Module 5: Psychobiology

Lecture 29: Psychobiology of memory

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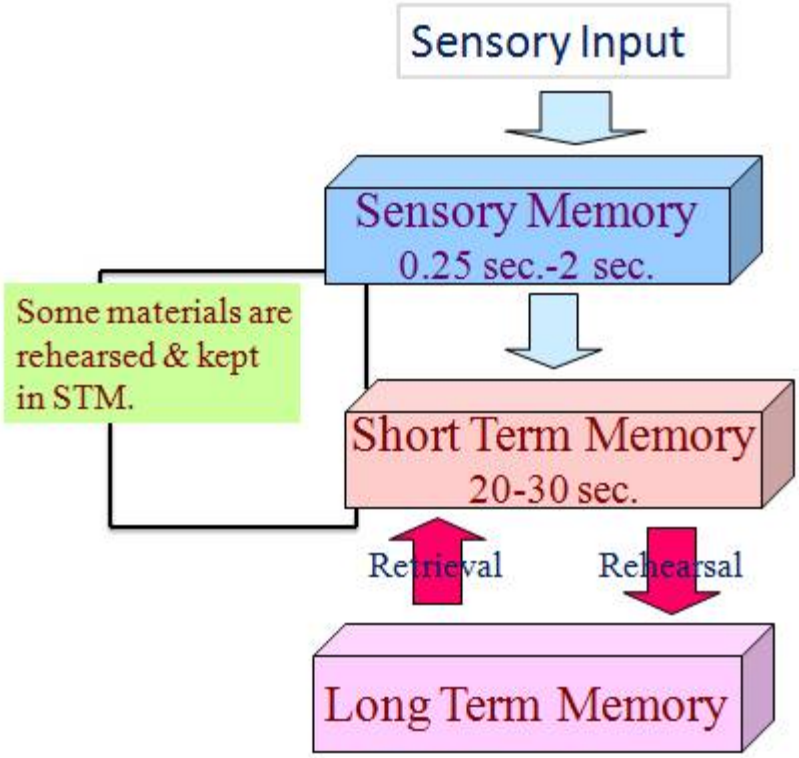
## Memory: Recapitulation

Till now our focus was on learning where the emphasis was on acquisition. We shall now have the recap of the deliberation on memory where the emphasis is on retention. Memory is studied in terms of mental processes involved in storage and retrieval of information. The three major types of memory are sensory, short-term, and long-term. The incoming sensory inputs can be stored for a very brief period of time ranging from 0.25-2 seconds. This is called sensory memory. Some of these items can further be retained for 20-30 seconds in our short-term storage. Some of them are stored for very long time, days, months, years, or even life time. This is diagrammatically represented below.




Further, there are various subtypes of these major types of memory.

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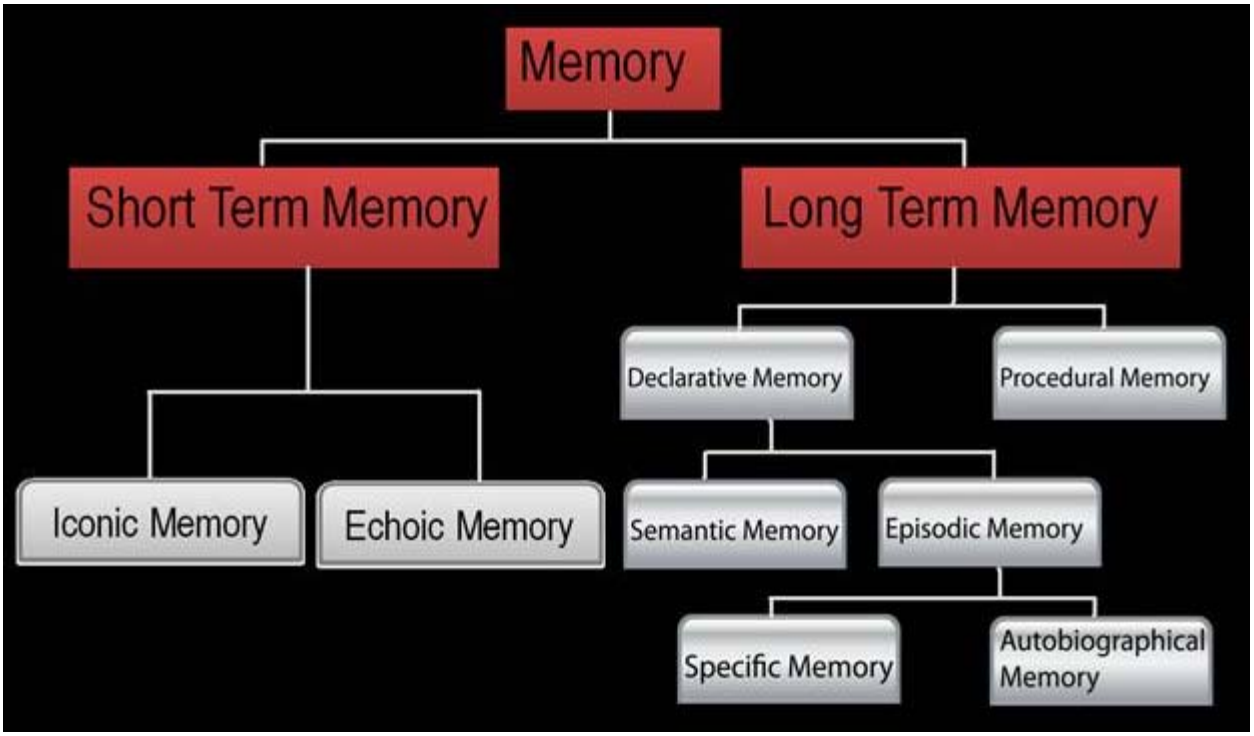
The flow chart given below will help you recollect the subtypes of memory system.




As such memory involves t hree distinct processes— encoding, storage and retrieval. Encoding is the p rocess of transformation of the physical stimulus into a form that human memory system accepts. Storage refers to retention of the encoded information, whereas recollecting information from storage is termed as retrieval.

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## Psychobiology of Memory

Our understanding of psychobiology of memory is largely dependent on the neuropsychological studies of humans and neurophysiological examinations of non-human primates. The knowledge about memory system has largely come from experimental studies, clinical cases, neuropsychological investigations, and brain imaging techniques. The findings indicate that human memory system is divisible, a summary of which has been mentioned above. Different types of memory help us develop an exclusive sense of a personal history.

Other than the way memory has been classified above, people also classify long-term memory as explicit and implicit memories. Explicit memory has been further classified as semantic and episodic memory. Other forms of memory are typically implicit. Tulving (1984, 1985) has described memory as a hierarchically organized system with a set of correlated processes. The lower system supports the higher one. For example, implicit memory is at the lowest level in the hierarchy facilitating connections between stimuli and responses. Implicit memory does not depend upon conscious recollection of earlier experience whereas explicit memory involves conscious awareness. It is assumed that initially the semantic memory system develops making one understand the world and eventually it provides structure and meaning to the episodic memory system.

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## Episodic Memory

Episodic memory contains different types of contextual details. These details include perceptual, emotional, and cognitive features. All of these need to be integrated. The process of formation of episodic memory includes binding. We encode the relationship among the stimuli and the selected features. We attribute an episode to its source on the basis of these contextual features. Developmental psychology research adopting familiarity-based versus recollection-based judgments (Remember/Know paradigm) have recorded improvement in recollecting contextual details as one grows from childhood to adulthood. This difference has also been attributed to the immature development of medial temporal and frontal lobe brain structures. This has been considered as the neurobiological cause of developmental difference in the source memory of children.

To certain degree the retrieval of episodic memory depends on the richness of the contextual details linked to the memory traces. For any given event, memory about the occurrence (content) is different from memory of the acquisition of the context of the occurrence. Memory of the content of the event occurs in the absence of contextual recollection. When we attempt to recollect the contextual details associated with a given episode, we are referring to source memory. As source memory has to do with the origin of information, it involves perceptual (color for example), contextual (spatiotemporal), affective (emotions), and cognitive (identification) features. Identification of source of memory is an important cognitive ability. Failure to recollect the source while remembering the content is a common memory failure that many people experience. Given that hippocampus and prefrontal cortex are important for episodic memory their involvement in developmental changes in source monitoring and binding is very likely. The animations given below shows the hippocampus and prefrontal cortex in the brain.

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Neuroimaging studies have reported activation in ventrolateral (Brodmann's Areas 44, 45, 47, and parts of 6), dorsolateral (Brodmann's 9 and parts of 46), and anterior (Brodmann's Areas 10 and parts of 46) prefrontal cortex during episodic long-term memory. The medial temporal lobe including the hippocampal formation (dentate gyrus, hippocampus, and entorhinal cortex), the perirhinal and parahippocampal cortices, and the amygdale play significant role in episodic memory. fMRI studies show strong blood flow in the right ventral prefrontal cortex during recall of episodic material. This activation extends partly towards the medial limbic regions. Greater activation in the left prefrontal cortex has been recorded during source memory judgments.

Studies of brain-damaged patients have also helped in understanding the locus of various memory functions in the brain. Neuropsychological studies comparing normal controls, frontal lobe damaged and amnesic patients revels no difference between the two patient groups. As compared to the normal controls both the patient groups could recall the same amount of factual knowledge. However, they suffer impairment of source memory performance. As frontal cortex is also sensitive to aging, source memory discrepancies can also appear due ageing. Damage to the medial temporal lobe (peri-and entorhinal cortex, parahippocampal gyrus), medial diencephalon (mediodorsal and anterior thalamic nuclei and mammillary bodies), and basal forebrain (cholinergic nuclei of the medial septal region, basal nucleus of Meynert and the diagonal band of Brocas' region) causes loss of information from episodic memory. Studies of brain damaged patients indicate that damage to the right hemisphere causes loss of episodic memory whereas damage to the left hemisphere results into loss of semantic memory.

As discussed above, explicit memory is classified into semantic and episodic memories. Autobiographical memory is a sub-classification of episodic memory. Looking at them from neuropsychological perspective, limbic system is instrumental in encoding autobiographical and semantic memory. Orbitofrontal and anterolateral temporo-polar regions are involved in the retrieval of information. Increased connectivity between the parahippocampal cortex and hippocampus has been observed during retrieval of autobiographical events. Retrieval of general knowledge has shown increased connectivity between the middle temporal gyrus and temporal pole (Maguire et al., 2000). PET studies show that the right hemisphere engages in retrieval of episodic memory, whereas the left hemisphere is involved in retrieval from the semantic memory. Regions of the fronto-temporal junction area perform these operations.

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As we know, encoding, storage and retrieval are the three functions that memory system performs. The information passes from sensory to short-term and then to the long-term memory. The behavioural outcomes that we give are mediated through the working memory. The prefrontal cortex plays significant role in the initial stages of information processing, especially short-term and working memory. It is important for sequencing and organizing the information. It is also likely to be the control center for metamemory and effortful initiation of recall. The temporo-polar and ventrolateral prefrontal cortex is significant for recall. The prefrontal cortex also has to do with sustained attention, verbal and spatial working memory, and semantic memory (Nyberg et al., 2003). Studies suggest that source monitoring rely on executive function abilities as content-context association depends on conscious working-memory. Frontal lobe is involved in integrating item and source information during encoding. The lateral prefrontal cortex (PFC) is activated during episodic memory retrieval. Bilateral ventrolateral prefrontal regions (Brodmann's Areas 6, 44, 45, and 47) and dorsolateral prefrontal regions (Brodmann's Areas 9/46) are activated during encoding and recognizing the context of worming memory and long-term memory tasks. Brodmann's Areas 10/46 activation has been recorded in the left anterior middle frontal gyrus during the recognition phases of these tasks. Maintenance and manipulation of information across short delays in working memory have been found to activate ventrolateral and dorsolateral prefrontal regions. Activation of ventrolateral prefrontal region has been observed during long-term memory encoding and retrieval tasks, whereas during long-term memory retrieval tasks dorsolateral and anterior prefrontal activation has been observed.

Activation of regions in dorsolateral and ventrolateral prefrontal cortex has been reported during encoding as well as recognition of objects. During retrieval left anterior prefrontal cortex was activated which further increased while retrieving perceptual details of the object. The left anterior prefrontal cortex is instrumental in on-line monitoring and appraisal of specific memory characteristics during retrieval. The inferior and lateral frontal lobes as well as the anterior and lateral temporal lobes are involved in retrieval.

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## Emotion and Memory

Memory of emotionally loaded information is mediated by amygdala. The memory of emotional items is better compared to neutral items. We have seen how reward facilitates human as well as animal learning. fMRI studies investigating brain mechanisms underlying reward induced episodic memory enhancement have shown better recall of pictures when monetary reward was anticipated (Adcock et al., 2006; Wittmann et al., 2005) with substantia nigra involved in reward anticipation and memory (Wittmann et al., 2005) and ventral tegmental area and nucleus accumbens related to memory facilitation by reward anticipation (Adcock et al., 2006). Memory and emotion are also interrelated. In an interesting study Tsukiura and Cabeza (2008) found that face-name associations were stronger for smiling face as compared to neutral expression. Further details pertaining to psychobiology of emotion follows in the next section.

## Emotion: Recapitulation

Eysenck has defined emotion as “a complex state involving heightened perception of an object or situation, wide-spread bodily changes, an appraisal of felt attraction or repulsion, and behavior organized toward approach or withdrawal.” It is a multifaceted process involving physiological, behavioural and expressive reactions as well as subjective experiences. Variation in the respiration rate is an example of physiological reactions. Behavioural reaction includes approach-avoidance reactions whereas smiling, frowning and so forth are our expressive reactions. Emotion always has subjective experience.

Emotional processes involve activation of both, the central and peripheral nervous systems. The emotional state gets depicted through face, body and voice and it further triggers certain psychological processes. As human beings we interact with the environment and mostly come forward with appropriate emotional response. An emotional state can be elicited by neuro-chemical, sensorimotor, motivational or cognitive factors.

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