From Recollection to Simulation: Exploring the Constructive and Distributed Nature of Memory for Future-Oriented Thinking

Islam Hani

Abstract

Memory is far more than just storing or recalling the past; it is fundamentally future-oriented. This research illuminates this forward-thinking aspect of memory by closely investigating two key aspects of the human memory system. Firstly, memory storage is spread rather than centralised, which means that each piece of information is divided into activity patterns and distributed across the brain. Secondly memory is not fixed, but rather constructed; rather than a literal recall of the past, the brain reconstructs the experience using prior beliefs and experiences. These characteristics make the brain vulnerable to a variety of errors, including source memory failure (falsely assigning the source of a specific memory) and gist-based distortions (failure to recall separate item-specific information). This paper argues that the error-prone nature of memory is not an undesirable consequence of a defective human brain, but rather a basic element of the human memory system that enables it to plan for the future. Drawing on the Constructive Episodic Simulation Hypothesis and supporting functional MRI (fMRI) and positron emission tomography (PET) data, the paper explains how memory's distributed and constructed nature allows us to "pre-experience" the future. Memory is naturally future-oriented, molded in a way that permits us to intentionally design our future cognitive landscape.

The Spread Nature of Memory

Memories stored in the hippocampus are not accumulated from the ground up. Instead, when a memory enters the hippocampus, it is decomposed into fragments and distributed across [1][2]. This process is more formally referred to as memory consolidation, involving multiple stages. The first stage includes the strengthening of synapses, or connections, among neurons in the hippocampus. As these connections become stronger and more enhanced, memories are stored gradually as patterns of activity between neurons. Eventually, the hippocampus slowly transfers memory to various brain areas, including the neocortex, for long-term memories [1]. For better understanding, refer to Figure 1, which illustrates how newly formed memories are fragmented into smaller patterns, dispersed across the brain, and reinforce their connections at the synapse.

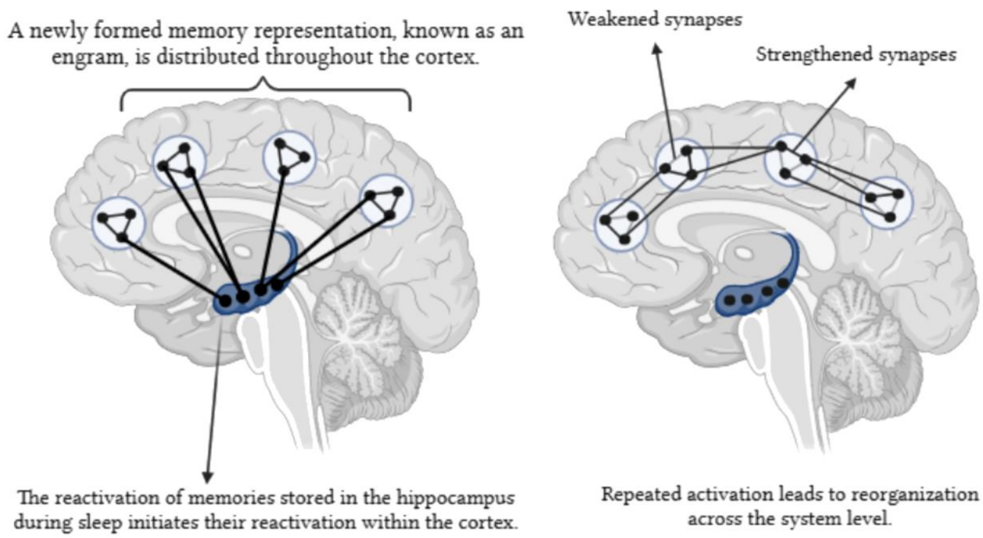

Figure 1. Stages of Memory Consolidation: Memory is represented as patterns of neural activity, stored in a distributed manner throughout the brain, and later reassembled through neural signaling [3].

In fact, numerous psychologists and neuroscientists have provided strong theoretical foundations for comprehending the distributed nature of memory. For example, Howard Eichenbaum introduced the idea of a “memory trace,” suggesting that memories are encoded as distributed patterns of neural activity spread across various neurons and synapses in the brain. An early expert in memory research, Donald Hebb, noted that partial activation of a specific memory within the distributed neural network triggers the activation of the whole network, facilitating the completion of neural patterns, and he also popularized the expression “*Neurons that fire together, Wire together*” [5]. Several decades later, Lynn Nadel proposed the concept of "multiple trace theory," which posits that each retrieval of a memory leads to the formation of a new memory trace in the brain [1]. This memory trace connects the various fragments of memories, suggesting that different types of memories could be stored in distinct areas of the brain and that memories may be processed and retrieved simultaneously through multiple neural pathways.

The Difficulties Arising from the Distributed Characteristics of Memory

The fragmented nature of memory demands considerable effort from the brain to piece together a past event. That is due to the fact that memory is distributed through the brain, a variety of distinct features that constitute an episode need to be tied together [6]. In the simplest terms, the process can be described in the following way. Initially, various areas and neural networks in our brain that are associated with a particular past experience work together. Next, the brain combines information from several sensory channels, such as visual, auditory, and emotional data, to create a unified memory. For instance, when recalling an event like our birthday celebration, our brain synthesizes information from different inputs, including the people we interacted with, the food we enjoyed, and the feelings we felt. This process demands a considerable amount of cognitive resources, which include attention, working memory, and other executive functions. [7][8]. These tasks are really bothersome; it wouldn't have been necessary to combine parts of a previous memory if it had been stored collectively instead of dispersedly.

Another difficulty arises after the binding phase. These episodes must be kept distinct from each other via the memory system [9]. Since the brain must distinguish between identical experiences and produce unique, non-overlapping representations of each experience in the memory system, this may actually be a more difficult task than the previous one. In addition to requiring a significant amount of cognitive resources, pattern separation can be especially difficult when memories are highly similar or when there is a high level of interference between them [10].

These "gist-based distortions," which have been observed since Bartlett [2][11], occur when episodes overlap too much but are not encoded with intervals, causing us to recall overlapping details but fail to recall distinctive item-specific information. In the first task, failure to link constituent elements of an episode leads to a problem commonly referred to as "source memory failure," which leads to falsely attributing the source of a particular memory or even failing to remember when or how that particular memory was acquired [9].

Daniel Schacter categorizes the many mistakes, delusions, and distortions of memory into the following seven "sins" in his book "The Seven Sins of Memory: How the Mind Forgets and Remembers": transience, absent-mindedness, blocking, misattribution, suggestibility, bias, and persistence [11]. Our everyday lives are influenced by these sins, which range from forgetting to misinterpreting reality. We end up with a lot of mistakes since memory is saved in a disorganized manner. To reiterate, people with deficient brains are not the only ones who make these mistakes [9] [10] [13]. They are the results of a system that requires every episode to be unpacked in order to be repackaged for a later use. All of this would appear to be a mystery. Why hasn't the human brain changed to record the past more accurately? Why risk all these mistakes by implementing such an ineffective system?

This problem is resolved by the constructive episodic simulation hypothesis. Memory wouldn't be constructed this way if its only purpose was to precisely record the past. Because our memory system must perform an adaptive role, it is built as such, fully recognizing the possibility of error [14][15]. Though we may consider memory to be a simple storage function, memory has another, possibly more significant function: it plays a crucial role in our ability to make decisions both now and in the future. This distributed aspect of memory is necessary for our future-focused actions because without previous experiences being encoded in fragments and dispersed throughout the brain, we would not be able to effectively piece them together when making decisions for the future. In other words, our memory assumes the risk of making mistakes in order to function in the future, which is why it is possible to say that memory is made with the future in mind.

The Constructive Episodic Simulation Hypothesis

Bartlett and others have repeatedly emphasized that memory is a constructive process. Bartlett contended that memory is shaped by an individual's existing knowledge, beliefs, and expectations, and that these elements are utilized to bridge memory gaps, forming a coherent narrative or story [2][11]. For instance, in one of his well-known experiments, Bartlett instructed participants to read a Native American folk story and subsequently remember it multiple times across a span of weeks or months. He found that over time, the participants' recollection of the story became altered; they adjusted to it.

Previous knowledge and societal anticipations. Specifically, participants often neglected or misrepresented information that did not align with their current cultural framework. Additionally, the renowned “War of the Ghosts” experiment demonstrated that memory is not simply an accurate account of events, but rather that we exert “effort after meaning.” Memory is influenced by a person's past experiences, present beliefs, and future anticipations, with these frameworks being utilized to construct a narrative. Instead of a direct recollection of the past, memory relies on these previous beliefs and experiences to recreate the event [16]. Tulving is yet another influential academic who highlighted the constructed aspect of episodic memory. Tulving states that when we remember past events, we don't merely pull out archived details about the occurrence; instead, we actively fill in the blanks using our own knowledge, expectations, and beliefs [6]. Bartlett and Tulving’s research during the 1960s and 70s has been profoundly influential, and numerous researchers exploring memory have expanded upon their framework to investigate the diverse methods through which memory is formed [14][15].

Although the idea that our memory is constructive is broadly acknowledged in the literature, there has been much debate over the reason for it. The Constructive Episodic Simulation Hypothesis represents one effort to offer an explanation. It is a theory regarding the "origins" of episodic memory, seeking to clarify why memory is formed in this way [15][17][18]. The hypothesis suggests that our memory is organized in a constructive manner for future use. Although many view memory mainly as a repository of the past, the hypothesis posits that it serves an essential future-focused role. As Schacter and Addis state, “a crucial role of a constructive episodic memory is to enable individuals to visualize or envision future episodes, events, and scenarios” [13]. Memory is fundamentally focused on the future, and this focus necessitates that memory be creative.

This indicates that the brain skillfully retrieves and reassembles components of past experiences for future forecasting. This occurs via the difficult two-step procedure of binding and separating mentioned earlier. As stated before, the brain manages various neural networks, integrates specific components to create a unified experience, and maintains the elements distinct for future cognitive activities. As the future is not a direct repetition of the past, it is essential to flexibly employ memories from earlier experiences for future forecasting. To put it differently, this entire process enables us to mimic, envision, or 'rehearse' situations that have never taken place in the precise manner we envision them [18].

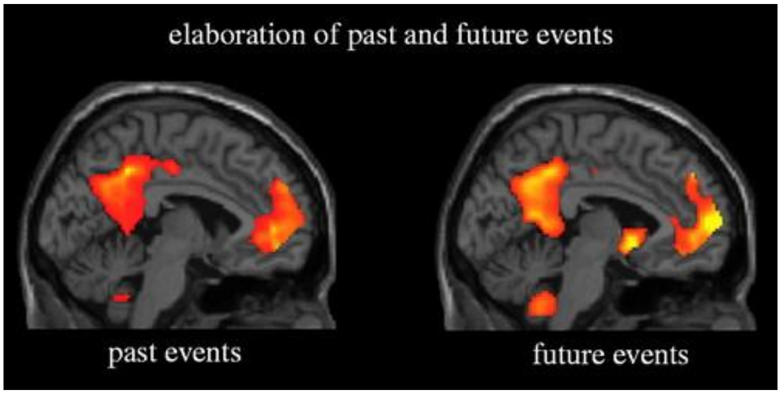

Figure 2. Comparable neural regions are activated when recalling past events and imagining future ones [12].

Researchers have characterized this constructive process with the idea of 'gist.' Gist, or semantic grouping, is a technique employed by the brain to efficiently organize all memory fragments. In reality, memory is not dispersed in an entirely random manner, but instead in a structured format. groups made up of comparable sets of 'gist' or significance [11][17]. The brain flexibly takes components from each 'gist' cluster and reassembles them to envision a future. Returning to the birthday party example, to recall the event, our brain must combine pieces from various gist groups that each symbolize the individuals we interacted with, the location of the party, the food consumed, and the feelings we felt. Conversely, to simulate or 'pre-experience' the upcoming birthday celebration, we utilize the same gist groups but employ different kernels from the group. State that the celebration occurred at a swimming pool last year. The upcoming birthday celebration could occur in a public park or at home, in a location different from the swimming pool used last year.

The Constructive Episodic Simulation Hypothesis is being supported by an increasing amount of research. Numerous brain areas engaged in episodic memory retrieval also show activity during future thinking and imagination (refer to Figure 1) [17]. To put it differently, the cognitive processes used to recall past experiences are also employed to envision and recreate future scenarios. This typical area is frequently called the Default Mode Network [17][18]. The specific area of the brain, known as the Default Mode Network, encompasses the medial temporal lobe, which includes the hippocampus, anterior cingulate cortex, medial prefrontal cortex, posterior cingulate cortex, and inferior parietal cortex (refer to Figure 3). Functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) have detected similarities in brain activity within default network areas during the recollection of past events and the visualization of future events [17]. The default network is precisely the area that performs the difficult two-step task of combining and dividing.

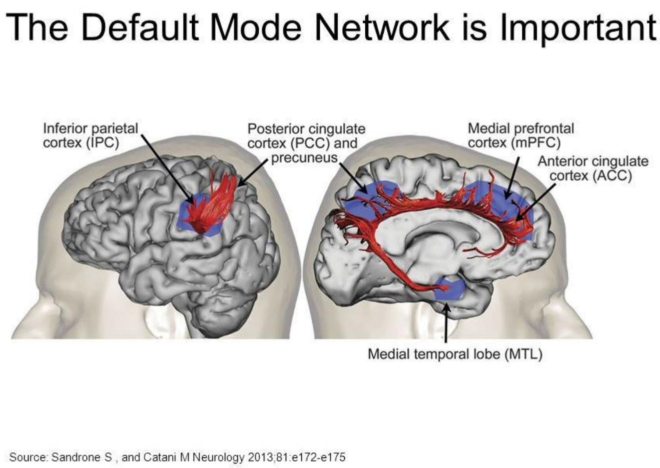

Figure 4 the Default Mode Network (DMN) key regions [20]

Adaptive Forgetting

Certainly, the Constructive Episodic Memory Hypothesis is merely a proposed idea. Although numerous researchers, including Schacter, Addis, Watson, and McDermott, have provided evidence supporting this perspective, the hypothesis is not universally accepted by the whole community. Additional work is required for the hypothesis to gain acceptance. Nonetheless, this theory isn’t the sole evidence of a future-oriented mindset [19]. In this paper, I highlight one specific area: research on adaptive forgetting.

Because the brain has a finite storage capacity, it needs to effectively handle memory retention. For instance, think about Ebbinghaus's pioneering research on the forgetting curve (represented in figure 4), in which subjects were required to learn meaningless syllables. As time passed, their capability to remember the syllables declined unless they were reviewed often, highlighting the brain's inclination to favor commonly used information while eliminating less significant details. Conversely, essential abilities such as identifying faces or understanding language, which we utilize every day, stay firmly rooted. This occurrence is referred to as adaptive forgetting [19]. Nonetheless, it is much more complicated than merely forgetting trivial details while remembering crucial information. Adaptive forgetting is a mental process in which the brain keeps memories from past experiences that might be helpful later while eliminating those considered unnecessary. Information is deemed valuable when it is regularly utilized in everyday activities or aids in predicting upcoming occurrences [16]. In contrast, memories that are older and less used are frequently seen as unimportant and slowly diminish. However, when a past memory is crucial for forecasting or grasping upcoming situations, the brain is capable of retrieving and rearranging it efficiently.

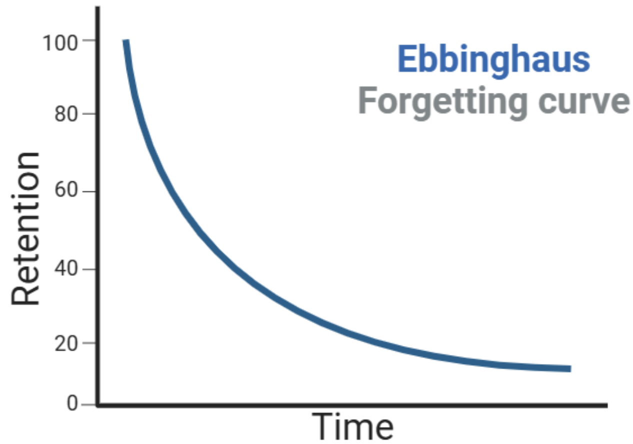

Figure 3: Ebbinghaus Forgetting Curve This figure illustrates the Ebbinghaus Forgetting Curve, which shows how memory retention declines over time. It demonstrates that we forget information rapidly within the first few hours after learning, with the rate of forgetting slowing down as time passes, highlighting the importance of repetition for long-term retention. [21]

Research on adaptive forgetting indicates that the constructive episodic memory hypothesis is not the sole evidence supporting the main argument of the paper, which asserts that memory is created with future considerations. Although further efforts are needed, several additional studies are indicating this trend.

Conclusion and Future Directions

This study investigates the complexities of memory's future-oriented aspects, showing that memories are broken up and spread throughout the brain via a detailed consolidation process. It underscores the difficulties presented by this fragmented memory system, such as the requirement to connect various aspects of an experience and preserve distinctiveness among memories. An important theoretical advancement in the field is the "Constructive Episodic Simulation Hypothesis," which proposes that memory is not just a record of past events but plays a vital role in future planning. This hypothesis suggests that memory is formed in a way that enables individuals to envision or anticipate future events, influencing choices and adaptive actions.

In the future, research ought to keep exploring and confirming the Constructive Episodic Simulation Hypothesis. This could include broader neuroimaging research, experimental interventions in memory retrieval and future contemplation, as well as creating computational models to replicate memory and future-focused thought processes. This research is significant not only for the field of cognitive neuroscience but also has potential uses in associated fields. For example, interdisciplinary uses of memory research could improve educational methods, guide marketing and consumer behavior analysis, affect public policy choices, and even invoke economic consequences. Moreover, comprehending the function of memory in decision-making might have clinical implications, especially concerning memory-related conditions such as amnesia and dementia, potentially resulting in treatment strategies that utilize memory's capabilities.

Memory is not merely a repository of the past but a flexible, dynamic system tailored for the future. Its distributed and constructive characteristics may introduce errors, but these “flaws” are essential for creativity, adaptability, and foresight. As we deepen our understanding of memory through advances in neuroscience, we gain valuable insights into how the brain envisions and shapes our cognitive future.

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