

Mirror networks and memory recall

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Abstract

This article investigates the computational problem of storage and recall of memories from the perspective of the mind-memory complex together with mirror structures. Two kinds of mirror structures are reviewed: those in neural networks and others between them and methylation processes in DNA, which sets up a complementary relationship with the information stored in brain circuits. A processing framework is provided in which the mind operates as a window on reality, with separate mirroring circuits for storage and recall. This existence of reflection opens the possibility of recursion, which is a fundamental characteristic of awareness.

Keywords: Neural networks; memory storage and recall; DNA memory storage; complementarity; consciousness

1. Introduction

We know ourselves by our memory and changes in it create the experience of time. Much remembrance is of things we have witnessed with our own senses, and some are created from the stories we hear and images we see. Time and consciousness go together; AI has memories without the depth of time, which is why it is not conscious. Memories come with a sense of ownership rooted in time which is a significant element of our sense of being conscious. The time coding of main memories located at specific centers in the brain has a space-coded component (Kandel, 2001). To consider memory in a general complementarity view, which includes time information or some relationship to it, it is important to have a local reference participating in the retrieval process. Normally, memory formation in the brain is viewed as being an outcome of the Hebbian mechanism, but at the most general level, this process sets up corresponding gene expression mechanisms, so that there is a relationship between brain memories and methylation processes in DNA (Burton & Greer, 2022; Dennis & Garcia, 2022). Enzymatic modifications within the nerve cells by methylation or demethylation (Griffith & Mahler, 1969) reside in patterns of chemical tags on DNA and on the histones that package it. Due to the role of epigenetic mechanisms in Hebbian learning, these two must be examined together and they can be viewed as complementary aspects of the memory formation process (Guzman-Karlsson et al., 2014; Kennedy & Sweatt, 2016; Levenson & Sweatt, 2005).

Epigenetic modifications direct the way DNA is packaged into the nucleus, making genes accessible to transcriptional machinery in a manner that influences genomic stability (Moore et al., 2013). Environmental factors in general and memories in particular have the potential to alter the epigenome, allowing genes that are silenced to be activated and vice versa that emphasizes the complementary view of information storage process (Reik, 2007). It is noteworthy that there is a relationship between cellular and epigenetic process even in aging (Lu et al., 2026).

Most explicit memory resides in the resonances within the neural networks of the brain. This is a huge capacity as the number of the associated neurons is about 86×10^9 (Azevedo et al., 2009). The self makes it possible to bind fragments from different locations to create impressions that inform the mind. The complementarity between the bottom-up aspect of memory recall and the top-down aspect facilitated by the self is an important issue that needs further elaboration.

The genetic memory store is sufficiently stable to permit the information encoded within DNA to persist during an individual lifetime and through successive generations, while retaining sufficient plasticity to allow mutations and the encoding of new genes. The information in messenger RNAs is translated as amino acid sequences (proteins) which gives expression to the corresponding phenotype. Both the cell and the individual may be seen as responding to the signals by expressing the recalled information in an adaptive manner.

The transmission of linguistic information between humans, both orally and in written form, is an addition to the direct transmission from generation to generation through heredity. In recent times, to this has been enhanced by the recordings on computers and direct access via the internet. The human brain literally mirrors the experience of the outer and the inner world. Mirror neurons were first described as a class of premotor cells discharging during both action execution and observation (Di Pellegrino et al., 1992). Recent studies in several species reveal that a variety of cell types distributed among multiple motor, sensory, and emotional brain areas form a “mirror mechanism” which has an evolutionarily conserved role in social interaction. This mechanism shows how recursion (via reflection) is fundamental, and this provides insight into the actions of others (Rizzolatti & Sinigaglia, 2016). We note this prior research from a motivational perspective and consider the mirroring mechanism in a more general and abstract setting as it is a requirement for cognitive processes that involve reflection or self-referral. This paper reviews several issues related to memory storage both in neural networks and the complementary DNA methylation processes. A processing framework is provided in which the mind operates as a window on reality, with separate representation circuits for storage and recall. This mechanism is fundamentally recursive and its ability to provide context is a component of the time element associated with stored memories.

2. Mind as mirror

The neural networks that are interposed between the raw sensory data and the mind-memory complex are emulated within brain structures and they form the ground on which the mind processes are performed. They are also where the mind’s internal dialogue takes place. The formation of a memory begins when attention is paid to an experience. Sub-populations of neurons are active across the brain, and on a cellular level, this activity leads to high levels of intracellular calcium inside these neurons. Calcium drives a host of down-stream signaling via calcium-dependent proteins in neurons and this signaling drives short-term biochemical plasticity as well as long-term structural plasticity. This increase in neuronal activity elicits transcription of plasticity-related genes, including a class of genes termed immediate early genes (IEGs) whose transcriptional activity is necessary for learning. It has been demonstrated that a critical feature of learning is the gene signaling changes that drive long-term synaptic plasticity in neurons (Rule et al., 2019). Notably, not all neuronal activity leads to expression of IEGs, and there is a relationship between a neuron’s electrical activity and IEG expression. For example, brief neuronal activation leads to expression of a smaller set of activity-regulated genes compared with sustained neuronal activation.

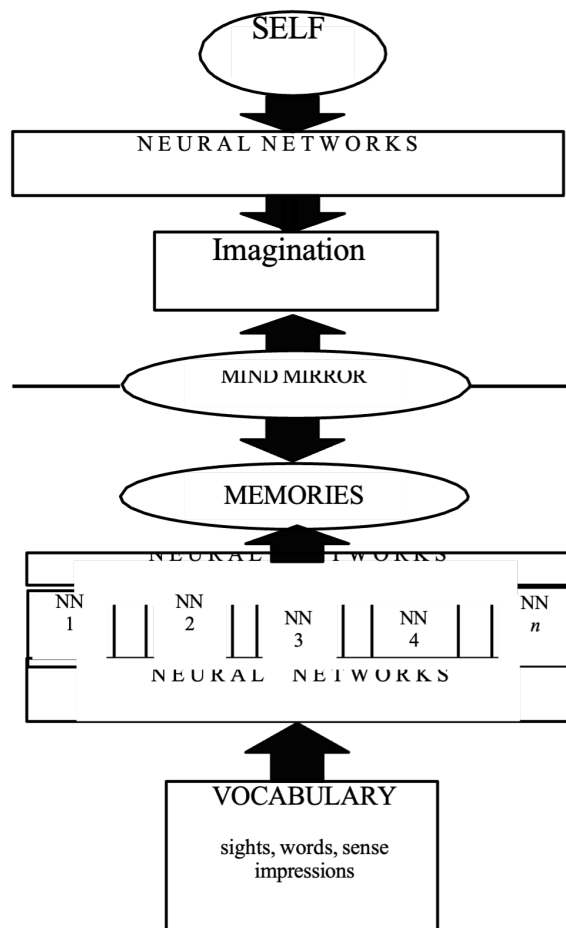


Figure 1 Model of mind as mirror.

Mirror neurons may be assumed to play a role in the ontogenetic development of sensorimotor mapping of otherness onto self. We propose that corresponding to the neural networks that process sensory information are representational networks that recreate sensory information in a code matched to the node called SELF where conscious thoughts are registered (Fig. 1). The mind by itself is an instrument and it requires the self for the contents in its various circuits to be recognized as conscious. But without this happening the mind can only autonomously respond to the incoming sensory signals.

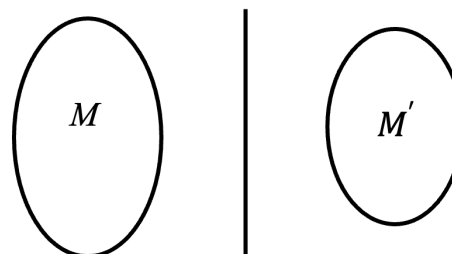


Figure 2 Impression M imaged as M'

The reflection mechanism (Fig. 2) is an emulator E that maps impressions M into M' in the neurons, and fundamentally this mechanism is recursive.

$$M' = E(M) \quad (1)$$

As mentioned in the Introduction there exists a further reflection mechanism that is mapped in the genetic code using methylation. Experiments have identified neurons that become active during learning, reactivate during recall, and can sometimes be artificially stimulated to evoke a remembered experience. This indicates that memories are encoded in specific neural ensembles rather than individual neurons. Different types of memory rely on different brain structures. In addition, astrocytes that make up most cells in the human central nervous system play an extensive adaptive role in function that appears to include epigenetic modifications (Morales Pantoja & Mintz, 2025; Vasile et al., 2017; Vasile & Rouach, 2023).

The memory storage system works through processes of encoding, consolidation, storage, and retrieval. In encoding, information is first processed in sensory areas and the hippocampus acts as an “index” or temporary binder, whereas in consolidation that takes place over time that can range from hours to much longer periods, memories are gradually transferred and stored more permanently in the neocortex, and the hippocampus becomes less critical for retrieving very old memories.

Memories are represented as strengthened synaptic connections across distributed networks rather than in single memory cells. In retrieval, there is reactivation of the same network that encoded the memory. However, it is also possible to associate memories with single cells where the initial activity recruits neighboring neurons, making it possible for single or group of neurons to become associated with vector memories. Thus, fragments that generate stored memories could be linked with single neurons through local spreading activity (Kak, 2009). Memories are reconstructed each time they are recalled, which is why they can change or become inaccurate over time. Engrams, as memory fragments, are not static sets of cells (Zaki & Cai, 2025). During consolidation, neurons can drop out or new ones can join the engram. This helps transition from unselective and broad activation to more selective, precise memory representations (Josselyn & Tonegawa, 2020). Inhibitory plasticity (e.g., involving certain inter-neurons) plays a key role in refining engram selectivity. The interaction mechanisms amongst large number of cells may be also seen through the context of e-dimensionality based optimization that considers optimum structures for information representation (Kak, 2026).

3. Memory and information complementarity

Consider a general information system, which can be of several forms such as genetic or sensory, that may be separated at a specific level into the observer and

the observed. Let Observer A which has internal states S_i , $i=1,2,\dots,n$, be represented by $A(S_i)$. When A forms or records a memory, M , it leads to the aggregated state that may be listed as SiM . The state has subparts that are entangled with each other in the sense that there is unknown interaction between them. If we see them as resonances, then they can be taken to be a superposition of waves. When the memory is recalled, Observer A obtains a projection, M^* , of the state M from the superposition, as happens in quantum measurement but is true in classical systems also, and the new state may be represented as $A(SiM^*, M^*)$. This shows that the stored state keeps on changing with each rehearsal or remembrance, and there is a reciprocity between remembrance and recall.

One may consider information at the level of the individual and the species. At the individual level, the haploid human genome (3×10^9 bases) DNA with its four-base letters (purines A and G, and pyrimidines C and T), has the information content of 6×10^9 bits. The information coded in fragments creates combinations that increase the number enormously. Conventional genes make up less than 2% of DNA and the remaining 98% clearly serve functions other than brain memory. The DNA is the source of innate primal memory of the animal, and it acquires further information from the environment. This implicit memory is expressed as skills that come to us naturally as we go through different developmental stages. DNA information processing acts through the epigenome. The genome is usually taken to be analogous to computer software in relation to neural function and in that case the epigenome analogy would be with adding or subtracting apps. On the other hand, if genes are compared to the hardware of a computer, the epigenome is its operating system. Epigenetic processes include DNA methylation, histone modifications, noncoding RNA, and nucleosome positioning. In methylation, a small chemical tag, which is a methyl group (CH_3), is added to molecules like DNA, proteins, or neurotransmitters to specific places. When DNA is methylated, it usually acts as a turn off switch for that gene, stopping it from making proteins. The body can also remove these tags through demethylation to turn genes back on when needed.

The enzymes that establish, recognize, and remove DNA methylation are broken into three classes: writers, erasers, and readers. Writers are the enzymes that catalyze the addition of methyl groups onto cytosine residues. Erasers modify and remove the methyl group. Readers recognize and bind to methyl groups to ultimately influence gene expression. These set of processes are analogous to how in a computer there are processes to read, write, and erase memory.

Histones are proteins that act as spools around which DNA winds to create structural units called nucleosomes. There is reciprocity in DNA methylation and specific histone modifications for they influence each

other. Histone methylation may direct DNA methylation patterns and DNA methylation may serve as a template for the establishment of certain histone marks. Non-coding RNAs (ncRNAs), which include transfer RNA (tRNA), ribosomal RNA (rRNA), and microRNA (miRNA), control embryonic gene expression by several means, ranging from microRNA induced degradation of mRNAs to long ncRNA-mediated modification of chromatin. It can guide or reinforce silencing and help transmit states in some organisms. DNA methylation and histone marks reinforce each other in many contexts.

DNA is central to social experience-dependent memories because DNA methylation can be passed on through either mitosis or meiosis and are relevant to early periods of life and inheritance across generations. Transgenerational inheritance occurs more readily in plants, worms, and some other organisms than in mammals, where germline reprogramming erases many marks (Hoffmann & Spengler, 2014).

Epigenetic effects can be transmitted to an indefinite number of generations. Conrad Waddington had exposed drosophila flies to extreme heat shock for several generations and the flies began to develop a new phenotype. The wings of the flies in the later generations of flies changed in shape and structure and persisted over sixteen generations, and still exist today (Waddington, 1940). Methylation can also partly explain how early social life experiences become embedded in the circuitry of the developing brain (Korolenko & Skinner, 2024).

The DNA-based storage of certain memories explains that animals of precocial species can walk, run, or fly quite soon after birth. Their young are relatively mature and mobile from the moment of birth or hatching. For example, the calves of the blue wildebeest can stand within six minutes from birth, walk within thirty minutes, and outrun a hyena within a day. The young of mammals are born helpless and require care for a length of time. Human children, and those of other primates, are born with minimal eyesight and grow in spurts, and quickly mature in features. Things learned by children between infancy and adolescence are memorized as instinct. It follows that a part of our memories is indirectly stored in the controlling aspects of the genes.

4. Processing at multiple levels

Mental operations include those that go up from the senses to the mind, and choices the self makes to filter what is arriving on the screen. Feedforward networks are the foundation of deep learning, designed for static data like images and text snippets and they can be trained superfast and even instantaneously (Kak, 2025). Memories may be classified into three types. Type I is a simple type of recall. Here the object or event that is stored in the memory can be recalled when

you present the same stimulus to reactivate the memory. The memory recall is due to reactivation of the existing dendritic pleats. This excitation is initiated by an external stimulus that matches the stored memory, and it gives a predictable and dependable response from the stored memory instantaneously. In Type II, we recall a memory from the past although it is triggered by the sequence of memories being rehearsed in the mind. In Type III, the memory traces may get transformed and rearranged to give rise to new complex ideas.

The memory system consists of indexed main memories that are listed by principal subjects and events which serve as doorways. These are located at specific centers in the brain and so may be seen as space coded. They are also indexed by capacities that are in specific centers of the brain. The conscious self has access to decision making that sets the memory recollection in motion.

Long-term memory includes episodic, semantic, and procedural types. There are also short-term forms of memory such as working memory. It has been shown that a long-term associative memory could be formed in the mouse completely artificially in the absence of experience, by simultaneously stimulating known neural circuits representing conditioned and unconditioned stimuli in the brain (Vetere et al., 2019).

The existence of many types of memory and their location within the brain is dependent on the system mediating the encoding of this memory. The cerebellum, striatum, cerebral cortex, hippocampus, and amygdala are thought to play an important role in this. For example, the hippocampus is believed to be involved in spatial and declarative memory, as well as consolidating short-term into long-term memory.

It appears that declarative memories move between the limbic system, deep within the brain, and the outer, cortical regions. These are distinct from the mechanisms of the more primitive cerebellum, which dominates in the blinking response and receives the input of auditory information directly.

High-level cognition, such as the expression of a specific memory, can be generated in a mammal by highly specific physical activation of a small subpopulation of brain cells. By reactivating these cells by physical means in mice, such as shining light on neurons affected by optogenetics, a long-term fear-related memory appears to be recalled. Memory as a history of past experiences guides future interactions with the ever-changing world. To that extent, memories are internal state of the brain machine that are used to modulate the response of the individual.

To gain a full understanding of memory, we need to investigate not only how a single memory is represented in the brain, but also how multiple memories interact (Pribram, 2013). It is also essential to understand the

implications of the creation of memories without experience as has been demonstrated in the lab.

The binding problem (e.g., [Feldman \(2013\)](#)) is about how an aggregation of subparts leads to a single, unified conscious experience. Straightforward reductive logic cannot explain how the brain takes the separately processed features of an object or scene and binds them together. Indeed, there is a mathematical theorem that no machine or physical system can develop the capacity of observation (as apart from computation) and, therefore, consciousness is a category that is independent of materiality ([Kak, 2023](#)). Different aspects of perception are handled by specialized, distributed regions that can be active at slightly different times and are separated by millimeters to centimeters of brain tissue. The brain somehow “glues” these features together correctly within about $\sim 100 - 200$ milliseconds. In a crowded scene, there is integration of information across senses as in the sight and sound of a person speaking, or the feel and appearance of an object one is holding. There is also temporal binding which is keeping features synchronized in time even though neural signals travel at different speeds and distances.

Mechanisms that have been proposed for the unity of consciousness focus on neural synchronization by means of oscillations or attention or some other brain process, but none of these addresses the computational complexity issue. Without a mechanism to link them, the system risks the “superposition catastrophe”, which is mixing features incorrectly. Bálint’s syndrome is a rare but striking neurological disorder that provides key insights into the binding problem and the role of the parietal lobes in visual attention, spatial awareness, and feature integration ([Chechlac & Humphreys, 2014](#)). Balint’s patients dramatically illustrate failures in feature binding; they can often detect individual features (color, shape, orientation) normally but struggle to determine which features belong to which object. This leads to illusory conjunctions that can combine features from different objects.

Presented with red vertical bars and blue horizontal bars, a patient might report seeing a blue vertical bar, even after prolonged viewing. Without proper spatial attention (mediated by parietal regions), features float unbound and join in incorrect arrangements. Implicit binding (e.g., unconscious effects) may persist, while explicit report of bound objects fails — suggesting the parietal lobes are critical for conscious, flexible binding. These cases highlight that binding is not automatic in early visual areas alone; it requires parietal coordination for attention, spatial tagging, and integration across the visual field.

5. Conclusion

The paper has presented arguments in support of the view that unified perception must include a top-down element in processing, and this corresponds to pari-

etal networks for synchronization, attention, and cross-feature integration. When the brain’s binding and attentional mechanisms break down, the resulting perception has features that are intact but failed integration. Cognitive processes are based on the complementarity view of memory formation and recall that operates at many levels – top-down and bottom-up, space and time, distributed and localized. The description of cognitive processes at different levels is usually done in terms of a variety of mechanisms together with a more fundamental quantum aspect to account for meaning which cannot be sub-divided. The transition between these descriptions, which are associative, reorganizational, and quantum cannot be captured by reductionism because of the holistic nature of thoughts and meanings. Consider recognizing a face: at one level, neurons respond to edges, colors, and shapes; at another level, the brain identifies a specific person; and at yet another level, that face evokes memories, emotions, and social meaning. These different descriptions can be regarded as different brain languages. Quantum neural computing suggests that the relationship among these levels involves holistic organization that is not reducible to a sequence of local neural events and this is where the SELF of the figure proposed in the paper resides. The computational problem of storage and recall of memories in the context of mirror neurons and more general complementarity mechanisms. A processing framework was provided in which the mind operates as a window on reality, with separate emulating circuits for storage and recall. The mirroring mechanism is recursive which is consistent with several features of awareness.

Conflict of Interest

The authors declare no competing interests.

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