Episodic Memory

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June 14, 2026

ARABPSYCHOLOGY.COM

RECOMMENDED CITATION

mohammad looti (2026). *Episodic Memory*. PSYCHOLOGICAL SCALES. Retrieved from https://scales.arabpsychology.com/?p=38259

Episodic memory is the memory of autobiographical events (times, places, associated emotions, and other contextual knowledge) that can be explicitly stated. Semantic and episodic memory together make up the category of declarative memory, which is one of the two major divisions in memory. The counterpart to declarative, or explicit memory, is procedural memory, or implicit memory.

Cognitive neuroscience

The formation of new episodic memories requires the medial temporal lobe, a structure that includes the hippocampus. Without the medial temporal lobe, one is able to form new procedural memories (such as playing the piano) but cannot remember the events during which they happened (See the hippocampus and memory).

The prefrontal cortex (and in particular the left hemisphere) is also involved in the formation of new episodic memories (also known as episodic encoding). Patients with damage to the prefrontal cortex can learn new information, but tend to do so in a disordered fashion. For example, they might show normal recognition of an object they had seen in the past, but fail to recollect when or where it had been viewed. Some researchers believe that the prefrontal cortex helps organize information for more efficient storage, drawing upon its role in executive function. Others believe that the prefrontal cortex underlies semantic strategies which enhance encoding, such as thinking about the meaning of the study material or rehearsing it in working memory.

The hippocampus's role in memory storage

Researchers do not agree about how long episodic memories are stored in the hippocampus. Some researchers believe that episodic memories always rely on the hippocampus. Others believe the hippocampus only stores episodic memories for a short time, after which the memories are consolidated to the neocortex. The latter view is strengthened by recent evidence that neurogenesis in the adult hippocampus may ease the removal of old memories and increase the efficiency of forming new memories.

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Relationship to semantic memory

Endel Tulving originally described episodic memory as a record of a person's experience that held temporally dated information and spatio-temporal relations. A feature of episodic memory that Tulving later elaborates on is that it allows an agent to travel back in time. A current situation may cue retrieval of a previous episode, so that context that colors the previous episode is experienced at the immediate moment. The agent is provided with a means of associating previous feelings with current situations. Semantic memory,on the other end, is a structured record of facts, concepts and skills that we have acquired. Semantic information is derived from accumulated episodic memory. Episodic memory can be thought of as a "map" that ties together items in semantic memory. For example, all encounters with how a "dog" looks and sounds like will make up the semantic representation of that word. All episodic memories concerning your dog will then reference this single semantic representation of "dog" and, likewise, all new experiences with your dog will modify your single semantic representation of your dog.

Together, semantic and episodic memory make up our declarative memory. They each represent different parts of context to form a complete picture. As such, something that affects episodic memory can also affect semantic memory. For example, anterograde amnesia, from damage of the medial temporal lobe, is an impairment of declarative memory that affects both episodic and semantic memory operations. Originally, Tulving proposed that episodic and semantic memory were separate systems that competed with each other in retrieval. However, this theory was rejected when Howard and Kahana completed experiments on latent semantic analysis (LSA) that supported the opposite. Instead of an increase in semantic similarity when there was a decrease in the strength of temporal associations, the two worked together so semantic cues on retrieval were strongest when episodic cues were strong as well.

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Age differences

Activation of specific brain areas (mostly the hippocampus) seems to be different between younger and older people upon episodic memory retrieval. Older people tend to activate both left and right hippocampus, while younger people activate only the left one. For more information, see aging and memory.

Relationship to emotion

The relationship between emotion and memory is complex, but generally, emotion tends to increase the likelihood that an event will be remembered later and that it will be remembered vividly. Flashbulb memory is one example of this.

Pharmacological enhancement

In healthy adults, longterm visual episodic memory can be enhanced specifically through administration of the Acetylcholine esterase inhibitor Donepezil, whereas verbal episodic memory can be improved in persons with the val/val genotype of the val158met polymorphism through administration of the CNS penetrant specific catecholamine-O-methyltransferase inhibitor Tolcapone. Furthermore, episodic memory is enhanced through AZD3480 a selective agonist at the neuronal alpha4beta2 nicotinic receptor, which is developed by the company Targacept.

Currently, there are several other products developed by several companies--including new catecholamine-O-methyltransferase inhibitors with fewer side effects--that aim for improving episodic memory. A recent placebo controlled study found that DHEA, which is a functional cortisol antagonist, improves episodic memory in healthy young men (Alhaj et al. 2006).

Damage

Based on a review of behavioral studies, it is suggested that there may be selective damage to the limbic-prefrontal episodic memory system in some people with autism. Another study points to evidence of autistic deficits in the episodic or self-conscious memory of personally experienced events (Joseph et al., 2003).
The label "amnesia" is most often given to patients with deficits in episodic memory.
Alzheimer's disease tends to damage the hippocampus before other brain areas. This means that AD patients are often classed as amnesiacs.
A rare type of shellfish poisoning called amnesic shellfish poisoning or "ASP" quite effectively and irreversibly damages the hippocampus, rendering one amnesic.
Korsakoff's syndrome is caused by thiamine (vitamin B1) deficiency, a form of malnutrition which can be precipitated by overconsumption of alcoholic beverages compared to other foods.
An acute cortisol level (by injection) has been found to significantly inhibit the recall of autobiographical memories which may contribute to memory deficits found in depression.
The use of some illicit drugs such as MDMA ("Ecstasy") has been associated with persistent deficits in episodic memory.

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In animals

In 1997, there was little evidence for episodic memory outside of humans. This is probably due to the difficulty in testing for it in animals. To meet the criteria of episodic memory, as espoused by Tulving (1983), evidence of conscious recollection must be provided. But demonstrating episodic memory in the absence of language, and therefore in non-human animals, is impossible because there are no agreed non-linguistic behavioral indicators of conscious experience (Griffiths et al., 1999).

Clayton & Dickinson (1998) were the first to provide evidence that animals may possess episodic memory. They demonstrated that Western scrub-jays (Aphelocoma californica) remember where they cached different food types and discriminately recovered them, depending on the perishability of the item and the amount of time that elapsed since caching. Thus, scrub-jays appear to remember the "what-where-and-when" of specific caching events in the past. Clayton & Dickinson (1998) argued that such performance met the behavioral criteria for episodic memory. However, because the study did not address the phenomenological aspects of episodic memory, the authors referred to this ability as "episodic-like" memory.

According to a study done by the University of Edinburgh in 2006, hummingbirds are the first animal to demonstrate two aspects of episodic memory--the ability to recall where certain flowers were located and how recently they were visited. Scientists tracked how often hummingbirds visited eight artificial flowers filled with a sucrose solution in the birds' feeding grounds. They refilled half the flowers at 10 minute intervals and the other half 20 minutes after they had been emptied. The birds' return to the flowers matched the refill schedules: flowers refilled at 10-minute intervals were visited sooner. "To our knowledge, this is the first demonstration that animals in the wild can remember both the locations of food sources and when they visited them," said Susan Healy, of the University of Edinburgh.

Other studies have demonstrated this episodic-like memory in other animal species, which have brains more similar to humans. For example, Kart-Teke and colleagues have demonstrated rats' preference for items it sees which is dependent on what it saw, where it saw it and when it saw it (Kart-Teke et al., 2006). In addition, studies by Eacott and colleagues (Eacott et al., 2005) have shown rats can recall (remember without any cueing influences) what they saw and where depending on which past situation they are being asked to remember.

Nonetheless, some scholars remain cautious about comparisons to human episodic memory (Suddendorf & Busby, 2003). Purported episodic-like memory often seems fixed to a particular domain or could be explained in terms of procedural or semantic memory. The problem may be better tractable by studying episodic memory's adaptive counterpart: the capacity to flexibly imagine future events. Suddendorf (2006) argues that the emergence of the human capacity to travel mentally to past and future events may have been a prime mover in hominin evolution.

A recent experiment addressed one of Suddendorf and Busby (2003)'s specific criticisms (the Bischof-Köhler hypothesis, which states that nonhuman animals can only take actions based on immediate needs, as opposed to future needs). Correia and colleagues demonstrated that Western scrub-jays can selectively cache different types of foods depending on which type of food they will desire at a future time, offering strong evidence against the Bischof-Köhler hypothesis by demonstrating that scrub-jays can flexibly adjust their behavior based on past experience of desiring a particular food.

Autobiographical memory

An autobiographical memory is a personal representation of general or specific events and personal facts. Autobiographical memory also refers to memory of a person's history. An individual does not remember exactly everything that has happened in one's past. Memory is constructive, where previous experience affects how we remember events and what we end up recalling from memory. Autobiographical memory is constructive and reconstructed as an evolving process of past history. A person's autobiographical memory is fairly reliable; although, the reliability of

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autobiographical memories is questionable because of memory distortions.

Autobiographical memories can differ for special periods of life. People recall few personal events from the first years of their lives. The loss of these first events is called childhood or infantile amnesia. People tend to recall many personal events from adolescence and early adulthood. This effect is called the reminiscence bump. Finally, people recall many personal events from the last few years. This is called the recency effect. For adolescents and young adults the reminiscence bump and the recency effect coincide.

It is known that autobiographical memories initially are stored as episodic memories, but it is currently unknown if autobiographical memories are the same as episodic memories or if the autobiographical memories become converted to semantic memories with time.

Types

When you first stepped foot in the ocean.

What it feels like stepping into the ocean in general. This is a memory of what a personal event is generally like. It might be based on the memories of having stepped in the ocean, many times during the years.

Who was the Prime Minister of Italy when I was born?

Flashbulb memories are critical autobiographical memories about a major event. Some flashbulb memories are shared within a social group:

"The assassination of John Kennedy?
"The assassination of Martin Luther King, Jr.?
"The Challenger explosion?
"The verdict in the O.J. Simpson trial?
When you learned that Princess Diana had died?
When you heard about 9/11?

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Neural network models

Episodic memories can be stored in autoassociative neural networks (e.g.,a Hopfield network) if the stored representation includes information on the spatiotemporal context in which an item was studied.

Autoassociative memory

Autoassociative memory, also known as auto-association memory or an autoassociation network, is often misunderstood to be only a form of backpropagation or other neural networks. It is actually a more generic term that refers to all memories that enable one to retrieve a piece of data from only a tiny sample of itself.

Traditional memory stores data at a unique address and can recall the data upon presentation of the complete unique address. Autoassociative memories are capable of retrieving a piece of data upon presentation of only partial information from that piece of data. Heteroassociative memories, on the other hand, can recall an associated piece of datum from one category upon presentation of data from another category. Hopfield networks have been shown to act as autoassociative memory since they are capable of remembering data by observing a portion of that data. Biological neural networks, on the other hand, are heteroassociative memories since they can remember a completely different item to the one presented as input. Bidirectional Associative Memories (BAM) are Artificial Neural Networks that have long been used for performing heteroassociative recall.

For example, the fragments presented below should be all that's necessary to retrieve the appropriate memory:

"A day that will live in ______"
"To be or not to be"
"I came, I saw, I conquered"

The first example will make the reader fill in the blank with the word "infamy", while making him or her think of Franklin D. Roosevelt. The second example is only a tiny phrase from William Shakespeare's Hamlet, yet readers will be able to associate it with the play. And finally, most people will be quick to translate Caesar's quote over to "Veni, Vidi, Vici". The conclusion to be drawn is that Autoassociation networks can recreate the whole from merely its small parts.

Hopfield network

A Hopfield network is a form of recurrent artificial neural network invented by John Hopfield. Hopfield nets serve as content-addressable memory systems with binary threshold units. They are guaranteed to converge to a local minimum, but convergence to one of the stored patterns is not guaranteed. Furthermore, it is through a Hopfield network that human memory can be further understood.

Human memory

The Hopfield model accounts for associative memory, through the incorporation of memory vectors. Memory vectors can be slightly used, and this would spark the retrieval of the most similar

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vector in the network. However, we will find out that due to this process, intrusions can occur. In associative memory for the Hopfield network, there are two types of operations: auto-association and hetero-association. The first being when a vector is associated with itself, and the latter being when two different vectors are associated in storage. Furthermore, both types of operations are possible to store within a single memory matrix, but only if that given representation matrix is not one or the other of the operations, but rather the combination (auto-associative and hetero-associative) of the two. It is important to note that Hopfield's network model utilizes the same learning rule as Hebb's (1949) learning rule, which basically tried to show that learning occurs as a result of the strengthening of the weights by when activity is occurring.

Rizzuto and Kahana (2001) were able to show that the neural network model can account for repetition on recall accuracy by incorporating a probabilistic-learning algorithm. During the retrieval process, no learning occurs. As a result, the weights of the network remains fixed, showing that the model is able to switch from a learning stage to a recall stage. By adding contextual drift we are able to show the rapid forgetting that occurs in a Hopfield model during a cued-recall task. The entire network contributes to the change in the activation of any single node.

The Network capacity of the Hopfield network model is determine by neuron amounts and connections within a given network. Therefore, the number of memories that are able to be stored are dependent on neurons and connections. Furthermore, it was shown that the recall accuracy between vectors and nodes was .138 (approximately 138 vectors can be recalled from storage for every 1000 nodes) (Hertz et al., 1991). Therefore, it is evident that many mistakes will occur if you try to store a large number of vectors. When the Hopfield model does not recall the right pattern, it is possible that an intrusion has took place, since semantically related items tend to confuse the individual, and recollection of the wrong pattern occurs. Therefore, the Hopfield network model is shown to confuse one stored item with that of another upon retrieval. But this can be improved before applying the dynamical rule (which is explained in the next paragraph) and adding some noise to the activations.

McCullough and Pitts (1943), dynamical rule, which describes the behavior of neurons, does so in a way that shows how the activations of multiple neurons map onto the activation of a new neuron's firing rate, and how the weights of the neurons strengthen the synaptic connections between the new activated neuron (and those that activated it). Hopfield would use McCullough and Pitts, dynamical rule, in order to show how retrieval is possible in the Hopfield network. However, it is important to note that Hopfield would do so in a repetitious fashion. Hopfield would use a nonlinear activation function, instead of using a linear function. This would therefore create the Hopfield dynamical rule and with this, Hopfield was able to show that with the nonlinear activation function, the dynamical rule will always modify the values of the state vector in the direction of one of the stored patterns.

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Running

At each step, pick a node at random. The node's behavior is then deterministic: it moves to a state to minimize the energy of itself and its neighbors. (In contrast, the Boltzmann machine has a stochastic update rule.)

Training

Training a Hopfield net involves lowering the energy of states that the net should "remember". This allows the net to serve as a content addressable memory system, that is to say, the network will converge to a "remembered" state if it is given only part of the state. The net can be used to recover from a distorted input the trained state that is most similar to that input. This is called associative memory because it recovers memories on the basis of similarity. For example, if we train a Hopfield net with five units so that the state (1, 0, 1, 0, 1) is an energy minimum, and we give the network the state (1, 0, 0, 0, 1) it will converge to (1, 0, 1, 0, 1). Thus, the network is properly trained when the energy of states which the network should remember are local minima.

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