed by **Nelson Cowan** attempts to address this problem by describing a verbal sensory memory input and storage in more detail. It suggests a pre-attentive sensory storage system that can hold a large amount of accurate information over a short period of time and consists of an initial phase input of 200-400ms and a secondary phase that transfers the information into a more long term memory store to be integrated into working memory that starts to decay after 10-20s

Iconic Memory :

Iconic memory is the visual sensory memory (SM) register pertaining to the visual domain and a fast-decaying store of visual information. It is a component of the visual memory system which also includes visual short-term memory (VSTM) and long-term memory (LTM). Iconic memory is described as a very brief (<1000 ms), pre-categorical, high capacity memory store. It contributes to VSTM by providing a coherent representation of our entire visual perception for a very brief period of time. Iconic memory assists in accounting for phenomena such as change blindness and continuity of experience during saccades. Iconic memory is no longer thought of as a single entity but instead, is composed of at least two distinctive components. Classic experiments including Sperling's partial report paradigm as well as modern techniques continue to provide insight into the nature of this SM store.

Evidences that support the separation b/w episodic & semantic memories

a) **Schachter's (1996) study :** Studied patients with certain parts of the brain damaged. Some had only semantic memory intact with diminshed episodic memory & vice-versa.

b) **PET scans** : show that different brain regions are active when individuals attempt to recall general info (semantic) & when they try to recall info acquired in a specific context (episodic).

Procedural Memory aka **Implicit Memory: Memory for skills**

Contains info that cannot be readily described verbally , it can only be 'demonstrated' . e.g. Playing the guitar & singing along.

Priming Effect: A source of evidence for procedural memory

Priming refers to the phemomenon that having seen or heard a stimulus once may facilitate our recognition of it on a later occasion. When the facilitation occurs even when we are unaware of the presence of the stimulus ,it is called ***automatic priming.*** This is something similar to how our procedural memory works & thus provides an evidence for it.

Some memory experts refer to priming effect as the diffference b/w ***remembering*** & ***knowing***. *Remembering* means being able to report an event & the circumstance under which it occured; whereas *Knowing* referes to the familiarity we have with a stimulus even when we can't remember it explicitly. This familiarity can actually strongly influence our behaviour (advertising industry) .

Erdley & D'Agostino (1989) study on Priming

Before making two groups of participants read an ambiguous description about an imaginary person, one group was exposed to flashes of words on a screen related to traits of **honesty** such as sincere, honorable , truthful etc. The **word flashes** were so quick that it was merely a blur & participants were unaware of them. The other group was exposed to neutral words unrelated to honesty e.g. many , little , more etc. Finally , the participants were made to rate this peson on different dimesnsions , some of which were related to honesty. 1st group of participants rated the imaginary person higher on traits related to honesty than the 2nd group. **Automatic Priming** [i.e. even when the participants were unaware of the presence of the stimulus] was in play here .

Case studies on "Supermemories"

1.**J.C. - The waiter** who could remember as many as 20 different orders simultaneously without writing them down. **Ercisson & Polson (1988)**who studied him found out that he did it by encoding orders in terms of basic categories such as entree (chicken, steak) , temperature (rare, medium) & starches (e.g. rice, fries) . He then used initial letters of these & other food related categories to form words & phrases that had meaning for him e.g. **S**teak cooked **R**are with **F**ries would be encoded by him as "**S**ue **R**arely **Fi**ghts". He translated this into the order on going back to the kitchen. But the remarkable thing here is that, over time he got so fluent with this method that he didint have to conciously build these codes, he directly took order & delivered them to kitchen , with the encoding process happening as 'automatic processing' – this kind of processing plays a vital role in Procedural Memory.

2. **Arturo Toscanini** : This orchestra musician had memorized the entire musical scores for more than 350 symphonies & operas ! - a super depiction of procedural memory. On one instance when right before a concert, one of the musicians came & told him that one of the notes on his instrument was broken , Toscaninni thought for a moment & remarked - " That's all right. That note doesn't appear in tonight's concert "

Flashbulb Memories : Vivid memories of both the event and what we were doing at the time of an emotion provoking event - almost like a photograph.

Autobiographical Memory : Memory for info about events in our own lives.

Infantile Amnesia : Our supposed inability to remember experiences during the first 2 or 3 years of life.

Repression : Active elimination from our consciousness the memories of experiences we find threatening.

Forgetting

Earliest view : Info in LTM fades away or **'decays'** with time. However, later studies showed that forgetting is not a function of how much time has elapsed , rather what happens during that period is more crucial; infact some other studies like **Erdelyi & Kleinbard (1978)** showed that in some cases, recall improves with passage of time.

Minami & Dallenbach (1946) study on cockroaches' memory : Roaches were taught to avoid a dark compartment by giving an electric shock whenever they entered it. After this, some were restrained in a paper cone & others were left free to move around in a darkened cage at will. Results indicated that the 2nd group showed more forgetting than those who were restrained. Hence, what the roaches did b/w learning & being tested for memory was more imp than mere passage of time.

Interference

Retroactive interference : Forgetting previous info due to entry of new info.

Proactive interference : Difficulty in retention of new info due to past info.

Interference is dir. prop. to the smilarity of materials interfering. Also, interference is more detrimental in case of nonsense/meaningless syllables or similar learnings than on meaningful passages.

Recent research has shown that interference is not the only reason for forgetting.

Retrieval Inhibition

When we try to recall/remember some info from our memory, the recall or retrieval of other related info gets inhibited.

For ex : Case 1 : We are told to recall the names of all European countries (around 50,some say 48 , some 51) freely , we might be able to recall say 'x' number of them

Case 2: We are given to read & remember the list of names of half of these European countries & then asked to recall the names of all of them, we might be able to recall < 'x' . Performance would be worse in this case due to retrieval inhibition.

Two Process Theory of Memory

Description

Recall works by a two-stage process:

1. A search through memory for something that might satisfy the search criteria.
2. A comparison of recalled memory with the detail of which being sought.

Recognition works only by a single process, where the stimulus leads to a memory already being found. Recognition thus only needs the second step from the two-stage recall process.

This makes recognition more likely to be successful as compared with recall.

Discussion

Bahrick (1970) found cued recall was predictable by multiplying the probability of free-association recall and the probability of recognition.

So what?

If you want someone to remember something, it is always better to get them to recognize it rather than wait for them to recall it. So show them and let them say 'that's it!'.

Memory Distortion & Memory Construction

Distortion = Alterations in what is retained & later recalled
Construction = Addition of info that wasn't actually present

Distortion can happen automatically & also when someone poses *suggestive comments or facts or details* **(Loftus, 1992)** as in case of *leading questions* by attorneys. Such distortions even occur when people are warned about them & even offered cash to resist their influence. **(Belli & Loftus, 1996)**

Why memory distortions occur ?
1. Coz. of opn. of **Schemas** – mental structures developed through experience involving individual's knowledge & assumptions about aspects of the world, providing basic frameworks for processing new information & relating it to existing knowledge (including knowledge held in LTM). Schemas exert strong effect on encoding, storage & retrieval, especially encoding. Thus, distortions can occur coz. we tend to notice & remember info that fits in our schema (&vv)

2. Coz. of **motives** : tendency to distort memories to make them coincide with goals being seeked. e..g : remembering only positive things about someone we like. (&vv).

> Related study : **McDonald & Hirt (1997) study-** (when expectancy meets desire)
>
> Participants watched an interview b/w 2 students, with 1 of these strangers possessing varying degrees of likeability (polite, rude or neutral). Later they were asked to recall the academic grades of this person (which was provided during the interview). Participants distorted their memories to put the likable strangers in better light &vv.

3. Errors in **Source Monitoring** : Confusion regarding sources of info in memory. e.g. reading something in Yojana and thinking it was in vision c.a. booklet. It also plays role in **eyewitness testimony**

A related effect is **Reality Monitoring :** not remembering whether an event actually occured or was it just in our imaginations & thoughts. e.g. remembering having taken the medicine pill when actually it was not taken.

Illusion of Outgroup Homogenity : people outside our own group appear to be more similar in appearance and characteristics than people in our own group. Coz of this illusion it is easy to identify an outgroup individual incorrectly as the prerpetrator of a crime; thus resulting in faulty eyewitness testimonies.

Methods to improve eyewitness testimony accuracy :

1. Asking witnesses in cognitive interviews to report everything they remember, this provides them multiple retrieval clues and can increase recall accuracy.

2. Witnesses should be asked to describe events in several diff. perspectives & diff. orders – not just in the order in which events actually occured.

3. Removing any element of *suggestibility* during questioning.

Repression : Active elimination from consciousness of memories of experiences we find threatening.

Amnesia : Loss of memory stemming from illness, injury, drug abuse or other casues.

Retrograde Amnesia : Loss of memory of events that occurred prior to an amnesia-inducing event.

Anterograde : Inability to form any further LTM after an amnesia-inducing event.

H.M. 's Brain operation

This patient had to undergo surgery at the age 27 in order to cure his epilepsy.

After the surgery, which was successful in its primary goal of controlling his epilepsy, HM developed severe anterograde amnesia: although his working memory and procedural memory were intact, he could not commit new events to his explicit memory. According to some scientists, he was impaired in his ability to form new semantic knowledge, but researchers argue over the extent of this impairment. He also had moderate retrograde amnesia, and could not remember most events in the 1-2 years period before surgery, nor some events up to 11 years before, meaning that his amnesia was temporally graded. However, his ability to form long-term procedural memories was intact; thus he could, for example, learn new motor skills, despite not being able to remember learning them.

HM's general condition has been described as heavy anterograde amnesia, as well as temporally graded retrograde amnesia. Since HM did not show any memory impairment before the surgery, the removal of the medial temporal lobes can be held responsible for his memory disorder. Consequently, the medial temporal lobes can be assumed to be a major component involved in the formation of semantic and episodic long-term memories (cf. medial temporal lobes described as a convergence zone for episodic encoding in Smith & Kosslyn, 2007). Further evidence for this assumption has been gained by studies of other patients with lesions of their medial temporal lobe structures.

Despite his amnesic symptoms, HM performed quite normally in tests of intellectual ability, indicating that some memory functions (e.g., short-term memories, stores for words, phonemes, etc.) were not impaired by the surgery. However, for sentence-level language comprehension and production, HM exhibited the same deficits and sparing as in memory. HM was able to remember information over short intervals of time. This was tested in a working memory experiment involving the recall of previously presented numbers; in fact, his performance was no worse than that of control subjects (Smith & Kosslyn, 2007). This finding provides evidence that working memory does not rely on medial temporal structures. It further supports the general distinction between short-term and long-term stores of memory). HM's largely intact word retrieval provides evidence that lexical memory is independent of the medial temporal structures .

Motor skill learning

In addition to his intact working memory and intellectual abilities, studies of HM's ability to acquire new motor skills contributed to a demonstrated preserved motor learning (Corkin, 2002). In a study conducted by Milner in the early 1960s, HM acquired the new skill of drawing a figure by looking at its reflection in a mirror (Corkin, 2002). Further evidence for intact motor learning was provided in a study carried out by Corkin (1968). In this study, HM was tested on three motor learning tasks and demonstrated full motor learning abilities in all of them.
Experiments involving repetition priming underscored HM's ability to acquire implicit (non-conscious) memories, in contrast to his inability to acquire new explicit semantic and episodic memories (Corkin, 2002). These findings provide evidence that memory of skills and repetition priming rely on different neural structures than memories of episodes and

facts; whereas procedural memory and repetition priming do not rely on the medial temporal structures removed from HM, semantic and episodic memory do (cf. Corkin, 1984).
The dissociation of HM's implicit and explicit learning abilities along their underlying neural structures has served as an important contribution to our understanding of human memory: Long-term memories are not unitary and can be differentiated as being either declarative or non-declarative (Smith & Kosslyn, 2007).

Spatial memory

According to Corkin (2002), studies of HM's memory abilities have also provided insights regarding the neural structures responsible for spatial memory and processing of spatial information. Despite his general inability to form new episodic or factual long-term memories, as well as his heavy impairment on certain spatial memory tests, HM was able to draw a quite detailed map of the topographical layout of his residence. This finding is remarkable since HM had moved to the house five years after his surgery and hence, given his severe anterograde amnesia and insights from other cases, the common expectation was that the acquisition of topographical memories would have been impaired as well. Corkin (2002) hypothesized that HM "was able to construct a cognitive map of the spatial layout of his house as the result of daily locomotion from room to room" .
Regarding the underlying neural structures, Corkin (2002) argues that HM's ability to acquire the floor plan is due to partly intact structures of his spatial processing network (e.g., the posterior part of his parahippocampal gyrus). In addition to his topographical memory, HM showed some learning in a picture memorization-recognition task, as well as in a famous faces recognition test, but in the latter only when he was provided with a phonemic cue. HM's positive performance in the picture recognition task might be due to spared parts of his ventral perirhinal cortex.
Furthermore, Corkin (2002) argues that despite HM's general inability to form new declarative memories, he seemed to be able to acquire small and impoverished pieces of information regarding public life (e.g., cued retrieval of celebrities' names). These findings underscore the importance of HM's spared extrahippocampal sites in semantic and recognition memory and enhance our understanding of the interrelations between the different medial temporal lobe structures. HM's heavy impairment in certain spatial tasks provides further evidence for the association of the hippocampus with spatial memory.

Memory consolidation

Another contribution of HM to understanding of human memory regards the neural structures of the memory consolidation process, which is responsible for forming stable long-term memories (Eysenck & Keane, 2005). HM displayed a temporally graded retrograde amnesia in the way that he "could still recall childhood memories, but he had difficulty remembering events that happened during the years immediately preceding the surgery". His old memories were not impaired, whereas the ones relatively close to the surgery were. This is evidence that the older childhood memories do not rely on the medial temporal lobe, whereas the more recent long-term memories seem to do so). The medial temporal structures, which were removed in the surgery, are hypothesized to be involved in the consolidation of memories in the way that "interactions between the medial temporal lobe and various lateral cortical regions are thought to store memories outside the medial temporal lobes by slowly forming direct links between the cortical representations of the experience".