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Author

Oruc, Ebrar

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From Parchment and Papyrus to Neurons and Neural Networks: PALIMPSESTS IN THE BRAIN

BY: EBRAR ORUC

INTRODUCTION

Palimpsests: a Greek word translating to “scraped again.”

In the Middle Ages, parchment and papyrus were precious materials. In fact, producing one copy of the Bible required the skins of 200 sheep.¹ The original pioneers of recycling, the Greco-Romans, remedied this scarcity in supply by erasing the original texts to make room for new text.² Now, historians can use modern technology to uncover traces of the “recycled” stories left behind—also known as palimpsests. While the exact number is contested, it is esti-

mated that one of every two papyrus sheets were reused during the first four centuries AD.¹ It was through these rediscovered texts that historians were able to reveal lost works of philosophy and science.

This ancient practice mirrors how our brains overwrite old neural traces of memories while retaining a faint record of past memories.

THE MYTH OF PERFECT MEMORY

It is commonly assumed that our memory is like a recording device—highly organized, recording in perfect sequence, and easily accessible in a mental library. Instead, memories are often reconstructed, blurred, misconstrued, and rewritten.³ Our brains have palimpsests of their own, also known as neural palimpsests.⁴ The old ink of previous neural connections never truly vanishes. Rather, our neural networks, a network of biological brain cells that transmit signals to process information, are re-

used, and those new memories become mingled with memories that came before.⁴

That is the essence of neural palimpsests: synapses, the junction where two nerve cells connect, undergoing both short term and long term modifications.⁵ New memories are encoded on top of preexisting neural networks and patterns while retaining residual traces of earlier memories.⁵

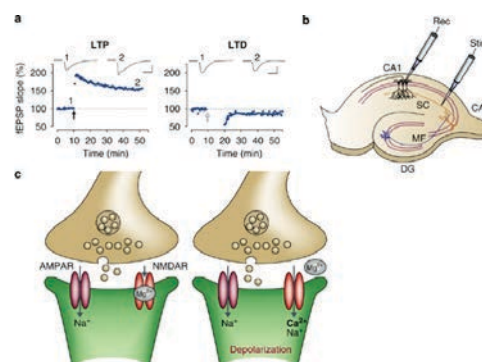


Figure 2. Synapse plasticity. Illustrates the specific mechanism by which stimulation to the junction between two neurons can cause short or long term modification in the synapses, impacting the strength and function of the neurons, affecting numerous cognitive functions such as memory.

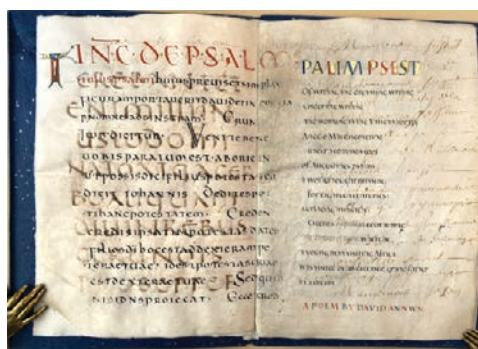


Figure 1. A representation of a historical palimpsest. Pages often had faded writing as papyrus was reused for multiple manuscripts.

HOW THE BRAIN REWRITES MEMORIES

Recent advancements in neuroscience are uncovering how neural palimpsests form, as researchers use functional magnetic resonance imaging (fMRIs) to track hippocampus-cortical interactions during memory retrieval and recall.⁴ The formation of neural palimpsests occurs through implicit processes, unfolding so subtly that people remain unaware of it. When walking into a situation evokes a strange, unplaceable sense of familiarity, when a bad gut feeling arises in a place that seems entirely new, or when a certain smell triggers an emotion with no clear context—these are examples of memories that have been traced over: dissipated, but not completely. Inside your brain, neural palimpsests are formed through a process known as reconsolidation.⁴ Every time a person retrieves a memory from their schemas (mental frameworks that help in organizing and structuring information to make it easier to retrieve) the memory becomes temporarily destabilized and malleable before it is re-stabilized.⁶ This process occurs in four key steps. First, a stable, long-term memory must be reactivated to make it temporarily liable for modification. Once the memory is retrieved, it enters a fragile state of destabilization. In doing so, the memory can be modified either with information that strengthens the memory, or contradicts it. Finally, the memory is restabilized and stored again, this time with the new information.⁷

LINGERING NEURAL NETWORKS: THE DESTABILIZATION OF MEMORIES

At the synaptic level, these faint neural traces of overwritten memories linger. Like the faint writing left behind a reused papyrus, these faded neural traces can resurface in subtle ways, influencing how humans perceive and remember, for better or for worse. However, this temporary destabilization allows the brain to modify involved neurons and integrate new information into the memory before it is saved again.⁶ When temporary destabilization occurs, it can modify and/or strengthen the function of communications of neurons at the synapse, also known as synaptical regulation. This is what enables the brain to adapt, learn, and

remember.⁶ For example, if someone recalls a painful event in their life, the initial neurological reaction can be negative. However, if they later receive comforting support or therapy, the emotional tone of that memory can change, highlighting how the brain can edit new experiences in light of adaptations to a memory.⁷

Honing in on the neural level, memory reconsolidation is a dynamic process that involves re-encoding information rather than statically retrieving memories. When a memory is reactivated, our brain's hippocampus (center of emotion and memory) undergoes transient communication with cortical networks (interconnected regions of the cerebral cortex responsible for cognition and perception).⁸ Transient communications are dynamic and temporary changes of activity in neural networks that allow flexible information processing in the brain. In order to reactivate a consolidated memory, the hippocampus engages in transient communication with the neocortex, the outermost layer of the brain responsible for thought, perception, memory, language, and reasoning.⁸ Activity between the hippocampus and the neocortex is what enables memory reconsolidation, specifically the destabilization of memory traces to make them susceptible to modification.⁹

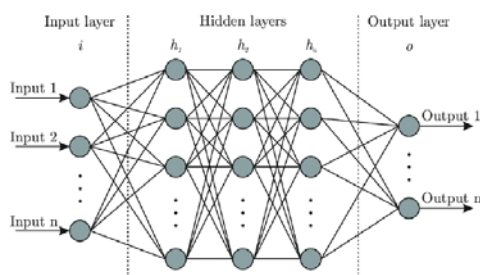


Figure 3. Diagram of a neural network. Neural networks consist of an input layer, multiple hidden layers, and an output layer. Each neuron (represented by the circles) is connected to another neuron.

Memory reconsolidation helps humans update their schemas but it also causes past and present memories to become muddled together in faint traces. The traces left behind remain in a latent state that can potentially be reactivated under the right conditions.¹⁰ Functional imaging studies have shown that older traces of memories can still influence perception even after the conscious recall is disrupted, demonstrating how suppressed memories can persist and affect human behavior.¹¹

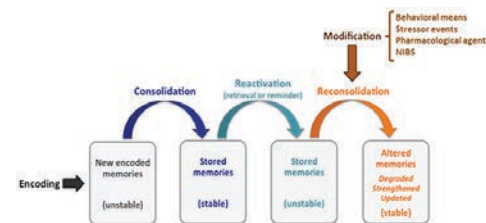


Figure 4. Diagram illustrating memory reconsolidation. As memories go through the process of encoding and retrieval, they undergo a phase of instability where external or internal modifications can lead to their alterations.

NEURAL PALIMPSESTS IN EVERYDAY

These supposedly overwritten memories, or neural palimpsests, help explain several cognitive phenomena. For example, déjà vu is hypothesized to occur when there is a partial activation of a previously encoded neural pattern. This causes a false sense of familiarity without full retrieval of an associated memory.¹² The brain mistakes the partial activation of an old memory trace for a current experience, like fragments of an erased manuscript. Even when that memory has been replaced or edited, these faint fragments can still influence perception, surfacing as a moment of misplaced recognition.

This same mechanism can also lead to the formation of false memories, where the consolidation process incorporates misleading information over an existing trace of a memory. Studies have shown that during the reconsolidation window, the brain can inaccurately retrieve memories even while genuine neural reactivation occurs in the hippocampus and prefrontal cortex. As the brain plays back the original memory, it can simultaneously overwrite parts of it with new information, which is why a false or distorted memory can still feel accurately recalled.¹³

This same mechanism of memory overwriting is often used in emotional and traumatic memories. In the context of PTSD, the process of reconsolidation becomes maladaptive rather than adaptive. When a traumatic memory is triggered, hyperactivity in the amygdala (the brain's center for emotion regulation) and impaired prefrontal cortex regulation means that even when an individual attempts to suppress traumatic memories, traces of the triggering memory integrate within newly formed memories during neural overwriting.¹⁴ This

is why trauma-related triggers can resurface unexpectedly, long after the initial trauma.

All these examples highlight how the same neural processes that lead to neural palimpsests in the brain can also lead to fragility, misinformation and memory distortion.

CONCLUSION: NEUROLOGICAL MARVEL OR HINDRANCE?

Ultimately, neural palimpsests serve important neurological adaptive functions. A memory system that is capable of overwriting and editing memories and information can lead to the prevention of cognitive overload in neural networks and enable flexible cognition or neuroplasticity. In doing so, rather than endlessly storing memories, the brain is able to remain efficient and adaptable by reorganizing and responding to change. Overlapping of memory traces leads to conceptual blending: a cognitive process in which mental spaces are combined to form new concepts.¹⁵ For example, the mental imagery of a flying car results from the blending of schemas surrounding cars and planes. This allows for analogy formation, problem solving, and abstraction.¹⁵

Thus, neural palimpsests represent a trade-off: While memories can be constantly reconstructed, adapted, and integrated with new experiences, it comes at the cost of perfect, reliable memory.



Figure 5. Neurons. A photorealistic depiction of neurons in the brain forming a neural network.

Neural palimpsests reveal how our memory system is both resilient and fragile. Our memories are constantly rewritten and don't remain static with one neural network reserved for one memory. Rather, these networks are reused, revised and continuously rewritten to fundamentally define human cognition.

Like the faint writing left behind on a reused papyrus, the traces of our old memories linger beneath the new.

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