

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

Understanding Memory Mechanisms: Encoding, Episodic Function, Hippocampal Roles, and Alzheimer's Impact

Muhammad Sohail

Department of Pharmacy, University of Poonch, Rawalakot, Azad Kashmir, Pakistan

Nargis Rehman

Nargis Rehman Hijama and Herbal Health Center, Bhimber Azad Kashmir, Pakistan

Muhammad Akram

Department of Eastern Medicine, Government College University Faisalabad
Pakistan

Imtiaz Mahmood Tahir

College of Allied Health Professionals, Government College University Faisalabad
Pakistan

Corresponding Author Email: imtiazmlt@hotmail.com

Nimra Shahid

Department of Eastern Medicine, Government College University Faisalabad
Pakistan

Muhammad Tayyab Aslam

Department of Eastern Medicine, Government College University Faisalabad
Pakistan

Arsalan Abid

Department of Nursing and Community Health, Faculty of Public Health, Glasgow
Caledonian University Glasgow

Mudassar Khan

Health Services Academy, Islamabad Pakistan

Muhammad Mudassar

College of Allied Health Sciences, Faculty of medical sciences, Government College
University Faisalabad, Pakistan

Sabira Sultan

Department of Eastern Medicine, Government College University Faisalabad
Pakistan

Hamad Ahmed

Department of Eastern Medicine, Government College University Faisalabad
Pakistan

Asif Saleem

College of Physiotherapy, Faculty of Medical Sciences, Government College
University Faisalabad, Pakistan

Rimsha Zainab

Department of Botany, Shaheed Benazir Bhutto Women University, Peshawar,
Pakistan

Fethi Ahmet Ozdemir

Department of Molecular Biology and Genetics, Faculty of Science and Art, Bingol
University, Bingol, 12000, Türkiye

Gawel Solowski

Department of Molecular Biology and Genetics, Faculty of Science and Art, Bingol
University, Bingol, 12000, Türkiye

ABSTRACT

Encoding, storing, and retrieving information is made possible by memory, a basic cognitive function that shapes besides an individual's identity also their capacity for learning, decision-making, and interaction with their surroundings. This article uses knowledge from behavioral sciences, cognitive psychology, and neuroscience to investigate memory systems from a multidisciplinary standpoint. Memory is typically divided into three interdependent processes: encoding, the registration of information; storage, the maintenance of that information over time; and retrieval, the ability to access it when needed. These phases are influenced by a dynamic interplay of internal and external factors, including attention, emotional state, context, and underlying neurobiological activity. Distinct brain regions support different types of memory. The prefrontal cortex contributes to working memory and executive functions, the amygdala regulates emotional aspects of memory, and the hippocampus plays a central role in the consolidation and storage of declarative memory. Current research emphasizes the plasticity of memory, showing that recollection involves reconstruction rather than simple playback, making memories susceptible to distortion or even the creation of false memories. Advances in neuroimaging, including positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), have revealed the complex neural networks underlying encoding and retrieval, deepening our understanding of the brain's role in memory. Parallel research into disorders such as amnesia and Alzheimer's disease has further expanded knowledge of how memory functions and how it deteriorates under pathological conditions.

Our knowledge of how memory works and deteriorates has also been expanded by research on memory diseases, including amnesia and Alzheimer's disease.

Keywords

Encoding, Episodic memory, Alzheimer's disease, Memory distortion, Hippocampus

Introduction

Recalling knowledge that has been learnt is the process of memory. To collect and

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

retain information so can locate and access it when need it, the brain's many regions collaborate. (Kirschner et al., 2009)Memory can be categorized in various ways, and as we age, our cognitive abilities may decline, which is a common natural process. However, memory-related brain functions can also be affected by certain underlying health conditions. If experience memory-related issues, consult a healthcare professional for assistance. Genetic makeup provides instructions that determine how brain develops and functions, influencing both short-term and long-term memory. Genetic mutations can lead to disorders that impair memory, some of which are inherited from biological family. Life experiences can shape body's and genes' functioning. Memories enable brain to learn from experiences and adapt to the environment, fostering continuous growth and understanding. Life events and interactions with surroundings make up memory. Do not inherit memories from grandparents. (King et al., 1997) encounter new things and learn new things all the time. Uncontrollable factors, such as underlying medical illnesses or injuries that harm the areas of brain involved in memory formation or storage, can also have an impact on memory. Stress, trauma, or sleep deprivation can impair one's ability to think and recall details (Nelson et al., 1998). Brain may selectively conceal negative memories to protect from their emotional impact, shaping life experiences and influencing thought processes. By reflecting on past events, one can gain insights and knowledge that guide future decisions and actions. Memory is always at work, whether are recalling the color of the wall in childhood bedroom, the three things needs to buy at the grocery store, or how to avoid touching a hot stove. Sometimes, may recall a friend's name, but struggle to remember the answer to a test question. It can be frustrating when memory isn't functioning optimally, as humans are not always skilled at organizing and retrieving memories. Memory performance may be influenced by overall health. To enhance ability to recall information effectively, consider reducing stress and improving sleep quality. However, home therapy isn't always sufficient. See a medical expert if have any concerns regarding memory. The term "memory" encompasses a wide range of skills, including the ability to temporarily retain information while working with it, recall life events, and have a general understanding of global events. Three steps are involved in remembering episodes: storing information (keeping it over time), retrieving it, and encoding

information (learning it by seeing it and connecting it to past knowledge). Any step of failure can result in forgetfulness or the creation of false memories (Newman et al., 2009). Improving encoding procedures and employing strategies that guarantee efficient retrieval are essential for enhancing memory. Forming mental pictures, making relationships between the information to be recalled, and connecting new knowledge to what is previously known are all examples of effective encoding processes. Creating efficient signals that guide the remembered back to the stored information is essential for successful retrieval. The employment of classical mnemonic devices, which date back to the ancient Greeks and are still employed by certain people today, may greatly increase memory capacity. We frequently think about episodic memory when we hear the word "memory." (In actuality, early Alzheimer's disease preserves semantic memory.) While recalling certain life events (such as sixth-grade experiences) might be referred to as autobiographical memory, we will mostly concentrate on episodic recollections of more recent occurrences. One kind of forgetting is when encounter someone met at the party, but can't remember their name. Misremembering (false recollection or false recognition) is the other mistake: call someone who resembles Lyn Goff by that name.

Encoding

The development of neuropsychology and biological foundation for encoding theories coincided with technological advancements. "Neurons that fire together wire together," according to Donald Hebb's 1949 discussion of the neuroscientific side of encoding, suggesting that encoding took place when connections between neurons were formed by repeated usage. Initially, the hypothesis focused on encoding as the method for information entry into memory. However, in the 1950s and 1960s, the emphasis shifted towards information processing in memory, influenced by the advancements in computer technology during that period. George Armitage Miller's paper, "The 1956 book 'The Magic Number Seven, plus or Minus Two' explored the fact that short-term memory can only store seven items, plus or minus two.

After chunking testing revealed that seven plus or minus two may indicate seven "packets of information," this number was included. Using the phonological loop as

the encoding method, the central executive, and the visuospatial sketchpad, Alan Baddeley and Graham Hitch introduced their working memory model in 1974. Words learned under semantic (deep) encoding conditions are recalled more effectively than those processed under shallow, non-semantic conditions, with significantly greater activation observed in Brodmann areas 45, 46, and 47 of the left inferior prefrontal cortex. Interestingly, with repeated semantic encoding, activation in these regions decreases, suggesting that neural efficiency improves with reprocessing. Evidence also implicates the orbitofrontal cortex in initial encoding and the left lateral prefrontal cortex in the semantic organization of information. At the biological level, the process of encoding starts with perception. Sensory information is integrated by the thalamus into a cohesive perceptual experience, which is then relayed to various regions of the brain. The hippocampus subsequently assesses these inputs to decide whether they should be consolidated into long-term memory. Encoding relies on both electrical and chemical processes: when electrical impulses cross the synapse between neurons, neurotransmitters are released, received by dendritic receptors, and incorporated into neural communication pathways. Despite advances in neuroscience, the precise mechanisms by which encoded experiences are later recognized and retrieved remain an active area of research. (Craik et al., 2021)

Episodic memory

Autobiographical memory, which comprises recollections of one's own life events, is a unique type of episodic memory. . Episodic memory processing requires sequential encoding of contextual information within hippocampal-neocortical networks, followed by systems-level consolidation involving gradual transfer from hippocampal to distributed cortical storage sites, and retrieval through coordinated reactivation of encoding networks, with the hippocampus and medial temporal lobe structures functioning within a broader default mode network encompassing medial prefrontal, posterior cingulate, and angular gyrus regions that support episodic recollection and autobiographical construction. In contrast to episodic memory, semantic memory encompasses factual knowledge and conceptual information independent of personal experience context. Remote episodic memories—those formed in the distant past—demonstrate distinct neural characteristics compared to

recently acquired memories. While the specific neuroanatomical substrates underlying remote memory remain incompletely characterized due to methodological constraints in patient-specific testing, evidence suggests these memories undergo progressive neocortical consolidation and reduced hippocampal dependence over time. This differential neural organization explains the clinical observation that patients with neurodegenerative conditions typically show preserved remote episodic memories relative to recent memory formation, reflecting the distributed cortical representation of consolidated memories, similarly to cell phone data storage. Working memory represents a distinct cognitive system responsible for the temporary maintenance and manipulation of information during ongoing mental operations. Although historically conflated with short-term memory, working memory functions as a component of executive control systems and demonstrates strong associations with attentional mechanisms rather than traditional memory consolidation pathways. We can only hold onto a little amount of knowledge at a time due to the limitations of our working memory (Baddeley et al., 2001). Kim et al., (2025) considered low selenium levels as the factor weakening episodic memory.

Alzheimer's disease

Alzheimer's disease is the most common cause of dementia. Alzheimer's is characterized by pathognomonic accumulation of extracellular amyloid- β plaques and intracellular neurofibrillary tangles composed of hyperphosphorylated tau protein, leading to progressive neurodegeneration, synaptic dysfunction, and cerebral atrophy. Over time, this leads to brain shrinkage and cell death. Alzheimer's disease affects more than 6.9 million Americans over 65. More than seventy percent of these individuals are 75 years of age or older. Of the more than 55 million people who suffer from dementia worldwide, 60% to 70% are believed to have Alzheimer's disease according to data from 2020 (Pandey et al., 2025). One of the first symptoms of Alzheimer's disease is forgetting previous conversations or events. Alzheimer's disease eventually causes significant memory loss and makes it harder for a person to do daily tasks. Alzheimer's disease is incurable. In more extreme situations, the

loss of brain function may lead to infections, malnourishment, or dehydration. One consequence of these issues is death. However, medication can reduce symptoms or slow down cognitive decline. Programs and services can help people with the condition and those who care for them. Patients with Alzheimer's disease may also struggle to do daily chores that require them to follow a predetermined order of steps. They might struggle to plan and prepare a meal or play a favorite game. Simple tasks like getting dressed and taking a shower become impossible for those with Alzheimer's disease. Despite significant memory and skill loss, people with Alzheimer's disease may still be able to do specific tasks as their symptoms worsen. These are referred to as "preserved skills." Storytelling, singing, dancing, playing music, reading or listening to literature, sharing recollections, drawing, or crafts are a few examples. Preserved talents may last longer since they are governed by brain areas affected later in the disease. Many diseases can cause memory loss or other signs of dementia. Some of these illnesses can be treated. If are worried about memory or other cognitive abilities, healthcare professional. If and a medical professional can communicate (Scheltens et al., 2021). Sleep regulation has been identified as an important factor, with disturbances in sleep potentially accelerating the progression of Alzheimer's disease (AD). In addition, careful management of pharmacological treatment is essential, as certain antiepileptic medications may negatively affect cognitive function and exacerbate symptoms (Zhou et al., 2024).

Memory distortion

Trauma may worsen memory distortions or even completely erase memories. Some of these recollections could appear later. They discovered that individuals' brain activity revealed indications of separation. When someone feels cut off from their life's experiences and is unable to incorporate them into their identity or awareness, it's known as dissociation. Neuroimaging studies have identified dissociative patterns in trauma survivors, characterized by altered connectivity between prefrontal regulatory regions and limbic memory structures, with functional magnetic resonance imaging demonstrating measurable neural correlates of dissociative states that suggest potential biomarkers for identifying individuals with compartmentalized traumatic memories. Advancing age increases susceptibility to memory distortion through compromised source monitoring abilities and age-

related prefrontal cortex changes that reduce inhibitory control mechanisms, whilst memory interference serves both as a challenge to accurate recall and an adaptive mechanism facilitating memory updating and cognitive flexibility. False memories constitute a distinct phenomenon characterized by vivid, detailed recollections of events that never occurred, accompanied by high confidence in their authenticity, differing fundamentally from typical memory errors and resulting from source misattribution, retroactive interference, and constructive recall processes that incorporate plausible but inaccurate schema-based details. It is about remembering something we have never encountered, not about forgetting or confusing specifics of earlier experiences. False memories can be caused by a variety of factors, such as inaccurate information and incorrect attribution of the information's source. Erroneous or completely incorrect remembrance of an event might result from prior information and previous memories interfering with the construction of a new memory. Memory researcher Elizabeth Loftus has demonstrated through her groundbreaking studies that false memories can be implanted through suggestive techniques (Loftus, E. F. (2024)). Her research reveals that these artificially created memories often become more detailed and convincing over time, making them increasingly difficult to distinguish from genuine recollections. Loftus conducted influential experiments examining how language influences memory formation. In one notable study, participants viewed footage of a car collision and were subsequently questioned about their observations. The research team deliberately varied the wording of their questions - some participants were asked about cars that "contacted" each other, while others heard questions using the word "smashed." This subtle linguistic difference significantly altered participants' recollections of the event's severity. The timing of memory retrieval also plays a crucial role in accuracy, particularly regarding eyewitness testimony. When individuals are interviewed immediately following an incident, their memories remain relatively resistant to external influence and suggestion. However, as time passes between the original event and the interview, people become increasingly susceptible to incorporating misleading information into their recollections, potentially compromising the reliability of their testimony.

h. (American et al., 1997)

Hippocampus

The hippocampus collaborates extensively with various brain regions that depend on its memory processing functions. A key example is the connection between the hippocampus and amygdala, which creates the link between stored memories and emotional responses. As a component of the limbic system, the hippocampus maintains important connections with both the amygdala and hypothalamus, facilitating integrated brain function. The "fight or flight" reaction is one of the many body processes that these structures aid in controlling. Imagine first impression of a dog. When the dog sees, it licks hand and wags its tail. Together, the hippocampus and amygdala preserve that information in the brain, allowing o recall previous encounter and feel content and at ease the next time see a dog. Other emotions like fear and rage are also influenced by this similar link. Using the same scenario of first-time dog sightings, consider what would happen if the dog behaved violently against or a loved one. To warn to flee from possible danger, the hippocampus coordinates with other brain regions, particularly those in limbic system. In the skull, close to the ears and temples, lies the temporal lobe. The hippocampus has a seahorse-like appearance. It is composed of several overlapping cells and is around 5 centimeters in length. The hippocampal formation is a broader collection of components that includes the hippocampus. The hippocampus's structures cooperate to carry out memory and learning-related cognitive processes. Dentate gyrus: aids in decision-making and spatial memory processing. Ammon's horn or the appropriate hippocampal region: This area creates, organizes, and stores memories. (Reznikov et al., 1991)Ammon's horn (Hippocampus proper) is one of four areas that support the hippocampus's healthy operation.To support memory retrieval and communication with other brain regions, the hippocampus serves as a central hub, transmitting information as it enters and exits its neural circuits. Although relatively small in size, the hippocampus plays a critical role in both learning and memory formation, operating continuously to help individuals process, adapt to, and learn from their environment. Because of its constant activity and functional importance, the hippocampus is particularly vulnerable to damage from neurological disorders, underlying disease, or traumatic injury.

. Daily tasks become challenging when someone struggles to remember essential activities like completing their morning routine or taking prescribed medications. Simple safety measures, such as turning off appliances before leaving home or remembering directions while driving, may become difficult or impossible to maintain. These memory deficits create potentially dangerous situations for both the individual and others around them. Consequently, many people with hippocampal disorders require continuous supervision and support to ensure their safety and well-being. Family members and caregivers often experience considerable stress when providing this level of care. The emotional toll can be particularly heavy when caring for someone who may not recognize familiar faces or understand why they need help. Healthcare professionals can provide valuable resources and support for both patients with memory disorders and their caregivers. It's important to discuss these challenges openly with medical providers to access appropriate mental health services and care giving assistance (Gondi et al., 2010)

Conclusion

Learning, decision-making, identity, and daily functioning are all supported by memory, a sophisticated and vital cognitive function. The complex interactions between the brain, behavior, and environment become clear when one understands the several forms of memory, including sensory, short-term, and long-term memory, as well as the processes of encoding, storing, and retrieving memory. Recent developments in cognitive psychology and neuroscience have revealed memory to be an inherently plastic and reconstructive phenomenon, subject to modulation by contextual factors, emotional valence, attentional resources, and external influences during both acquisition and recall phases. Furthermore, memory research has applications in a wide range of fields, such as artificial intelligence, aging, mental health, and education. The significance of normal memory function and the necessity of ongoing study into preventative and therapeutic techniques are highlighted by conditions like amnesia, dementia, and PTSD. Recent technologies, particularly advanced neuroimaging modalities and brain-computer interface systems, continue to enhance our mechanistic understanding of memory formation, synaptic consolidation, and adaptive modification processes, offering promising avenues for future clinical applications and therapeutic developments.

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

References

- American Association for Research into Nervous and Mental Diseases, Johnson MK. Source monitoring and memory distortion. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*. 1997 Nov 29;352(1362):1733-45.
- Baddeley A. The concept of episodic memory. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*. 2001 Sep 29;356(1413):1345-50.
- Craik FI, Rose NS. Memory encoding and aging: A neurocognitive perspective. *Neuroscience & Biobehavioral Reviews*. 2012 Aug 1;36(7):1729-39.
- Gondi V, Tomé WA, Mehta MP. Why avoid the hippocampus? A comprehensive review. *Radiotherapy and Oncology*. 2010 Dec 1;97(3):370-6.
- Loftus, E. F. (2024). Memory, but Not Memory. *Proceedings of the American Philosophical Society*, 165(1), 26-31.
- Kim, S. G., Keum, M., Choe, Y. M., Suh, G.-H., Lee, B. C., Kim, H. S., Lee, J. H., Hwang, J., Yi, D., & Kim, J. W. (2025). Selenium and Episodic Memory: The Moderating Role of Apolipoprotein E ϵ 4. *Nutrients*, 17(3), 595. <https://doi.org/10.3390/nu17030595>
- King V, Elder Jr GH. The legacy of grandparenting: Childhood experiences with grandparents and current involvement with grandchildren. *Journal of Marriage and the Family*. 1997 Nov 1;848-59.
- Kirschner F, Paas F, Kirschner PA. A cognitive load approach to collaborative learning: United brains for complex tasks. *Educational psychology review*. 2009 Mar;21(1):31-42.
- Nelson CA, Carver LJ. The effects of stress and trauma on brain and memory: A view from developmental cognitive neuroscience. *Development and Psychopathology*. 1998 Dec;10(4):793-809.
- Newman EJ, Lindsay DS. False memories: What the hell are they for?. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*. 2009 Nov;23(8):1105-21.
- Pandey, N., Yang, Z., Cieza, B. *et al*. Plasma phospho-tau217 as a predictive biomarker for Alzheimer's disease in a large south American cohort. *Alz Res Therapy* 17, 1 (2025). <https://doi.org/10.1186/s13195-024-01655-w>
- Reznikov KY. Hippocampal Formation in the Mouse and Rat—Structural Organization and Development: A Review. *Cell Proliferation and Cytogenesis in the Mouse Hippocampus*. 1991:1-
- Scheltens P, De Strooper B, Kivipelto M, Holstege H, Chételat G, Teunissen CE, Cummings J, van der Flier WM. Alzheimer's disease. *The Lancet*. 2021 Apr 24;397(10284):1577-90.
- Zhou, X., Liu, Y., Wu, Z., Zhang, X., & Tao, H. (2024). Alzheimer's disease and epilepsy: Research hotspots for comorbidity in the era of global aging. *Epilepsy & Behavior*, 157, 109849.