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Meditation, Memory, and Attention

▶ Attention, Memory, and Meditation

Medium

▶ Cue Summation and Learning

Membership

▶ Identity and Learning

Memory

Refers to the ability to store, retain, and recall information and experiences. This ability allows one to use past experience to plan future actions.

Cross-References

▶ Video-Based Learning

Memory Adaptation

▶ Adaptive Memory and Learning

Memory Aids

▶ Mnemonic Learning
▶ Mnemotechnics and Learning

Memory Capacity

Memory capacity is an important performance measure for associative memories. Different definitions coexist. For example, memory capacity has been quantified as the number of retrievable memories per neuron (Hopfield 1982) or the total information that can be retrieved normalized by the number of synapses (Willshaw et al. 1969). The information-theoretic definition of memory capacity is more general, for instance, it can be used to assess how sparseness in the memory patterns affects the performance of associative memory.

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Memory Code

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Synonyms

Neural memory algorithm

Definition

The term *memory code* refers to a relationship that describes the transformation of a cardinal aspect of experience into an enduring neural form. Memory codes may be appreciated by comparing them with sensory codes, the operation of which enables the representation of a sensory parameter by neural activity. For example, the loudness of a sound may be represented as an increasing rate of discharge of auditory system neurons: the louder the sound, the greater the rate of discharge. However, unlike sensory codes, *memory codes* provide for the long-term representation of a general attribute of experience. For example, the *behavioral importance* of an experience might be represented as an increasing function of the number of neurons that represent that experience (Weinberger 2001).

Theoretical Background

Views on the nature of memories differ. Some workers regard them as somewhat veridical records of experiences while other consider memories as reconstructions based on bits and pieces of stored information, subject to a host of other processes that compromise accuracy. Undoubtedly, different forms of memory are differentially subject to these problems and the list of variables that affect memory strength and memory clarity is known to be long and surely is still incomplete. Nonetheless, whatever one's views about the veracity of memories, for memory as a fundamental competency of the brain to have any function at all, for organisms to derive any benefit from past experience, there must be the storage of *sufficient correct detail* to support future adaptive behavior.

Memory storage has at least two faces: the *specific content* of an experience, e.g., "Was that car red or blue?"; the *meaning* of an experience, e.g., "Did that car almost hit me?". It is generally agreed that the more important an experience, the greater will be its strength. For example, traumatic experiences are generally more difficult to forget and less subject to interference or conflation than less meaningful experiences. At the extreme, memories can be intrusive as in post-traumatic stress disorder (PTSD). The basolateral amygdala (BLA) is thought to be a major mechanism that modulates the strength of memories via its reactivity to stress hormones that are secreted by the adrenal glands (McGaugh 2004). But as most memories are not traumatic, yet enduring (e.g., your mother's maiden name), they must have a neural substrate which enables their maintenance. One way in which this could be accomplished is by the instantiation of memory codes for particular features of memories. While general neural algorithms for the representation of the specific content of individual experiences are unlikely because of the unique aspects of particular occurrences, memory codes could be used to represent fundamental features that are common to all memories.

Important Scientific Research and Open Questions

Currently, there is some confusion among the terms *memory code*, *memory encoding*, and *engram*. Memory encoding refers to the psychological level strategy employed to represent a stimulus or event. For example, the spoken word "bird" could be encoded as the animal to which it refers (semantic level of encoding) or as the sound of the word itself (phonological level of encoding). The term *engram* is usually employed to refer to the *totality of neural changes that comprise a memory*, whether stored in a local or distributed manner.

A memory code is neither a psychological level strategy nor the actual neural substrate of a memory. Rather, a memory code denotes a particular type of "input–output" function. A memory code describes the transform from, e.g., patterns of sensory-derived neuronal discharges [INPUT] into long-lasting changes in neural organization that represent a cardinal feature of memory [OUTPUT].

The major current issue is whether memory codes are merely hypothetical constructs or actually are instantiated by brains. There is now direct evidence for a memory code for the *behavioral importance of a sensory event*, one that operates (perhaps surprisingly) in the primary auditory cortex. For example, the relative behavioral importance of a tone was manipulated in rats trained to bar-press for water reward in the presence of that tone. The area that represented the frequency of this tonal signal in (the "tonotopic map" of) the auditory cortex was expanded as an increasing function of the level of its behavioral significance (Rutkowski and Weinberger 2005). Insofar as important memories are more resistant to interference, such as in behavioral extinction, one might expect that the stronger the memory, the larger the area of cortical representation and the slower its extinction. This relationship also has been found (Bieszczad and Weinberger 2010).

Research on memory codes is still in its early stages, perhaps because most brain-memory studies are concerned with the processes responsible for memory storage while inquiry on how the brain represents *memory content* has lagged. The nascent status of memory codes clearly provides many opportunities for additional inquiry.

Cross-References

- ▶ Memory Consolidation and Reconsolidation
- ▶ Memory Persistence
- ▶ Mental Representations
- ▶ Sensory Memory

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Memory Consolidation

▶ Dreaming: Memory Consolidation and Learning

Memory Consolidation and Reconsolidation

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Synonyms

Memory storage; Restabilize; Re-storage; Stabilize; Time-dependent processes

Definition

The terms *consolidation* and *reconsolidation* are theoretical constructs closely, but not exclusively, linked to the phenomenon of retrograde amnesia. The term "consolidation" refers to the presumed underlying neural processes involving the storage of memory that would account for the time-dependent characteristics of retrograde amnesia, in which recent information is more vulnerable than older information. Reconsolidation represents a special case in which an old memory that has been reactivated by exposure to the learning situation becomes susceptible to an amnesic event. Thus, reconsolidation involves the putative neural mechanisms involved in re-storage of memory. Both terms are also used in a more descriptive sense to refer to a variety of findings indicating that processing of information in animals as well as humans can continue for a short period of time after an input or event has ended.

Theoretical Background

That traumatic closed-head brain injury such as concussion could lead to forgetting of earlier events or retrograde amnesia (RA) has long been recognized. In addition, clinical observations in the 1800s on patients with traumatic brain injuries suggested that memory for events shortly before the injury were more likely to be forgotten than memory for earlier events. This finding of a temporal gradient of memory loss, based on case studies, became an important aspect of what came to be referred to as consolidation. Similar observations were later made when patients undergoing electroconvulsive shock therapy (ECT) for depression seemed to forget events just before the ECT treatment but not earlier ones. These informal findings were subsequently verified experimentally. Patients learned two lists of material, one shortly before ECT and the other several hours prior to treatment. When the patients were tested, the memory loss was greater for the more recently learned material.

The term "consolidation" seems to have originated with laboratory work with humans done by Muller and Pilzecker in their studies on retroactive interference. It appeared that interpolating the new information shortly after the target material was acquired was more detrimental to the original memory than interpolating the second material after a delay. Although their finding has not held up in more recent studies, that outcome and related observations led them to suggest that during learning the information persisted or perseverated in memory for a brief period after an

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