Where Are Old Memories Stored in the Brain?

By Moheb Costandi on February 10, 2009

A new study suggests that the location of a recollection in the brain varies based on how old that recollection is

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In the 1920s the behavioral psychologist Karl Lashley conducted a now famous series of experiments in an attempt to identify the part of the brain in which memories are stored. He trained rats to find their way through a maze, then made lesions in different parts of the cerebral cortex in an attempt to erase what he called the "engram," or the original memory trace. Lashley failed to find the engram—his experimental animals were still able to find their way through the maze, no matter where he put lesions on their brains. He therefore concluded that memories are not stored in any single area of the brain, but are instead distributed throughout it.

Subsequent work on amnesics—most notably the studies of the recently deceased patient known only as H.M. carried out by Brenda Milner—implicated a part of the brain called the hippocampus as being crucial for memory formation. More recently, it was established that the frontal cortex is also involved; current thinking holds that new memories are encoded in the hippocampus and then eventually transferred to the frontal lobes for long-term storage. A new study, led by Christine Smith and Larry Squire at the University of California at San Diego, now provides evidence that the age of a memory determines the extent to which we are dependent on the frontal cortex and hippocampus for recalling it. In other words, the **location of a recollection in the brain varies based on how old that recollection is.**

Smith and Squire assessed the brain activity associated with the recollection of old and new memories. They recruited 15 healthy male participants, and used functional magnetic resonance imaging (fMRI) to scan their brains while they answered 160 questions about news events that took place at different periods of time during the past 30 years. The study sounds simple, but the design of the experiments was actually somewhat complex, because the researchers had to overcome a number of confounding variables.

First, when one is asked to recall any given memory, the brain encodes not only the questions that were asked to cue the retrieval, but also the resulting recollection, so the associated activity could therefore interfere with that which is being assessed. Second, more recent memories are likely to be richer and more vivid than older ones, so the strength of the fMRI signal could be related not just to the time at which a recalled event occurred but also to the richness of the participants' recollection of it. Finally, recalled memories could be strongly associated with personal events in the participants' lives, which could make them easier to remember.

Testing Old Memories

Smith and Squire therefore designed their experiments so that they could assess the effects of the age of a memory independently of both the encoding of the test questions and richness of the recollection of the memory. At the beginning of the task, the researchers presented in random order blocks of questions about events in each time period, and they asked participants to indicate whether or not they knew the answer. About 10 minutes later, while still in the scanner, the participants were asked three questions about each news event. First, they were asked to recall the original question they had been asked about the event (to assess how well they had encoded the information). Then, they were asked the answer to that question (to assess the accuracy of recall) and, finally, how much they knew about each of the events (to assess the richness of each memory).

In general, the participants' ability to recall any given news event decreased in relation to the amount of time that had passed since the event had occurred. As expected, they were better able to recollect more recent events than older ones. The researchers also found that the participants' memory of the questions they had been asked, and of the content of each news event, was independent of how long ago the events had occurred. The richness of the participants' memories was also unrelated to when a particular event occurred; the memories of events that occurred in the distant past were often as rich as those of more recent events.

In their analyses, the researchers used only those fMRI data from the questions that had been answered correctly. This data set showed that medial temporal lobe structures (the **hippocampus and amygdala**) exhibited gradually decreasing activity as the participants recalled progressively older memories. This drop in activity was true for memories of news events that occurred up to 12 years before, but the recollection of events that took place longer than 12 years was associated with a constant level of activity in those areas. The opposite activation pattern was observed in areas of the frontal, parietal and lateral temporal lobes: activity in these areas increased with the age of the news event being recalled, but remained constant during the recollection of more recent events.

File Cabinets in the Brain

This study therefore provides anatomical and functional evidence supporting the findings obtained from brain-damaged patients with memory impairments. Patients such as H.M., who have lesions in the hippocampus on both sides of the brain, not only lose the ability to form new memories, but also lose memories for events that occurred in the years preceding the onset of their amnesia. The memories of events that took place in the distant past remain intact, whereas those that occurred at intermediate times are lost in a graded manner. This finding suggests that, **with time, the hippocampus becomes less important for a given memory, and the frontal cortex more so.**

Lashley's theory of memory was not right, but neither was it completely wrong. **Why, then, might old memories be transferred from the hippocampus to the frontal cortex?** It may be because retrieving older memories requires stronger associations and increased effort—memory encoding in the frontal cortex is more complex than in the hippocampus, and involves a widely distributed network with a greater number of connections. The frontal cortex may therefore be better suited to the task of retrieving memories that were encoded in the distant past.

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