Article on memory may make a lasting impression, depending on theta phase lock

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They say there's only one chance to make a first impression, but what makes that memory last?

Research scientists at Cedars-Sinai Medical Center and the California Institute of Technology suggest in an article in the March 24, 2010, journal *Nature* that when memory-related neurons in the brain fire in sync with certain brain waves, the resulting image recognition and memories are stronger than if this synchronization does not occur.

Synchronization is influenced by "theta waves," which are associated with relaxation, daydreaming and drowsiness, but also with learning and memory formation. While it has long been understood that a relaxed mind is one that is ready to receive new information, this study pinpoints a mechanism by which this state of mind allows neurons to work together to improve memory retention. Further exploration of these events could have implications for developing new therapies to treat learning disabilities and some types of dementia, according to the authors.

Brain waves oscillate, with rhythmic highs and lows, and can be measured with electroencephalograms, which use electrodes to record electrical activity. One measure of waves is the frequency of peaks per second, but two waves of the same frequency may not be locked in "phase." Like the sound waves of two musical instruments that are slightly out of tune, two out-of-phase brain waves of the same frequency would be similar but slightly out of sync.

"Theta oscillations are known to be involved in memory formation, and previous studies have identified correlations between memory strength and the activity of certain neurons, but the relationships between these events have not been understood. Our research shows that when memory-related neurons are well coordinated to theta waves during the learning process, memories are stronger," said Adam N. Mamelak, M.D., a neurosurgeon at Cedars-Sinai Medical Center whose areas of expertise include treatment of seizure disorders. Mamelak is one of the article's senior authors, with Erin M. Schuman, Ph.D., professor of biology at the California Institute of Technology.

"We have yet to discover all factors that influence theta oscillations and the coordination of spike timing, but this study establishes a direct relationship between events at the circuit level of the brain - individual neuron spike timing relative to the local brain wave environment - and their effects on human behavior," said Ueli Rutishauser, Ph.D., a postdoctoral scholar at the California Institute of Technology, and the article's first author. He noted that the study also found that while the predictability of memory strength was determined by spike timing relative to theta oscillations, it was not influenced by other related factors, such as the neuron firing rate or the amplitude of the theta oscillations.

Subjects in the study were presented with novel stimuli that they had not previously seen. These were in the form of 100 photographs of a wide range of objects, each viewed for one second. Fifteen to 30 minutes later, they were shown a set of 100 photos, 50 that were new and 50 that had been in the first set. They were asked to recall which ones they had seen before and to estimate how confident they were in their answers.

While these activities were in progress, the researchers recorded the activity of single neurons - 296 in all - and the "background" local electrical signals in regions of the brain where memories are encoded (the hippocampus and the amygdala). According to the results, image recognition was stronger when learning occurred while neuronal spikes were in sync with local theta waves.

Most studies of theta waves have been conducted in rats, with only a few studies in humans, in part because EEG electrodes need to be placed directly on the brain's surface for highly precise measurements. This study was conducted with eight volunteers who suffer from epilepsy and were undergoing intracranial EEGs. These are often used to pinpoint the source of epileptic seizure activity. The authors note that steps were taken to ensure that the patients' underlying medical condition did not affect the outcome of the study.

Brain wave frequency is measured per second and quantified in hertz (Hz). A wave that cycles 10 times per second is considered a 10 Hz wave. Most brain waves recorded in humans range up to about 40 Hz, although they also go much higher. Theta waves oscillate toward the lower end of the scale, in about the four Hz to seven Hz range.

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