The role of sleep in memory

Some evidence that neuronal connections may be remodeled during sleep, and this may explain why young birds and mammals need so much more sleep than adults.
Some memory tasks appear to be more vulnerable to sleep deprivation than others.
Sleep deprivation may produce effects in the brain that resemble those associated with aging.

The evidence now seems reasonably convincing that sleep plays an important role in memory consolidation — at least for procedural/skill memory.
It also seems most likely that it is the deep, slow-wave (non-REM) sleep that is important for this process.
New sleep studies support a view of a "memory life-cycle", which involves three stages — stabilization, consolidation, and re-consolidation.
Initial stabilization of memories may take as much as six hours.

Why do we need sleep?

A lot of theories have been thrown up over the years as to what we need sleep for (to keep us wandering out of our caves and being eaten by sabertooth tigers, is one of the more entertaining possibilities), but noone has yet been able to point to a specific function of the sleep state that would explain why we have it and why we need so much of it.

One of the things we do know is that young birds and mammals need as much as three times the amount of sleep as adult birds and mammals. It has been suspected that neuronal connections are remodeled during sleep, and this has recently been supported in a study using cats (Cats who were allowed to sleep for six hours after their vision was blocked in one eye for six hours, developed twice as many new or modified brain connections as those cats who were kept awake in a dark room for the six hours after the period of visual deprivation).

Certainly a number of studies have shown that animals and humans deprived of sleep do not perform well on memory tasks, and research has suggested that there may be a relationship between excessive daytime sleepiness (EDS) and cognitive deficits. A recent study has found that for seniors at least, EDS is an important risk factor for cognitive impairment.

The effect of sleep on memory and learning

Some memory tasks are more affected be sleep deprivation than others. A recent study, for example, found that recognition memory for faces was unaffected by people being deprived of sleep for 35 hours. However, while the sleep-deprived people remembered that the faces were familiar, they did have much more difficulty remembering in which of two sets of photos the faces had appeared. In other words, their memory for the context of the faces was significantly worse. (The selective effect of sleep on contextual memory is also supported in a recent mouse study – see below)

While large doses of caffeine reduced the feelings of sleepiness and improved the ability of the sleep-deprived subjects to remember which set the face had appeared in, the level of recall was still significantly below the level of the non-sleep-deprived subjects. (For you coffee addicts, no, the caffeine didn’t help the people who were not sleep-deprived).

Interestingly, sleep deprivation increased the subjects’ belief that they were right, especially when they were wrong. In this case, whether or not they had had caffeine made no difference.

In another series of experiments, the brains of sleep-deprived and rested participants were scanned while the participants performed complex cognitive tasks. In the first experiment, the task was an arithmetic task involving working memory. Sleep-deprived participants performed worse on this task, and the fMRI scan confirmed less activity in the prefrontal cortex for these participants. In the second experiment, the task involved verbal learning. Again, those sleep-deprived performed worse, but in this case, only a little, and the prefrontal areas of the brain remained active, while parietal lobe activity actually increased. However, activity in the left temporal lobe (a language-processing area) decreased. In the third study, participants were given a "divided-attention" task, in which they completed both an arithmetic and a verbal-learning task. Again, sleep-deprived participants showed poorer performance, depressed brain activation in the left temporal region and heightened activation in prefrontal and parietal regions. There was also increased activation in areas of the brain that are involved in sustained attention and error monitoring.

These results indicate that sleep deprivation affects different cognitive tasks in different ways, and also that parts of the brain are able to at least partially compensate for the effects of sleep deprivation.

Sleep deprivation mimics aging?

A report in the medical journal *The Lancet*, said that cutting back from the standard eight down to four hours of sleep each night produced striking changes in glucose tolerance and endocrine function that mimicked many of the hallmarks of aging. Dr Eve Van Cauter, professor of medicine at the University of Chicago and director of the study, said, "We suspect that chronic sleep loss may not only hasten the onset but could also increase the severity of age-related ailments such as diabetes, hypertension, obesity and memory loss."

Should we draw any conclusion from the finding that sleep deprivation increased the subjects' belief that they were right, especially when they were wrong, and the finding that chronic sleep deprivation may mimic the hallmarks of aging? No, let us merely note that many people become more certain of their own opinions as they mature into wisdom.

Is sleep necessary to consolidate memories?

This is the big question, still being argued by the researchers. The weight of the evidence, however, seems to be coming down on the answer, yes, sleep is necessary to consolidate memories — although maybe for only some types of memory. Most of the research favoring sleep's importance in consolidation has used procedural / skill memory — sequences of actions.

From this research, it does seem that it is the act of sleep itself, not simply the passage of time, that is critical to convert new memories into long-term memory codes.

Some of the debate in this area concerns the stage of sleep that may be necessary. The contenders are the deep "slow wave" sleep that occurs in the first half of the night, and "REM" (rapid eye movement) sleep (that occurs while you are dreaming). Experiments that have found sleep necessary for consolidation tend to support slow-wave sleep as the important part of the cycle, however REM sleep may be important for other types of memory processing.

Sleep studies cast light on the memory cycle

Two new studies provide support both for the theory that sleep is important for the consolidation of procedural memories, and the new theory of what I have termed the "memory life-cycle".

In the first study, 100 young adults (18 to 27) learned several different finger-tapping sequences. It was found that participants remembered the sequence even if they learned a second sequence 6 hours later, and performance on both sequences improved slightly after a night's sleep. However, if, on day 2, people who had learned one sequence were briefly retested on it and then trained on a new sequence, their performance on the first sequence plummeted on day 3. If the first sequence wasn't retested before learning the new sequence, they performed both sequences accurately on day 3.

In another study, 84 college students were trained to identify a series of similar-sounding words produced by a synthetic-speech machine. Participants who underwent training in the morning performed well in subsequent tests that morning, but tests later in the day showed that their word-recognition skill had declined. However, after a full night's sleep, they performed at their original levels. Participants trained in the evening performed just as well 24 hours later as people trained in the morning did. Since they went to bed shortly after training, those in the evening group didn't exhibit the temporary performance declines observed in the morning group.

On the basis of these studies, researchers identified three stages of memory processing: the first stage of memory — its stabilization — seems to take around six hours. During this period, the memory appears particularly vulnerable to being “lost”. The second stage of memory processing — consolidation — occurs during sleep. The third and final stage is the recall phase, when the memory is once again ready to be accessed and re-edited. (see my article on consolidation for more explanation of the processes of consolidation and re-consolidation)

The researchers made a useful analogy with creating a word-processing document on the computer. The first stage is when you hit “Save” and the computer files the document in your hard drive. On the computer, this takes seconds. The second stage is comparable to someone coming and tidying up your word document — reorganizing it and tightening it up.

The most surprising aspect of this research is the time it appears to take for memories to initially stabilize — seconds for the computer saving the document, but up to six hours for us!

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Sleep loss and temporal memory

Journal Article:

Harrison, Yvonne & Horne, James A. 2000. Sleep loss and temporal memory. The Quarterly Journal of Experimental Psychology, 53A (1), 271-279.

Recognition memory for faces was unaffected by being deprived of sleep for 35 hours.

However, sleep-deprived subjects were significantly worse in remembering in which of two sets of photos particular faces had appeared in.

Sleep-deprived subjects who had been given significant doses of caffeine remembered the set better than those who had not, but were still poorer at remembering than those not deprived of sleep.

Although their performance was poorer, sleep-deprivation seemed to increase the subjects' belief in their own accuracy.

It seems likely that sleep-deprivation affects memory for context.

In this study, subjects were shown two sets of 12 color photographs of people’s faces (24 in total). Five minutes after seeing the last one, the subjects were then shown another 48 faces (one by one, as before) and had to say whether or not they had seen the face earlier. If so, they were asked whether they saw it in the first or second set of photographs. Half the subjects had been deprived of sleep for the previous 35 hours. Some of these had been given significant amounts of caffeine to offset their sleepiness.

It was found that the sleep-deprived subjects, whether or not they had had caffeine, were as good as the non-sleep-deprived subjects at recognizing which faces they had seen before. However, the sleep-deprived subjects were significantly worse at remembering which set the faces had appeared in. This occurred even though otherwise optimum conditions for recall existed (the test was novel, stimulating, and relatively short; it was given at the best time of day for maximum alertness).

Caffeine significantly reduced the feelings of sleepiness and did appear to improve the ability of the sleep-deprived subjects to remember which set the face had appeared in, but the level of recall was still significantly below the level of the non-sleep-deprived subjects. Caffeine made no difference to the memory performance of subjects who were not sleep-deprived.

Interestingly, sleep deprivation increased the subjects' belief that they were right, especially when they were wrong. In this case, whether or not they had had caffeine made no difference.

It may be that the problem with temporal memory reflects a more general problem with remembering context information.

Sleep's role in cognition - news reports

Sleep and memory - round-up of recent reports

A round-up of recent reports relating to the role of sleep in consolidating memory.

Sleep can boost classroom performance of college students

There's a lot of evidence that memories are consolidated during sleep, but most of it has involved skill learning. A new study extends the findings to complex declarative information — specifically, information from a lecture on microeconomics.

The study involved 102 university undergraduates who had never taken an economics course. In the morning or evening they completed an introductory, virtual lecture that taught them about concepts and problems related to supply and demand microeconomics. They were then tested on the material either immediately, after a 12-hour period that included sleep, after 12 hours without sleep, or after one week. The test included both basic problems that they had been trained to solve, and "transfer" problems that required them to extend their knowledge to novel, but related, problems.

Performance was better for those who slept, and this was especially so for the novel, 'transfer' integration problems.

Rule-learning task also benefits from sleep

Another complex cognitive task was investigated in a study of 54 college undergraduates who were taught to play a card game for rewards of play money in which wins and losses for various card decks mimic casino gambling (the Iowa Gambling Task is typically used to assess frontal lobe function). Those who had a normal night's sleep as part of the study drew from decks that gave them the greatest winnings four times more often than those who spent the 12-hour break awake, and they better understood the underlying rules of the game.

The students were given a brief morning or afternoon preview of the gambling task (too brief to learn the underlying rule). They returned twelve hours later (i.e., either after a normal night's sleep, or after a day of their usual activities), when they played the full gambling task for long enough to learn the rules. Those who got to sleep between the two sessions played better and showed a better understanding of the rules when questioned.

To assure that time of day didn't explain the different performance, two groups of 17 and 21 subjects carried out both the preview and the full task either in the morning or the evening. Time of day made no difference.

Sleep problems may be a link between perceived racism and poor health

Analysis of data from the 2006 Behavioral Risk Factor Surveillance System, involving 7,093 people in Michigan and Wisconsin, suggests that sleep deprivation may be one mediator of the oft-reported association between discrimination and poorer cognitive performance.

The survey asked the question: "Within the past 12 months when seeking health care, do you feel your experiences were worse than, the same as, or better than for people of other races?" Taking this as an index of perceived racism, and comparing it with reports of sleep disturbance (difficulty sleeping at least six nights in the past two weeks), the study found that individuals who perceived racial discrimination were significantly more likely to experience sleep difficulties, even after allowing for socioeconomic factors and depression. Risk of sleep disturbance was nearly doubled in those who perceived themselves as discriminated against, and although this was reduced after depression was taken into account, it remained significant.

Sleep problems more prevalent than expected in urban minority children

Ten families also underwent sleep monitoring at home for five to seven days. All children who completed actigraphy monitoring had shortened sleep duration, with an average sleep duration of 8 hours, significantly less than the 10 to 11 hours recommended for children in this age group.

It's worth noting that parents consistently overestimated sleep duration. Although very aware of bedtime and wake time, parents are less aware of time spent awake during the night.

(Also note that the figures I quote are taken from the conference abstract, which differ from those quoted in the press release.)

Rocking really does help sleep

If you or your loved one is having troubles getting to sleep, you might like to note an intriguing little study involving 12 healthy males (aged 22-38, and good sleepers). The men twice took a 45-minute afternoon nap on a bed that could slowly rock. On one occasion, it was still; on the other, it rocked. Rocking brought about faster sleep, faster transition to deeper sleep, and increased slow oscillations and sleep spindles (hallmarks of deep sleep). All these results were evident in every participant.

Sleep helps long-term memory in two ways

A fruit fly study points to two dominant theories of sleep being correct. The two theories are (a) that synapses are pruned during sleep, ensuring that only the strongest connections survive (synaptic homeostasis), and (b) that memories are replayed and consolidated during sleep, so that some connections are reactivated and thus made stronger (memory consolidation).

The experiment was made possible by the development of a new strain of fruit fly that can be induced to fall asleep when temperatures rise. The synaptic homeostasis model was supported when flies were placed in socially enriched environments, then either induced to sleep or not, before being taught a courtship ritual. Those that slept developed long-term memories of the ritual, while those that didn't sleep didn't remember it. The memory consolidation theory was supported when flies trained using a protocol designed to give them short-term memories retained a lasting memory, if sleep was induced immediately after the training.

In other words, it seems that both pruning and replaying are important for building long-term memories.

Mouse studies identify the roots of memory impairment resulting from sleep deprivation

Sleep deprivation in known to result in increased levels of adenosine in the brain, whether fruit fly or human (caffeine blocks the effects of adenosine). New mice studies now reveal the mechanism.

Mice given a drug that blocked a particular adenosine receptor in the hippocampus (the A1 receptor) failed to show the normal memory impairment evoked by sleep deprivation (being woken halfway through their normal 12-hour sleep schedule). The same results occurred if mice were genetically engineered to lack a gene involved in the production of glial transmitters (necessary to produce adenosine).

Memory was tested by the mice being allowed to explore a box with two objects, and then returned to the box on the next day, where one of the two objects had been moved. They would normally explore the moved object more than other objects, but sleep-deprived mice don't usually react to the change, because they don't remember where the object had been. In both these cases, the sleep-deprived mice showed no memory impairment.

Both the drugged and genetically protected mice also showed greater synaptic plasticity in the hippocampus after being sleep deprived than the untreated group.

The two groups reveal two parts of the chemical pathway involved in sleep deprivation. The genetic engineering experiment shows that the adenosine comes from glia's release of adenosine triphosphate (ATP). The drug experiment shows that the adenosine goes to the A1 receptor in the hippocampus.

The findings provide the first evidence that astrocytic ATP and adenosine A_1R activity contribute to the effects of sleep deprivation on hippocampal synaptic plasticity and hippocampus-dependent memory, and suggest a new therapeutic target to reverse the cognitive deficits induced by sleep loss.

Scullin M, McDaniel M, Howard D, Kudelka C. 2011. Sleep and testing promote conceptual learning of classroom materials. Presented Tuesday, June 14, in Minneapolis, Minn., at SLEEP 2011, the 25th Anniversary Meeting of the Associated Professional Sleep Societies LLC (APSS).

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Sleep can boost classroom performance of college students
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Rule-learning task also benefits from sleep
http://medicalxpress.com/news/2011-05-excellent-science-based-advice.html
Sleep problems may be a link between perceived racism and poor health
http://medicalxpress.com/news/2011-06-problems-link-racism-poor-health.html
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http://medicalxpress.com/news/2011-05-problems-prevalent-urban-minority-...
Rocking really does help sleep
http://www.scientificamerican.com/podcast/episode.cfm?id=rocking-increas...
Sleep helps long-term memory in two ways
http://the-scientist.com/2011/06/23/sleep-on-it/
Mouse studies identify the roots of memory impairment resulting from sleep deprivation
http://www.eurekalert.org/pub_releases/2011-05/uop-pri051711.php

Learning ability is refreshed by sleep spindles

A new study confirms that learning ability declines with time awake, and shows that stage 2 non-REM sleep, achieved during a long afternoon nap, can re-invigorate your brain.

In a study involving 44 young adults given a rigorous memorizing task at noon and another such task at 6pm, those who took a 90-minute nap during the interval improved their ability to learn on the later task, while those who stayed awake found it harder to learn.

The degree to which the nappers were refreshed correlated with the amount of stage 2 non-REM sleep they experienced. This sleep phase is characterized by sleep spindles, which are associated with brain activity between the hippocampus and prefrontal cortex. Spindle-rich sleep occurs mostly in the second half of the night, so those who don't get their quota of sleep are probably getting less.

The finding confirms the idea that learning ability decreases the more time you spend awake.

Mander, B. A., Santhanam S., Saletin J. M., & Walker M. P. (2011). Wake deterioration and sleep restoration of human learning. Current Biology. 21(5), R183-R184 - R183-R184.

http://www.physorg.com/news/2011-03-speedy-brain-boost-ability.html
http://news.discovery.com/human/sleep-naps-learning-110309.html

Role of expectation on memory consolidation during sleep

A new study suggests sleep's benefits for memory consolidation depend on you wanting to remember.

Two experiments involving a total of 191 volunteers have investigated the parameters of sleep's effect on learning. In the first experiment, people learned 40 pairs of words, while in the second experiment, subjects played a card game matching pictures of animals and objects, and also practiced sequences of finger taps. In both groups, half the volunteers were told immediately following the tasks that they would be tested in 10 hours. Some of the participants slept during this time.

As expected, those that slept performed better on the tests (all of them: word recall, visuospatial, and procedural motor memory), but the really interesting bit is that it turned out it was only the people who slept who also knew a test was coming that had improved memory recall. These people showed greater brain activity during deep or "slow wave" sleep, and for these people only, the greater the activity during slow-wave sleep, the better their recall.

Those who didn't sleep, however, were unaffected by whether they knew there would be a test or not.

Of course, this doesn't mean you never remember things you don't intend or want to remember! There is more than one process going on in the encoding and storing of our memories. However, it does confirm the importance of intention, and cast light perhaps on some of your learning failures.

Wilhelm, I., Diekelmann S., Molzow I., Ayoub A., Mölle M., & Born J. (2011). Sleep Selectively Enhances Memory Expected to Be of Future Relevance. The Journal of Neuroscience. 31(5), 1563 - 1569.

http://www.eurekalert.org/pub_releases/2011-02/sfn-sss012811.php

Sleep reorganizes your memories

New studies show how sleep sculpts your memories, emphasizing what's important and connecting it to other memories in your brain.

The role of sleep in consolidating memory is now well-established, but recent research suggests that sleep also reorganizes memories, picking out the emotional details and reconfiguring the memories to help you produce new and creative ideas. In an experiment in which participants were shown scenes of negative or neutral objects at either 9am or 9pm and tested 12 hours later, those tested on the same day tended to forget the negative scenes entirely, while those who had a night's sleep tended to remember the negative objects but not their neutral backgrounds.

Follow-up experiments showed the same selective consolidation of emotional elements to a lesser degree after a 90-minute daytime nap, and to a greater degree after a 24-hour or even several-month delay (as long as sleep directly followed encoding).

These findings suggest that processes that occur during sleep increase the likelihood that our emotional responses to experiences will become central to our memories of them. Moreover, additional nights of sleep may continue to modify the memory.

In a different approach, another recent study has found that when volunteers were taught new words in the evening, then tested immediately, before spending the night in the sleep lab and being retested in the morning, they could remember more words in the morning than they did immediately after learning them, and they could recognize them faster. In comparison, a control group who were trained in the morning and re-tested in the evening showed no such improvement on the second test.

Deep sleep (slow-wave sleep) rather than rapid eye movement (REM) sleep or light sleep appeared to be the important phase for strengthening the new memories. Moreover, those who experienced more sleep spindles overnight were more successful in connecting the new words to the rest of the words in their mental lexicon, suggesting that the new words were communicated from the hippocampus to the neocortex during sleep. Sleep spindles are brief but intense bursts of brain activity that reflect information transfer between the hippocampus and the neocortex.

The findings confirm the role of sleep in reorganizing new memories, and demonstrate the importance of spindle activity in the process.

Taken together, these studies point to sleep being more important to memory than has been thought. The past decade has seen a wealth of studies establishing the role of sleep in consolidating procedural (skill) memory, but these findings demonstrate a deeper, wider, and more ongoing process. The findings also emphasize the malleability of memory, and the extent to which they are constructed (not copied) and reconstructed.

Payne, J. D., & Kensinger E. A. (2010). Sleep's Role in the Consolidation of Emotional Episodic Memories. Current Directions in Psychological Science. 19(5), 290 - 295.

Tamminen, J., Payne J. D., Stickgold R., Wamsley E. J., & Gaskell G. M. (2010). Sleep Spindle Activity is Associated with the Integration of New Memories and Existing Knowledge. J. Neurosci.. 30(43), 14356 - 14360.

http://www.eurekalert.org/pub_releases/2010-11/afps-smy111210.php
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Why quiet time is important for learning & memory

As well as during sleep, it now appears that restful periods while you are awake are also times when consolidation can occur.

It is now well established that memories are consolidated during sleep. Now a new study has found that restful periods while you are awake are also times when consolidation can occur. The imaging study revealed that during resting (allowed to think about anything), there was correlated activity between the hippocampus and part of the lateral occipital complex. This activity was associated with improved memory for the previous experience. Moreover, the degree of activity correlated with how well it was remembered. You can watch a 4 ½ minute video where the researchers explain their study at http://www.cell.com/neuron/abstract/S0896-6273%2810%2900006-1

Tambini, A., Ketz, N. & Davach, L. 2010. Enhanced Brain Correlations during Rest Are Related to Memory for Recent Experiences. Neuron, 65 (2), 280-290.

http://www.eurekalert.org/pub_releases/2010-01/nyu-ama012210.php

A midday nap markedly boosts the brain's learning capacity

Students given a 90-minute nap in the early afternoon, after a rigorous learning task, did markedly better at a later round of learning exercises, compared to those who remained awake throughout the day.

Following on from research showing that pulling an all-nighter decreases the ability to cram in new facts by nearly 40%, a study involving 39 young adults has found that those given a 90-minute nap in the early afternoon, after being subjected to a rigorous learning task, did markedly better at a later round of learning exercises, compared to those who remained awake throughout the day. The former group actually improved in their capacity to learn, while the latter became worse at learning. The findings reinforce the hypothesis that sleep is needed to clear the brain's short-term memory storage and make room for new information. Moreover, this refreshing of memory capacity was related to Stage 2 non-REM sleep (an intermediate stage between deep sleep and the REM dream stage).

The preliminary findings were presented February 21, at the annual meeting of the American Association of the Advancement of Science (AAAS) in San Diego, Calif.

http://www.eurekalert.org/pub_releases/2010-02/uoc--amn021110.php

Sleep helps consolidation of a complex motor-learning task

Another study demonstrating the benefits of sleep for learning motor skills (in this case, a popular video game called "Guitar Hero III".

A number of studies have shown the benefits of sleep for consolidating motor learning. A new study extends this research to a more complex motor task: "Guitar Hero III", a popular video game. There was significantly greater improvement after a night's sleep (average 68% in performance accuracy vs 63% for students who learnt the task in the morning and were tested in the evening), and a significant correlation between sleep duration and the amount of improvement.

Higginson, C.D. et al. 2010. So you wanna be a rock star? Sleep on it. Presented at SLEEP 2010, the 24th annual meeting of the Associated Professional Sleep Societies LLC, in San Antonio, Texas.

http://www.eurekalert.org/pub_releases/2010-06/aaos-smh052610.php

Dreams are the brain's way of communicating important memory functions

It's now well established that sleep plays an important role in memory and learning. Now a new study suggests that dreams also play a part in consolidating memories — perhaps reflecting the brain's attempt to find useful associations.

It's now well established that sleep plays an important role in memory and learning. Now a new study suggests that dreams also play a part in consolidating memories. The study involved 99 subjects training for an hour on a computerized maze task, and then either taking a 90-minute nap or engaging in quiet activities. Intermittently, subjects were asked to describe what was going through their minds, or what they had been dreaming about. Five hours after training, the subjects were retested on the maze task. While those who hadn't slept showed no improvement on the second test (even if they had reported thinking about the maze during their rest period), and those nappers who reported no maze-related dreams also showed little improvement, those who dreamed about the task showed dramatic improvement. Those who dreamed about the task were not more interested or motivated, but they were more likely to have performed relatively poorly during training — suggesting that the sleeping brain is more likely to focus on areas of greatest need. The researchers believe not that dreaming causes you to remember, but that dreaming is a marker that the brain is working on a problem at many levels — perhaps reflecting the brain's attempt to find useful associations.

Wamsley, E. J., Tucker M., Payne J. D., Benavides J. A., & Stickgold R. (2010). Dreaming of a Learning Task Is Associated with Enhanced Sleep-Dependent Memory Consolidation. Current Biology. 20(9), 850 - 855.

http://www.eurekalert.org/pub_releases/2010-04/bidm-dat042010.php
http://www.eurekalert.org/pub_releases/2010-04/cp-tlb041510.php

A midday nap markedly boosts the brain's learning capacity

Following on from research showing that pulling an all-nighter decreases the ability to cram in new facts by nearly 40%, a study involving 39 young adults has found that those given a 90-minute nap in the early afternoon, after being subjected to a rigorous learning task, did markedly better at later round of learning exercises, compared to those who remained awake throughout the day. The former group actually improved in their capacity to learn, while the latter became worse at learning. The findings reinforce the hypothesis that sleep is needed to clear the brain's short-term memory storage and make room for new information. Moreover, this refreshing of memory capacity was related to Stage 2 non-REM sleep (an intermediate stage between deep sleep and the REM dream stage).

The preliminary findings were presented February 21, at the annual meeting of the American Association of the Advancement of Science (AAAS) in San Diego, Calif.

http://www.eurekalert.org/pub_releases/2010-02/uoc--amn021110.php

Helping memory consolidation while you sleep

The role of sleep in consolidating new learning is now well-established, but now a study intriguingly reveals that you can improve that learning by playing sounds associated with the learning while you are asleep. The study involved 12 volunteers learning to associate each of 50 images with a random location on a computer screen. Each object was paired with its associated sound. Some 45 minutes after they had successfully mastered this task, each participant lay down in a quiet, darkened room. Once deeply asleep, 25 of these sounds were played. Although none of the participants noticed these sounds, performance was subsequently more accurate for those objects whose sounds had been played during sleep. The findings reveal that memory consolidation can be directed to specific memories through use of such cues. Another recent study found smells could also be used in this way.

Rudoy, J. D., Voss J. L., Westerberg C. E., & Paller K. A. (2009). Strengthening Individual Memories by Reactivating Them During Sleep. Science. 326(5956), 1079 - 1079.

http://www.eurekalert.org/pub_releases/2009-11/nu-wum111209.php

Sleep helps reduce errors in memory

A study in which college students were shown lists of words and then, 12 hours later, asked to identify which words they had seen or heard earlier, found that those who trained at night and tested the following morning were less prone to falsely recognizing semantically similar words than those who trained in the morning and tested in the evening. It's suspected that sleep may help strengthen the source of the memory, thus helping protect against false memories.

Fenn, K. M., Gallo D. A., Margoliash D., Roediger H. L., & Nusbaum H. C. (2009). Reduced false memory after sleep. Learning & Memory. 16(9), 509 - 513.

http://www.eurekalert.org/pub_releases/2009-09/msu-shr_1091009.php

How sleep consolidates memory

A rat study provides clear evidence that "sharp wave ripples", brainwaves that occur in the hippocampus when it is "off-line", most often during stage four sleep, are responsible for consolidating memory and transferring the learned information from the hippocampus to the neocortex, where long-term memories are stored. The study found that when these waves were eliminated during sleep, the rats were less able to remember a spatial navigation task.

Girardeau, G., Benchenane K., Wiener S. I., Buzsaki G., & Zugaro M. B. (2009). Selective suppression of hippocampal ripples impairs spatial memory. Nat Neurosci. 12(10), 1222 - 1223.

http://www.eurekalert.org/pub_releases/2009-09/ru-deo091509.php

Memories practiced throughout the day, not just while sleeping

It is known that a certain amount of replaying of experiences occurs in the hippocampus immediately afterwards, but it has been thought that this is confined to the immediate past, while the replaying that occurs during sleep and is thought to be part of the memory consolidation process, ranges far more widely. Now a new rat study indicates that the replaying that occurs while the animal is awake is more extensive than thought, and more accurate than that which occurs during sleep. Data from the neurons indicated that the events being replayed (repeatedly) were from 20 to 30 minutes earlier, and involved different settings, indicating the replay wasn't dependent on incoming sensory cues. It's suggested that the less-accurate replays seen during sleep are more aimed at making connections, rather than consolidating the actual experience. The waking replays occurred during pauses in activity, perhaps suggesting the importance of making pauses for reflection during your day!

Karlsson, M. P., & Frank L. M. (2009). Awake replay of remote experiences in the hippocampus. Nature Neuroscience. 12(7), 913 - 918.

http://www.eurekalert.org/pub_releases/2009-06/uoc--mmb061109.php

Creative problem solving enhanced by REM sleep

A study investigating the role of sleep in creative problem-solving has found that those who experienced REM sleep between two tests performed significantly better on the later test compared to those who simply had a quiet rest, or those who napped but had no REM sleep. The findings support the idea that REM sleep (when dreams occur) has a role in forming new associations. It's suggested that the process may be facilitated by changes to neurotransmitter systems (cholinergic and noradrenergic) during REM sleep.

Cai, D. J., Mednick S. A., Harrison E. M., Kanady J. C., & Mednick S. C. (2009). REM, not incubation, improves creativity by priming associative networks. Proceedings of the National Academy of Sciences. 106(25), 10130 - 10134.

http://www.eurekalert.org/pub_releases/2009-06/uoc--lms060309.php

Sleep may be important in regulating emotional responses

A study involving 44 college students who were asked to remember scenes with neutral or negative objects on a neutral background has found that those who trained and tested on the scenes in the evening remembered the negative scenes better than those who were trained and tested in the morning. However, neutral objects were not better remembered, and the backgrounds associated with negative objects were more poorly remembered by this group. The pattern persisted when the students were tested four months later. The findings suggest that the sleeping brain calculates what is most important about an experience and selects only what is adaptive for consolidation and long term storage.

Payne, J.D., Kensinger, E., Wamsley, E. & Stickgold, R. 2009. Sleep Promotes Lasting Changes in Memory for Emotional Scenes. Presented on June 11 at SLEEP 2009, the 23rd Annual Meeting of the Associated Professional Sleep Societies; Abstract ID: 1244.

http://www.eurekalert.org/pub_releases/2009-06/aaos-smb060209.php

Sleep may help clear the brain for new learning

Although fruit flies may seem little like us, their response to sleep deprivation is similar, and so they are useful models for sleep effects on the human brain. In a recent study, flies genetically altered to make it easier to track individual synapses have revealed that during sleep the number of new synapses formed during earlier learning decreased. This decline didn't happen if the flies were deprived of sleep. It's theorized that this activity during sleep is a way of pruning the less relevant and important synapses (clearing away the junk, as it has been conceptualized). The study follows earlier fruit fly research showing that more learning resulted in longer sleep. It also supports recent rat research that found synaptic strength increases during the day, then weakens during sleep. The study also identified three genes essential to the links between learning and increased need for sleep, one of which is equivalent to a human gene known as serum response factor (SRF) and previously linked to brain plasticity.

Donlea, J. M., Ramanan N., & Shaw P. J. (2009). Use-Dependent Plasticity in Clock Neurons Regulates Sleep Need in Drosophila. Science. 324(5923), 105 - 108.

http://www.eurekalert.org/pub_releases/2009-04/wuso-smh033109.php
http://www.eurekalert.org/pub_releases/2009-04/uow-ssc033009.php

Sleep helps you learn complicated tasks & recover forgotten skills

A study involving 200 mostly female college students, who had little experience of video games. The students were taught to play a complicated, multisensory video game in which players must use both hands to deal with continually changing visual and auditory signals. Half were tested 12 hours after the training session, and the others 24 hours later. Some were given a night's sleep before testing, others were tested the same day. Performance in the former dropped by half at testing, but when tested again the following morning, they showed a 10 percentage point improvement over their pre-test performance. For those given evening training, scores improved by about 7 percentage points, then went to 10 percentage points the next morning – which was maintained over the day. The findings indicate that although people may appear to forget much of their learning over the course of a day, a night's sleep will restore it; moreover, sleep protected the memory from loss over the course of the next day. The findings confirm the role of sleep in consolidating memory for skills, and extends the research to complicated tasks.

Brawn, T. P., Fenn K. M., Nusbaum H. C., & Margoliash D. (2008). Consolidation of sensorimotor learning during sleep. Learning & Memory, 15(11), 815 - 819.

http://www.eurekalert.org/pub_releases/2008-11/uoc-shp111708.php

Sleep selectively preserves emotional memories

It's now generally accepted that sleep plays an important role in consolidating procedural (skill) memories, but the position regarding other types of memory has been less clear. A new study has found that sleep had an effect on emotional aspects of a memory. The study involved showing 88 students neutral scenes (such as a car parked on a street in front of shops) or negative scenes (a badly crashed car parked on a similar street). They were then tested for their memories of both the central objects in the pictures and the backgrounds in the scenes, either after 12 daytime hours, or 12 night-time hours, or 30 minutes after viewing the images, in either the morning or evening. Those tested after 12 daytime hours largely forgot the entire negative scene, forgetting both the central objects and the backgrounds equally. But those tested after a night's sleep remembered the emotional item (e.g., the smashed car) as well as those who were tested only 30 minutes later. Their memory of the neutral background was however, as bad as the daytime group. The findings are consistent with the view that the individual components of emotional memory become 'unbound' during sleep, enabling the brain to selectively preserve only that information it considers important.

Payne, J. D., Stickgold R., Swanberg K., & Kensinger E. A. (2008). Sleep preferentially enhances memory for emotional components of scenes. Psychological Science, 19(8), 781 - 788.

http://www.physorg.com/news137908693.html
http://www.eurekalert.org/pub_releases/2008-08/bidm-sft081308.php

Aging impairs the 'replay' of memories during sleep

During sleep, the hippocampus repeatedly "replays" brain activity from recent experiences, in a process believed to be important for memory consolidation. A new rat study has found reduced replay activity during sleep in old compared to young rats, and rats with the least replay activity performed the worst in tests of spatial memory. The best old rats were also the ones that showed the best sleep replay. Indeed, the animals who more faithfully replayed the sequence of neural activity recorded during their earlier learning experience were the ones who performed better on the spatial memory task, regardless of age. The replay activity occurs during slow-wave sleep.

Gerrard, J. L., Burke S. N., McNaughton B. L., & Barnes C. A. (2008). Sequence Reactivation in the Hippocampus Is Impaired in Aged Rats. J. Neurosci., 28(31), 7883 - 7890.

http://www.eurekalert.org/pub_releases/2008-07/sfn-ait072408.php

A nap can help you learn

A study of 33 younger adults (average are 23) has found that a 45 minute afternoon nap (containing only non-REM sleep) improved performance on 3 different declarative memory tasks, but only when the subjects had reached a certain level of performance during training.

Tucker, M. A., & Fishbein W. (2008). Enhancement of declarative memory performance following a daytime nap is contingent on strength of initial task acquisition. Sleep. 31(2), 197 - 203.

http://www.eurekalert.org/pub_releases/2008-02/aaos-jss012808.php

Brain connections strengthen during waking hours, weaken during sleep

New research provides support for a much-debated theory that we need sleep to give our synapses time to rest and recover. The human brain is said to expend up to 80% of its energy on synaptic activity, constantly adding and strengthening connections in response to stimulation. The researchers have theorized that we need an 'off-line period', when we are not exposed to the environment, to take synapses down. The rodent study has revealed by several measures that synapses — the all-important points of connection between neurons — are very active when the animal is awake and very quiet during sleep. The researchers feel that these findings support the idea that our brain circuits get progressively stronger during wakefulness and that sleep helps to recalibrate them to a sustainable baseline. This theory is of course opposite to the currently dominant hypothesis, that during sleep synapses are hard at work replaying the information acquired during the previous waking hours, consolidating that information by becoming even stronger.

Vyazovskiy, V. V., Cirelli C., Pfister-Genskow M., Faraguna U., & Tononi G. 2008). Molecular and electrophysiological evidence for net synaptic potentiation in wake and depression in sleep. Nat Neurosci. 11(2), 200 - 208.

http://www.physorg.com/news120059987.html

Sleep reinforces the temporal sequence in memory

Following on from research showing long-term memory is consolidated during sleep through the replaying of recently encoded experiences, a study has found that the particular order in which they were experienced is also strengthened, probably by a replay of the experiences in "forward" direction. The study involved students being asked to learn triplets of words presented one after the other. Those whose recall of the order of the words was tested after sleep showed better recall, but only when they were asked to reproduce the learned words in forward direction.

Drosopoulos, S., Windau E., Wagner U., & Born J. (2007). Sleep Enforces the Temporal Order in Memory. PLoS ONE. 2(4), e376 - e376.

http://www.eurekalert.org/pub_releases/2007-04/plos-set041707.php

Sleep protects against interference

A study involving 48 people (aged 18—30) found that those who learned 20 pairs of words at 9pm and were tested at 9am the following morning, after a night's sleep, performed better than those who learned them at 9am and were tested at 9pm of the same day. Moreover, for those who were given a second list of word pairs to remember just before testing, where the first word in each pair was the same as on the earlier list, the advantage of sleep was dramatically better. For those who experienced the interference manipulation, those in the sleep group recalled 12% more word pairs than the wake group, but with interference, the recall rate was 44% higher for the sleep group.

The findings were presented by Dr Jeffrey Ellenbogen at the American Academy of Neurology's 59th Annual Meeting in Boston, April 28 – May 5, 2007.

http://www.eurekalert.org/pub_releases/2007-04/aaon-ssy040307.php

Sleeping helps us put facts together

And in yet another sleep study, researchers found evidence that sleep also helps us see the big picture. The study involved 56 students who were shown oval images of colorful abstract patterns nicknamed "Fabergé eggs." Participants were first shown a combination of five pairs of the eggs, all of which were given ratings. The students were given 30 minutes to learn which shape rated higher and so should be chosen over another shape. They were not told the hidden connection that linked all five pairs together. They were then tested either after 20 minutes, after 12 hours, or after 24 hours. Half of those in the 12-hour group slept before the test, the other half did not. The 20-minute group performed the worst, showing no evidence of seeing the pattern. Those who had longer before being tested were much more likely to show signs of inferential judgment (75% vs 52%), and for the most distant (and difficult) inferential judgment, the students who had had periods of sleep in between learning and testing significantly outperformed those who hadn't slept (93% vs 69%). The researchers are interested in exploring whether meditation can provide a similar benefit.

[749] Ellenbogen, J. M., Hu P. T., Payne J. D., Titone D., & Walker M. P. (2007). Human relational memory requires time and sleep. Proceedings of the National Academy of Sciences. 104(18), 7723 - 7728.

http://www.physorg.com/news98376198.html
http://www.eurekalert.org/pub_releases/2007-04/bidm-tut042007.php

More on how memories are consolidated during sleep

A new study sheds more light on how memory is consolidated during sleep. Using a new technique, the research confirms that new information is transferred between the hippocampus and the cerebral cortex, and, unexpectedly, provides evidence suggesting that the cerebral cortex actively controls this transfer.

[834] Hahn, T. T. G., Sakmann B., & Mehta M. R. (2006). Phase-locking of hippocampal interneurons' membrane potential to neocortical up-down states. Nat Neurosci. 9(11), 1359 - 1361.

http://www.eurekalert.org/pub_releases/2006-12/m-lds120506.php

Still more on how memories are consolidated during sleep

In research following up an earlier study in which rats were shown to form complex memories for sequences of events experienced while they were awake, and that these memories were replayed while they slept, it has been shown that these replayed memories do contain the visual images that were present during the running experience. By showing that the brain is replaying memory events in the visual cortex and in the hippocampus at the same time, the finding suggests that this process may contribute to or reflect the result of the memory consolidation process.

[317] Ji, D., & Wilson M. A. (2007). Coordinated memory replay in the visual cortex and hippocampus during sleep. Nat Neurosci. 10(1), 100 - 107.

http://www.eurekalert.org/pub_releases/2006-12/miot-mtr121806.php

Brainwave oscillations responsible for memory benefits of sleep?

Passing a mild electrical current through the brain while students were asleep improved their ability to remember words on waking up. 13 medical students were given 46 pairs of words to learn. Before sleeping, they remembered an average 37.42 words; after sleep, those not given the stimulation remembered an average of 39.5, while those given the stimulation remembered an average of 41.27. The memory enhancement only occurred at a certain frequency and during a particular part of the sleep cycle, confirming the idea that slow oscillations of electrical activity are responsible for the memory consolidation effects of sleep. The benefit also only applied to fact learning; skill learning was not affected.

[238] Marshall, L., Helgadottir H., Molle M., & Born J. (2006). Boosting slow oscillations during sleep potentiates memory. Nature. 444(7119), 610 - 613.

http://www.guardian.co.uk/science/story/0,,1940475,00.html
http://www.sciam.com/article.cfm?chanID=sa003&articleID=BEC346B2-E7F2-99DF-350CC33BA6757700
http://www.nature.com/news/2006/061030/full/444133a.html

More support that sleep helps consolidate learning

An experiment involving fruitflies has found that those in a social environment with at least 30 other flies slept four times as long during their daytime naps as flies in isolation. There was no difference in night-time sleep. The length of the nap increased with the size of the group they socialized with. Confirming that this effect was due to an increase in social interactions, rather than, for example, physical exhaustion from flying around more, flies deprived of their sight and sense of smell (meaning they could still fly around but could not socialize) showed no difference in daytime sleep patterns. Of 49 genes known to be involved in learning and memory, switching off seventeen (all related to long-term memory) made the flies sleep equally long regardless of whether they were social or not.

[894] Ganguly-Fitzgerald, I., Donlea J., & Shaw P. J. (2006). Waking Experience Affects Sleep Need in Drosophila. Science. 313(5794), 1775 - 1781.

http://www.nature.com/news/2006/060918/full/060918-9.html
http://www.livescience.com/humanbiology/060921_flies_sleep.html

Human study supports value of daytime napping for learning

REM sleep, when most dreaming occurs, has been shown in a number of studies to be important in consolidating procedural (skill) learning, while non-REM (slow-wave) sleep seems to be more important for declarative (knowledge-based) learning. However, because normal sleep contains both REM and non-REM cycles, research hasn't been able to clearly distinguish the effects. Now a new study using brief daytime napping confirms the role of non-REM sleep for declarative learning. Volunteers who memorized pairs of words and practiced tracing images in a mirror test scored 15% better in the word test if they had been allowed a nap in the six hour period before being tested. However, they did no better at the action test.

[414] Tucker, M. A., Hirota Y., Wamsley E. J., Lau H., Chaklader A., & Fishbein W. (2006). A daytime nap containing solely non-REM sleep enhances declarative but not procedural memory. Neurobiology of Learning and Memory. 86(2), 241 - 247.

Sleep makes memories resistant to interference

It's pretty clear now that sleep consolidates procedural (skill) learning, but the question of whether or not it helps other types of memory is still very much a matter of debate. However, a new study has found a marked effect of sleep on our ability to remember information. The study involved 60 healthy college-aged adults, who were asked them to memorize 20 pairs of random words. Half were given the words at 9am and tested at 9pm, and the other half were given the words at 9pm and tested at 9am. While the sleepers did perform better (94% recall compared to 82%), it was the introduction of another factor that made the benefits of sleep undeniable. Participants who were given a new set of words to learn just 12 minutes before testing revealed a dramatic difference — sleepers recalled 76% of the original words compared to 32% of the sleepless.

[974] Ellenbogen, J. M., Hulbert J. C., Stickgold R., Dinges D. F., & Thompson-Schill S. L. (2006). Interfering with Theories of Sleep and Memory: Sleep, Declarative Memory, and Associative Interference. Current Biology. 16(13), 1290 - 1294.

http://www.sciencedaily.com/releases/2006/07/060711095912.htm
http://www.sciam.com/article.cfm?chanID=sa003&articleID=0006A257-BBB4-14B2-B8B983414B7F4945

Asleep or awake we retain memory

We've learned that skill memory is reinforced during sleep, but now new imaging technology reveals that this kind of reinforcement occurs while we're awake too — even while we're learning something new.

[475] Peigneux, P., Orban P., Balteau E., Degueldre C., Luxen A., Laureys S., et al. (2006). Offline Persistence of Memory-Related Cerebral Activity during Active Wakefulness. PLoS Biol. 4(4), e100 - e100.

http://www.eurekalert.org/pub_releases/2006-03/plos-aoa032206.php
http://www.sciencedaily.com/releases/2006/03/060329085308.htm

How sleep improves memory

While previous research has been conflicting, it does now seem clear that sleep consolidates learning of motor skills in particular. A new imaging study involving 12 young adults taught a sequence of skilled finger movements has found a dramatic shift in activity pattern when doing the task in those who were allowed to sleep during the 12 hour period before testing. Increased activity was found in the right primary motor cortex, medial prefrontal lobe, hippocampus and left cerebellum — this is assumed to support faster and more accurate motor output. Decreased activity was found in the parietal cortices, the left insular cortex, temporal pole and fronto-polar region — these are assumed to reflect less anxiety and a reduced need for conscious spatial monitoring. It's suggested that this is one reason why infants need so much sleep — motor skill learning is a high priority at this age. The findings may also have implications for stroke patients and others who have suffered brain injuries.

[670] Walker, M. P., Stickgold R., Alsop D., Gaab N., & Schlaug G. (2005). Sleep-dependent motor memory plasticity in the human brain. Neuroscience. 133(4), 911 - 917.

http://www.eurekalert.org/pub_releases/2005-06/bidm-ssh062805.php

More evidence that learning is consolidated during sleep

A new study provides more evidence for the role of sleep in the consolidation of long-term memories. In the study, volunteers learned the layout of a virtual town, and were then tested by having to quickly find routes to various locations in the town. Those so trained showed greater activity in their hippocampus and an adjacent learning-related region (compared to those not trained) as they took the route tests, with greater activity correlated with better performance. They also showed greater hippocampal brain activity during sleep. Most importantly, the higher the gain in post-sleep performance on the tests, the higher had been their NREM brain activity during sleep. No such correlation was found in REM brain activity. The findings support the view that spatial memory traces are processed during NREM sleep in humans.

[1182] Aerts, J., Luxen A., Maquet P., Peigneux P., Laureys S., Fuchs S., et al. (2004). Are spatial memories strengthened in the human hippocampus during slow wave sleep?. Neuron. 44(3), 535 - 545.

http://www.eurekalert.org/pub_releases/2004-10/cp-etl102204.php

Mentally, sleep may be as active a state as waking state

Why do we sleep? A question we keep asking. Recent research leads us another step in the road. The study has identified a number of genes upregulated specifically during sleep – at least as many as are turned on while we are awake. These "sleep genes" largely fall into four categories: genes involved in synaptic plasticity (supporting the view that sleep aids memory consolidation); genes underlying translation (supporting observations that protein synthesis increases during sleep); genes regulating membrane and vesicle trafficking; and genes for synthesizing cholesterol (which may be crucial for synapse formation and maintenance, which could, in turn, enhance neural plasticity (the brain's ability to change and learn)). The study also found, to the researchers' surprise, that the cerebellum showed largely the same pattern of gene-expression during sleep as the cortex.

[1021] Cirelli, C., Gutierrez C. M., & Tononi G. (2004). Extensive and divergent effects of sleep and wakefulness on brain gene expression. Neuron. 41(1), 35 - 43.

More on what goes on during sleep

Brain activity patterns vary during sleep, with particular distinction being made between "REM" sleep and "deep" sleep. Both these phases of sleep have been associated with memory processing. The chemical composition of the brain also varies a great deal in the sleep and wakefulness cycle. New research from Germany now report that some of these differences are crucial in memory formation during sleep. In particular, the level of acetylcholine (a neurotransmitter) is high during wakefulness and REM sleep but drops to the minimum in deep sleep. In an experiment that involved subjects performing two memory tasks – learning 40 pairs of semantically related words, and learning to trace figures seen in a mirror – before sleeping for four hours, it was found that those who were given a cholinesterase inhibitor, (cholinesterase being an enzyme that breaks down acetylcholine), performed significantly less well in the wordlist task on wakening. The mirror-tracing task didn't seem to be affected. This supports the idea that a low level of acetylcholine is necessary for strengthening explicit memory during deep sleep, and fits in with a proposed two-stage model of long-term memory formation, in which the cortex transfers newly acquired experiential data to the hippocampus for processing and temporary storage (a process requiring high levels of acetylcholine), and then, during sleep, the processed memory traces in the hippocampus are relayed back to the cortex for long-term storage. This feedback process is blocked by acetylcholine and, thus, only happens in sleep when the acetylcholine level drops to the minimum.
The research may also have important implications for treating memory loss associated with

Alzheimer's disease, as cholinesterase inhibitors are widely used in such treatment. Because of common side-effects of the drug, patients are usually told to take it at night, which may well weaken the drug's effectiveness.

[999] Gais, S., & Born J. (2004). Low acetylcholine during slow-wave sleep is critical for declarative memory consolidation. Proceedings of the National Academy of Sciences of the United States of America. 101(7), 2140 - 2144.

Now definite? Memories are consolidated during sleep

Researchers of a new study claim that their research finally settles the question of whether or not sleep consolidates new memories. The study involved detailed recording of specific learning- and memory- related areas (hippocampus and forebrain) in the brains of rats. The rats were exposed to four kinds of novel objects. Analysis of brain signals before, during, and after this experience, revealed "reverberations" of distinctive brain wave patterns across all the areas being monitored for up to 48 hours after the novel experience. This pattern was much more prevalent in slow-wave sleep than in REM sleep. Previous studies by the same researchers have found that the activation of genes that affect memory consolidation occurs during REM sleep, not slow-wave sleep. It is proposed that both stages of sleep are important for memory consolidation. Previous studies have tended to focus solely on the hippocampus, and have observed brain activity for a much shorter period.

[793] Ribeiro, S., Gervasoni D., Soares E. S., Zhou Y., Lin S. - C., Pantoja J., et al. (2004). Long-lasting novelty-induced neuronal reverberation during slow-wave sleep in multiple forebrain areas. PLoS Biology. 2(1), E24 - E24.

http://www.eurekalert.org/pub_releases/2004-01/dumc-etm011304.php
http://www.eurekalert.org/pub_releases/2004-01/plos-brd011204.php
Full text available at http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0020037

Sleep helps insight

A new German study provides evidence for what we all suspected — "sleeping on" a problem can really work. In the study, participants were given a mathematical puzzle to solve; a puzzle which could be solved by trial-by-trial learning, or almost immediately if participants grasped the hidden rule. After training in the trial-by-trial learning, some of the participants were allowed to sleep through the night, while others were prevented from sleeping. When they returned to the problem eight hours later, those that had slept were twice as likely to realize the rule. Another group that trained in the morning, and were then tested later that day, were also slower at finding the rule, suggesting that the slowness was not solely due to fatigue. Sleep did not, however, help participants who had not had the initial training. It is suggested that sleep can act to restructure new memory representations.

[1382] Wagner, U., Gais S., Haider H., Verleger R., & Born J. (2004). Sleep inspires insight. Nature. 427(6972), 352 - 355.

http://www.sciam.com/article.cfm?chanID=sa003&articleID=000088CE-E9DC-100E-A9DC83414B7F0000
http://www.nature.com/nsu/040119/040119-10.html
http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v427/n6972/abs/nature02223_fs.html

Stages of memory clarified in sleep studies

Two new studies add to our understanding of the effects of sleep on memory. Both studies involved young adults and procedural (skill) learning, and found temporary declines in performance in particular contexts (a brief description of these studies is given here). On the basis of these studies, researchers identified three stages of memory processing: the first stage of memory — its stabilization — seems to take around six hours. During this period, the memory appears particularly vulnerable to being "lost". The second stage of memory processing — consolidation — occurs during sleep. The third and final stage is the recall phase, when the memory is once again ready to be accessed and re-edited. (see my article on consolidation for more explanation of the processes of consolidation and re-consolidation). The surprising aspect to this is the time it appears to take for memories to initially stabilize. The studies also confirm the role of sleep in the consolidation process.

[1027] Fenn, K. M., Nusbaum H. C., & Margoliash D. (2003). Consolidation during sleep of perceptual learning of spoken language. Nature. 425(6958), 614 - 616.

[518] Walker, M. P., Brakefield T., Allan Hobson J., & Stickgold R. (2003). Dissociable stages of human memory consolidation and reconsolidation. Nature. 425(6958), 616 - 620.

http://www.eurekalert.org/pub_releases/2003-10/bidm-som100703.php
http://www.sciencenews.org/20031011/fob4.asp
http://education.guardian.co.uk/higher/research/story/0,9865,1059138,00.html

More support for the theory that sleep is necessary to consolidate memories

A study used fear conditioning in mice to investigate the effect of sleep deprivation on memory. The mice were given a mild electric shock either in a distinctive setting, or subsequent to a tone. Those who experienced the tone continued to freeze when they heard the tone on the following day, whether or not they had been deprived of sleep. Those who associated the environment with the shock, however, were less likely to freeze after sleep deprivation. Mice who had been deprived of sleep during the five hours following training, spent just 4% of their time frozen when returned to the 'shock environment' the following day, compared to 15% among mice who were allowed to sleep during this period. The five hours following training was a critical period – those who were deprived of sleep in the 5-10 hours after training showed no sign of memory impairment. The fact that the context association was affected but not the tone cue, suggests that sleep is affecting processes in the hippocampus (important in context memory but not memory for specific facts or events).

[625] Graves, L. A. (2003). Sleep Deprivation Selectively Impairs Memory Consolidation for Contextual Fear Conditioning. Learning & Memory. 10(3), 168 - 176.

http://www.eurekalert.org/pub_releases/2003-07/uop-sdw070803.php

Another step in understanding how sleep affects memory

The value of sleep for memory takes a further step in being understood in new rodent research, which found that, as the rodents slept, the thalamus at the base of their brains originated bursts of electrical activity ("sleep spindles"), which were then detected in the somatosensory neocortex. Some 50 msec later, the hippocampus responded with a pulse of electricity (a "ripple"). "This neocortical-hippocampal dialogue may provide a selection mechanism for the time-compressed replay of information learned during the day." It's suggested that the ripple is the hippocampus sending back neat, compact waves of memory to the neocortex where they are filed away for future reference. Most of this activity took place during slow wave sleep, the stage which makes up the majority of the sleep cycle.

[907] Wirth, S., Yanike M., Frank L. M., Smith A. C., Brown E. N., & Suzuki W. A. (2003). Single Neurons in the Monkey Hippocampus and Learning of New Associations. Science. 300(5625), 1578 - 1581.

http://www.eurekalert.org/pub_releases/2003-06/nyu-fir060503.php

Napping reverses information overload

Evidence is mounting that sleep helps information processing and learning. A new study has showed that subjects performing a visual task (reporting the horizontal or vertical orientation of three diagonal bars against a background of horizontal bars in the corner of a computer screen) got worse over the course of four daily practice sessions. However, allowing subjects a 30-minute nap after the second session prevented any further deterioration, and a 1-hour nap actually boosted performance in the third and fourth sessions back to morning levels. It appears that the fatigue is limited to the brain visual system circuits involved in the task. When the image was switched to a different right corner of the computer screen on the fourth practice session, subjects performed about as well as they did in the first session -- or after a short nap. Recordings of brain activity reveal that the 1-hour naps contained more than four times as much deep, or slow wave sleep and rapid eye movement (REM) sleep than the half-hour naps.

[758] Mednick, S. C., Nakayama K., Cantero J. L., Atienza M., Levin A. A., Pathak N., et al. (2002). The restorative effect of naps on perceptual deterioration. Nat Neurosci. 5(7), 677 - 681.

http://www.eurekalert.org/pub_releases/2002-07/niom-np070102.php

Improving motor skills through sleep

People taught a simple motor sequence (to type a sequence of keys on a computer keyboard as quickly and accurately as possible) practised it for 12 minutes and were then re-tested 12 hours later. Those who practised in the morning and tested later that same day improved their performance by about 2%. Those trained in the evening and re-tested after a good night's sleep, however, improved by about 20%. The amount of improvement was directly correlated with the amount of Stage 2 (a stage of non-rapid eye movement or NREM) sleep experienced, particularly late in the night. "This is the part of a good night's sleep that many people will cut short by getting up early in the morning."

[767] Laureys, S., Peigneux P., Perrin F., & Maquet P. (2002). Sleep and motor skill learning. Neuron. 35(1), 5 - 7.

http://www.eurekalert.org/pub_releases/2002-07/hms-pmp070102.php

Controversy over sleep's role in memory

Does sleep play a role in memory or not? Two new research papers reach opposite conclusions. One is from Robert Stickgold, who has published several papers supporting the role of sleep in memory consolidation. But the other is a new review of REM sleep studies concluding that REM (rapid eye movement) sleep, or dreaming, plays little role in memory formation, chiefly on the basis that depriving animals and humans of REM sleep by awakening them or by drug treatments does not impair their ability to form long-term memories. In addition, the time spent in REM sleep does not correlate with learning ability across humans, nor is there a positive relation between amount or intensity of REM sleep and learning ability across species.

[987] Stickgold, R., Hobson J. A., Fosse R., & Fosse M. (2001). Sleep, Learning, and Dreams: Off-line Memory Reprocessing. Science. 294(5544), 1052 - 1057.

[1388] Siegel, J. M. (2001). The REM sleep-memory consolidation hypothesis. Science (New York, N.Y.). 294(5544), 1058 - 1063.

http://www.sciencemag.org/cgi/content/abstract/294/5544/1052
http://www.sciencemag.org/cgi/content/abstract/294/5544/1058

New motor skills consolidated during sleep

An imaging study that sheds light on the gain in performance observed during the day after learning a new task. Following training in a motor skill, certain brain areas appear to be reactived during REM sleep, resulting in an optimization of the network that subtends the subject's visuo–motor response.

[775] van der Linden, M., Cleeremans A., Smith C., Maquet P., Laureys S., Peigneux P., et al. (2001). Experience-dependent changes in cerebral functional connectivity during human rapid eye movement sleep. Neuroscience. 105(3), 521 - 525.

Deep "slow wave" sleep necessary to consolidate memories

Sleep is necessary to consolidate memories. Remembering a new task is more difficult if you don't sleep within 30 hours of learning the task. "Catch-up" sleep on subsequent nights doesn't make up for losing that first night's sleep. Moreover, it appears that the deep "slow wave" sleep that occurs in the first half of the night is the type of sleep necessary to consolidate memories. Other types of memory however, may require "REM" sleep (that occurs while you are dreaming).

Stickgold, R., James, L. & Hobson, J.A. 2000. Visual discrimination learning requires sleep after training. Nature Neuroscience,3, 1237-1238.

Sleep deprivation & cognition - news reports

Helping students & children get enough sleep

Simple interventions can help college students improve their sleep. Regular sleep habits are important for young children. Sleep deprivation especially affects performance on open-ended problems.

One survey of nearly 200 undergraduate college students who were not living with a parent or legal guardian found that 55% reported getting less than seven hours sleep. This is consistent with other surveys. The latest study confirms such a result, but also finds that students tend to think their sleep quality is better than it is (70% of students surveyed described their sleep as "fairly good" or better). It’s suggested that this disconnect arises from students making comparisons in an environment where poor sleep is common — even though they realized, on being questioned, that poor sleep undermined their memory, concentration, class attendance, mood, and enthusiasm.

None of this is surprising, of course. But this study did something else — it tried to help.

The researchers launched a campuswide media campaign consisting of posters, student newspaper advertisements and a "Go to Bed SnoozeLetter", all delivering information about the health effects of sleep and tips to sleep better, such as keeping regular bedtime and waking hours, exercising regularly, avoiding caffeine and nicotine in the evening, and so on. The campaign cost less than $2,500, and nearly 10% (90/971) said it helped them sleep better.

Based on interviews conducted as part of the research, the researchers compiled lists of the top five items that helped and hindered student sleep:

Helpers

- Taking time to de-stress and unwind
- Creating a room atmosphere conducive to sleep
- Being prepared for the next day
- Eating something
- Exercising

Hindrances

- Dorm noise
- Roommate (both for positive/social reasons and negative reasons)
- Schoolwork
- Having a room atmosphere not conducive to sleep
- Personal health issues

In another study, this one involving 142 Spanish schoolchildren aged 6-7, children who slept less than 9 hours and went to bed late or at irregular times showed poorer academic performance. Regular sleep habits affected some specific skills independent of sleep duration.

69% of the children returned home after 9pm at least three evenings a week or went to bed after 11pm at least four nights a week.

And a recent study into the effects of sleep deprivation points to open-ended problem solving being particularly affected. In the study, 35 West Point cadets were given two types of categorization task. The first involved categorizing drawings of fictional animals as either “A” or “not A”; the second required the students to sort two types of fictional animals, “A” and “B.” The two tests were separated by 24 hours, during which half the students had their usual night’s sleep, and half did not.

Although the second test required the students to learn criteria for two animals instead of one, sleep deprivation impaired performance on the first test, not the second.

These findings suggest the fault lies in attention lapses. Open-ended tasks, as in the first test, require more focused attention than those that offer two clear choices, as the second test did.

[2521] Orzech, K. M., Salafsky D. B., & Hamilton L. A. (2011). The State of Sleep Among College Students at a Large Public University. Journal of American College Health. 59, 612 - 619.

[2515] Cladellas, R., Chamarro A., del Badia M. M., Oberst U., & Carbonell X. (2011). Efectos de las horas y los habitos de sueno en el rendimiento academico de ninos de 6 y 7 anos: un estudio preliminarEffects of sleeping hours and sleeping habits on the academic performance of six- and seven-year-old children: A preliminary study. Cultura y Educación. 23(1), 119 - 128.

Maddox WT; Glass BD; Zeithamova D; Savarie ZR; Bowen C; Matthews MD; Schnyer DM. The effects of sleep deprivation on dissociable prototype learning systems. SLEEP 2011;34(3):253-260.

http://www.eurekalert.org/pub_releases/2011-08/bu-cff083011.php
http://www.eurekalert.org/pub_releases/2011-08/uoc-wcf083011.php
http://medicalxpress.com/news/2011-09-primary-schoolchildren-hours.html
http://www.scientificamerican.com/article.cfm?id=outsmarting-sleep-loss

Sleep and memory - round-up of recent reports

A round-up of recent reports relating to the role of sleep in consolidating memory.

Sleep can boost classroom performance of college students

There's a lot of evidence that memories are consolidated during sleep, but most of it has involved skill learning. A new study extends the findings to complex declarative information — specifically, information from a lecture on microeconomics.

The study involved 102 university undergraduates who had never taken an economics course. In the morning or evening they completed an introductory, virtual lecture that taught them about concepts and problems related to supply and demand microeconomics. They were then tested on the material either immediately, after a 12-hour period that included sleep, after 12 hours without sleep, or after one week. The test included both basic problems that they had been trained to solve, and "transfer" problems that required them to extend their knowledge to novel, but related, problems.

Performance was better for those who slept, and this was especially so for the novel, 'transfer' integration problems.

Rule-learning task also benefits from sleep

Another complex cognitive task was investigated in a study of 54 college undergraduates who were taught to play a card game for rewards of play money in which wins and losses for various card decks mimic casino gambling (the Iowa Gambling Task is typically used to assess frontal lobe function). Those who had a normal night's sleep as part of the study drew from decks that gave them the greatest winnings four times more often than those who spent the 12-hour break awake, and they better understood the underlying rules of the game.

The students were given a brief morning or afternoon preview of the gambling task (too brief to learn the underlying rule). They returned twelve hours later (i.e., either after a normal night's sleep, or after a day of their usual activities), when they played the full gambling task for long enough to learn the rules. Those who got to sleep between the two sessions played better and showed a better understanding of the rules when questioned.

To assure that time of day didn't explain the different performance, two groups of 17 and 21 subjects carried out both the preview and the full task either in the morning or the evening. Time of day made no difference.

Sleep problems may be a link between perceived racism and poor health

Analysis of data from the 2006 Behavioral Risk Factor Surveillance System, involving 7,093 people in Michigan and Wisconsin, suggests that sleep deprivation may be one mediator of the oft-reported association between discrimination and poorer cognitive performance.

The survey asked the question: "Within the past 12 months when seeking health care, do you feel your experiences were worse than, the same as, or better than for people of other races?" Taking this as an index of perceived racism, and comparing it with reports of sleep disturbance (difficulty sleeping at least six nights in the past two weeks), the study found that individuals who perceived racial discrimination were significantly more likely to experience sleep difficulties, even after allowing for socioeconomic factors and depression. Risk of sleep disturbance was nearly doubled in those who perceived themselves as discriminated against, and although this was reduced after depression was taken into account, it remained significant.

Sleep problems more prevalent than expected in urban minority children

Ten families also underwent sleep monitoring at home for five to seven days. All children who completed actigraphy monitoring had shortened sleep duration, with an average sleep duration of 8 hours, significantly less than the 10 to 11 hours recommended for children in this age group.

It's worth noting that parents consistently overestimated sleep duration. Although very aware of bedtime and wake time, parents are less aware of time spent awake during the night.

(Also note that the figures I quote are taken from the conference abstract, which differ from those quoted in the press release.)

Rocking really does help sleep

If you or your loved one is having troubles getting to sleep, you might like to note an intriguing little study involving 12 healthy males (aged 22-38, and good sleepers). The men twice took a 45-minute afternoon nap on a bed that could slowly rock. On one occasion, it was still; on the other, it rocked. Rocking brought about faster sleep, faster transition to deeper sleep, and increased slow oscillations and sleep spindles (hallmarks of deep sleep). All these results were evident in every participant.

Sleep helps long-term memory in two ways

A fruit fly study points to two dominant theories of sleep being correct. The two theories are (a) that synapses are pruned during sleep, ensuring that only the strongest connections survive (synaptic homeostasis), and (b) that memories are replayed and consolidated during sleep, so that some connections are reactivated and thus made stronger (memory consolidation).

The experiment was made possible by the development of a new strain of fruit fly that can be induced to fall asleep when temperatures rise. The synaptic homeostasis model was supported when flies were placed in socially enriched environments, then either induced to sleep or not, before being taught a courtship ritual. Those that slept developed long-term memories of the ritual, while those that didn't sleep didn't remember it. The memory consolidation theory was supported when flies trained using a protocol designed to give them short-term memories retained a lasting memory, if sleep was induced immediately after the training.

In other words, it seems that both pruning and replaying are important for building long-term memories.

Mouse studies identify the roots of memory impairment resulting from sleep deprivation

Sleep deprivation in known to result in increased levels of adenosine in the brain, whether fruit fly or human (caffeine blocks the effects of adenosine). New mice studies now reveal the mechanism.

Mice given a drug that blocked a particular adenosine receptor in the hippocampus (the A1 receptor) failed to show the normal memory impairment evoked by sleep deprivation (being woken halfway through their normal 12-hour sleep schedule). The same results occurred if mice were genetically engineered to lack a gene involved in the production of glial transmitters (necessary to produce adenosine).

Memory was tested by the mice being allowed to explore a box with two objects, and then returned to the box on the next day, where one of the two objects had been moved. They would normally explore the moved object more than other objects, but sleep-deprived mice don't usually react to the change, because they don't remember where the object had been. In both these cases, the sleep-deprived mice showed no memory impairment.

Both the drugged and genetically protected mice also showed greater synaptic plasticity in the hippocampus after being sleep deprived than the untreated group.

The two groups reveal two parts of the chemical pathway involved in sleep deprivation. The genetic engineering experiment shows that the adenosine comes from glia's release of adenosine triphosphate (ATP). The drug experiment shows that the adenosine goes to the A1 receptor in the hippocampus.

The findings provide the first evidence that astrocytic ATP and adenosine A_1R activity contribute to the effects of sleep deprivation on hippocampal synaptic plasticity and hippocampus-dependent memory, and suggest a new therapeutic target to reverse the cognitive deficits induced by sleep loss.

Scullin M, McDaniel M, Howard D, Kudelka C. 2011. Sleep and testing promote conceptual learning of classroom materials. Presented Tuesday, June 14, in Minneapolis, Minn., at SLEEP 2011, the 25th Anniversary Meeting of the Associated Professional Sleep Societies LLC (APSS).

[2297] Pace-Schott, E. F., Nave G., Morgan A., & Spencer R. M. C. (Submitted). Sleep-dependent modulation of affectively guided decision-making. Journal of Sleep Research.

Grandner MA, Hale L, Jackson NJ, Patel NP, Gooneratne N, Troxel WM. 2011. Sleep disturbance and daytime fatigue associated with perceived racial discrimination. Presented Tuesday, June 14, in Minneapolis, Minn., at SLEEP 2011, the 25th Anniversary Meeting of the Associated Professional Sleep Societies LLC (APSS).

Sheares, B.J., Dorsey, K.B., Lamm, C.I., Wei, Y., Kattan, M., Mellins, R.B. & Evans, D. 2011. Sleep Problems In Urban Minority Children May Be More Prevalent Than Previously Recognized. Presented at the ATS 2011 International Conference in Denver.

[2330] Bayer, L., Constantinescu I., Perrig S., Vienne J., Vidal P. - P., Mühlethaler M., et al. (2011). Rocking synchronizes brain waves during a short nap. Current Biology. 21(12), R461-R462 - R461-R462.

[2331] Donlea, J. M., Thimgan M. S., Suzuki Y., Gottschalk L., & Shaw P. J. (2011). Inducing Sleep by Remote Control Facilitates Memory Consolidation in Drosophila. Science. 332(6037), 1571 - 1576.

[2287] Florian, C., Vecsey C. G., Halassa M. M., Haydon P. G., & Abel T. (2011). Astrocyte-Derived Adenosine and A1 Receptor Activity Contribute to Sleep Loss-Induced Deficits in

Hippocampal Synaptic Plasticity and Memory in Mice. The Journal of Neuroscience. 31(19), 6956 - 6962.

Sleep can boost classroom performance of college students
http://www.eurekalert.org/pub_releases/2011-06/aaos-scb060611.php
Rule-learning task also benefits from sleep
http://medicalxpress.com/news/2011-05-excellent-science-based-advice.html
Sleep problems may be a link between perceived racism and poor health
http://medicalxpress.com/news/2011-06-problems-link-racism-poor-health.html
Sleep problems more prevalent than expected in urban minority children
http://medicalxpress.com/news/2011-05-problems-prevalent-urban-minority-...
Rocking really does help sleep
http://www.scientificamerican.com/podcast/episode.cfm?id=rocking-increas...
Sleep helps long-term memory in two ways
http://the-scientist.com/2011/06/23/sleep-on-it/
Mouse studies identify the roots of memory impairment resulting from sleep deprivation
http://www.eurekalert.org/pub_releases/2011-05/uop-pri051711.php

Cognitive impairment in obese improved by surgery

Consistent with evidence linking obesity and impaired cognition, a new study has found improved cognition in obese patients after bariatric surgery.

Growing evidence links obesity and poorer cognitive performance. Many factors associated with obesity, such as high blood pressure, type 2 diabetes and sleep apnea, damage the brain.

A study involving109 bariatric surgery patients and 41 obese control subjects has found that the bariatric surgery patients demonstrated improved memory and concentration 12 weeks after surgery, improving from the slightly impaired range to the normal range. That of the obese controls actually declined over this period. The improvement of those who had surgery seemed to be particularly related to improved blood pressure.

Study participants will be tested one year and two years after surgery.

[2224] Gunstad, J., Strain G., Devlin M. J., Wing R., Cohen R. A., Paul R. H., et al. (2010). Improved memory function 12 weeks after bariatric surgery. Surgery for Obesity and Related Diseases.

http://www.eurekalert.org/pub_releases/2011-04/ksu-wli041211.php

Temporary cognitive impairment for many hospitalized seniors

Hospitalization can temporarily impair seniors' cognitive function, and more support is needed. Discharge instructions should be given with this in mind.

A study involving 200 older adults (70+) experiencing a stay in hospital has found that at discharge nearly a third (31.5%) had previously unrecognized low cognitive function (scoring below 25 on the MMSE if high-school-educated, or below 18 if not). This impairment had disappeared a month later for more than half (58%).The findings are consistent with previous research showing a lack of comprehension of discharge instructions, often resulting in rehospitalization.

The findings demonstrate the effects of hospitalization on seniors, and point to the need for healthcare professionals and family to offer additional support. It's suggested that patient self-management may be better taught as an outpatient following discharge rather than at the time of hospital discharge.

Sleep disruption and stress are presumed to be significant factors in why this occurs.

[2240] Lindquist, L. A., Go L., Fleisher J., Jain N., & Baker D. (2011). Improvements in Cognition Following Hospital Discharge of Community Dwelling Seniors. Journal of General Internal Medicine.

http://www.eurekalert.org/pub_releases/2011-04/nu-tml041411.php

Sleep problems contribute to cognitive problems in childhood cancer survivors

Many survivors of childhood cancer suffer cognitive impairment in adulthood. A new study finds this is more likely for those with sleep or fatigue problems.

A study involving 1426 long-term survivors of childhood cancer (survivors of eight different childhood cancers who were treated between 1970 and 1986) has revealed cognitive impairment in over a fifth. Those who reported problems sleeping or frequent daytime sleepiness and fatigue were three to four times more likely to have attention and memory problems.

Additionally, those who were taking antidepressants were 50% more likely to report attention problems and 70% more likely to report memory problems.

The findings emphasize the need for help in sleep hygiene for this group.

[2217] Clanton, N. R., Klosky J. L., Li C., Jain N., Srivastava D. K., Mulrooney D., et al. (Submitted). Fatigue, vitality, sleep, and neurocognitive functioning in adult survivors of childhood Cancer. Cancer.

http://www.eurekalert.org/pub_releases/2011-04/w-sic040611.php

Adverse changes in sleep duration associated with cognitive decline in middle-aged adults

A large long-running study has found that middle-aged adults whose night's sleep had decreased from 6-8 hours or increased from 7-8 hours performed worse on some cognitive tests.

From the Whitehall II study, data involving 5431 older participants (45-69 at baseline) has revealed a significant effect of midlife sleep changes on later cognitive function. Sleep duration was assessed at one point between 1997 and 1999, and again between 2002 and 2004. A decrease in average night's sleep from 6, 7, or 8 hours was significantly associated with poorer scores on tests of reasoning, vocabulary, and the MMSE. An increase from 7 or 8 hours (but not from 6 hours) was associated with lower scores on these, as well as on tests of phonemic and semantic fluency. Short-term verbal memory was not significantly affected. The magnitude of these effects was equivalent to a 4–7 year increase in age.

Around 8% of participants showed an increase from 7-8 hours of sleep over the five-year period (7.4% of women; 8.6% of men), while around a quarter of women and 18% of men decreased their sleep amount from 6-8 hours. About 58% of men and 50% of women reported no change in sleep duration during the study period. Some 27% of the participants were women.

The optimal amount of sleep (in terms of highest cognitive performance) was 7 hours for women, closely followed by 6 hours. For men, results were similar at 6, 7 and 8 hours.

Analysis took into account age, sex, education and occupational status. The Whitehall II study is a large, long-running study involving British civil servants. Sleep duration was assessed simply by responses to the question "How many hours of sleep do you have on an average week night?"

A very large Chinese study, involving 28,670 older adults (50-85), of whom some 72% were women, also supports an inverted U-shaped association between sleep duration and cognitive function, with 7-8 hours sleep associated with the highest scores on a delayed word recall test.

I would speculate that this finding of an effect of short-term verbal memory (in contrast to that of the Whitehall study) may reflect a group distinction in terms of education and occupation. The Whitehall study is the more homogenous (mostly white-collar), with participants probably averaging greater cognitive reserve than the community-based Chinese study. The findings suggest that memory is slower to be affected, rather than not affected.

Ferrie JE; Shipley MJ; Akbaraly TN; Marmot MG; Kivimäki M; Singh-Manoux A. Change in sleep duration and cognitive function: findings from the Whitehall II study. SLEEP 2011;34(5):565-573.

Xu L; Jiang CQ; Lam TH; Liu B; Jin YL; Zhu T; Zhang WS; Cheng KK; Thomas GN. Short or long sleep duration is associated with memory impairment in older Chinese: the Guangzhou Biobank Cohort Study. SLEEP 2011;34(5):575-580.

http://esciencenews.com/articles/2011/05/01/adverse.changes.sleep.durati...
http://www.guardian.co.uk/lifeandstyle/2011/may/02/sleep-changes-loss-br...

More evidence for the cognitive benefit of treating sleep apnea

Another study has come out showing the benefits of CPAP treatment for cognitive impairment caused by obstructive sleep apnea.

Comparison of 17 people with severe obstructive sleep apnea (OSA) with 15 age-matched controls has revealed that those with OSA had reduced gray matter in several brain regions, most particularly in the left parahippocampal gyrus and the left posterior parietal cortex, as well as the entorhinal cortex and the right superior frontal gyrus. These areas were associated with deficits in abstract reasoning and executive function. Deficits in the left posterior parietal cortex were also associated with daytime sleepiness.

Happily, however, three months of treatment with continuous positive airway pressure (CPAP), produced a significant increase in gray matter in these regions, which was associated with significant improvement in cognitive function. The researchers suggest that the hippocampus, being especially sensitive to hypoxia and innervation of small vessels, is the region most strongly and quickly affected by hypoxic episodes.

The findings point to the importance of diagnosing and treating OSA.

[1979] Canessa, N., Castronovo V., Cappa S. F., Aloia M. S., Marelli S., Falini A., et al. (2010). Obstructive Sleep Apnea: Brain Structural Changes and Neurocognitive Function Before and After Treatment. Am. J. Respir. Crit. Care Med.. 201005-0693OC - 201005-0693OC.

http://www.eurekalert.org/pub_releases/2010-11/ats-sal110910.php

Extraverts more vulnerable to effects of sleep deprivation after social interaction

A small study suggests that social activities are more tiring for extraverts than introverts, and that this personality trait may influence the effect of sleep loss on attention.

A study involving 48 healthy adults aged 18-39 has found that extraverts who were deprived of sleep for 22 hours after spending 12 hours in group activities performed worse on a vigilance task that did those extraverts who engaged in the same activities on their own in a private room. Introverts were relatively unaffected by the degree of prior social interaction.

The researchers suggest that social interactions are cognitively complex experiences that may lead to rapid fatigue in brain regions that regulate attention and alertness, and (more radically) that introverts may have higher levels of cortical arousal, giving them greater resistance to sleep deprivation.

Rupp TL; Killgore WDS; Balkin TJ. Socializing by day may affect performance by night: vulnerability to sleep deprivation is differentially mediated by social exposure in extraverts vs introverts. SLEEP 2010;33(11):1475-1485.

http://www.physorg.com/news/2010-11-extraverts-vulnerable-effects-depriv...

CPAP therapy provides a memory boost for adults with sleep apnea

Patients with obstructive sleep apnea treated with CPAP therapy not only outperformed untreated OSA patients on a memory task, but they outperformed those without OSA.

A study involving 135 adults (33-65) has found that, not only did patients with obstructive sleep apnea who were being treated with CPAP therapy outperform untreated OSA patients on an overnight picture memory task, but they outperformed controls who did not have OSA. The memory task involved being shown 20 photographs before spending the night in the sleep lab, and then having to choose the familiar photo from 20 similar pairs in the morning. CPAP therapy provides a steady stream of air through a mask that is worn during sleep.

Payne, J.D. et al. 2010. Regeneration of overnight memory consolidation ability in cpap patients. Presented at SLEEP 2010, the 24th annual meeting of the Associated Professional Sleep Societies LLC, in San Antonio, Texas.

http://www.eurekalert.org/pub_releases/2010-06/aaos-ctp052610.php

Sleep apnea in children and teens linked to lower academic grades

A study of overweight children and adolescents has found that moderate to severe obstructive sleep apnea was linked to both lower academic grades and behavioral concerns.

A study involving 163 overweight children and adolescents aged 10 to 17 has revealed that moderate to severe obstructive sleep apnea was linked to both lower academic grades and behavioral concerns. None of the students with moderate to severe OSA had an "A" average, and 30% had a "C" average or lower. In contrast, roughly 15% of those without sleep-disordered breathing had an "A" average, and only about 15% had a "C" average or lower. The results remained significant after adjustment for sex, race, socioeconomic status and sleep duration on school nights. OSA was particularly associated with inattention and poor study skills in real-world situations Forty-two students had moderate to severe OSA; 58 had mild OSA; 26 students were snorers; 37 had no sleep-disordered breathing.

Beebe, D.W. et al. 2010. The association between sleep-disordered breathing, academic grades, and neurobehavioral functioning among overweight subjects during middle to late childhood. Presented at SLEEP 2010, the 24th annual meeting of the Associated Professional Sleep Societies LLC, in San Antonio, Texas.

http://www.eurekalert.org/pub_releases/2010-06/aaos-sls052510.php

Regular bedtimes linked to better language, reading and math skills in preschool children

A large study reveals language and math skills were all better in 4-year-old children whose parents reported having rules about what time their child goes to bed.

A national study involving some 8,000 children, has revealed receptive and expressive language, phonological awareness, literacy and early math abilities were all better in 4-year-old children whose parents reported having rules about what time their child goes to bed. Having an earlier bedtime also was predictive of higher scores for most developmental measures. Recommendations are that preschool children get a minimum of 11 hours of sleep each night. These findings (which confirm earlier studies) indicate not only that lower scores on phonological awareness, literacy and early math skills are associated with getting less than this recommended amount of sleep, but that many children are not getting the recommended amount of sleep.

Gaylor, E., Wei, X. & Burnham, M.M. 2010. Associations between nighttime sleep duration and developmental outcomes in a nationally representative sample of preschool-age children. Presented at SLEEP 2010, the 24th annual meeting of the Associated Professional Sleep Societies LLC, in San Antonio, Texas.

www.physorg.com/news195105427.html

Traffic noise disturbs sleep, affects morning performance

A sleep lab study has revealed that traffic noise during sleep produces significantly slower reaction times on a vigilance task in the morning.

It's not just a matter of quantity; quality of sleep matters too. A study involving 72 adults (average age 40), whose sleep was monitored for 11 consecutive nights, has revealed that reaction times on a morning psychomotor vigilance task was significantly slower after exposure to recorded traffic noise during sleep. The slowing was directly related to the frequency and sound-pressure level of the nightly noise. Traffic noise has been identified as one cause of "environmental sleep disorder," which involves an environmental disturbance that causes a complaint of insomnia or daytime sleepiness. Other common causes include bright light and temperature extremes. The researchers also note that nighttime traffic noise may have even stronger effects on the performance of people who are more susceptible to sleep disturbances. Risk groups include children, shift workers, the elderly and people with chronic medical conditions. White noise, produced by fans, sound machines, and special applications for computers and smart phones, can be used to mask other noise.

Elmenhorst, E. et al. 2010. Nocturnal traffic noise and morning cognitive performance. Presented at SLEEP 2010, the 24th annual meeting of the Associated Professional Sleep Societies LLC, in San Antonio, Texas.

www.physorg.com/news195194598.html

Sleep apnea therapy improves golf game

A study involving 24 golfers with diagnosed moderate to severe obstructive sleep apnea (OSA) has found that the 12 who received nasal positive airway pressure (NPAP) for their disorder not only improved their daytime sleepiness scores, but lowered their golf handicap by as much as three strokes. It is assumed this is because of improvements in cognitive function. The effect was greatest for the best golfers (those with a handicap lower than 12), even though these were often older. The findings may help improve compliance — a big issue in NPAP therapy — in golfers.

The study was presented at CHEST 2009, the 75th annual international scientific assembly of the American College of Chest Physicians (ACCP).

http://www.eurekalert.org/pub_releases/2009-11/acoc-sat102709.php

Alcoholism's effect on sleep persists

A study involving 42 long-term alcoholics who had not had a drink for up to 719 days (mean age 49 years, 27 men) has found that, compared to controls, alcoholics had significantly poorer sleep quality, measured by a significantly lower percentage of slow wave sleep and significantly more stage 1 non-rapid eye movement (NREM) sleep. Moreover, estimated lifetime alcohol consumption was significantly related to the scores on the Pittsburgh Sleep Quality Index, with higher lifetime consumption predicting less sleep satisfaction. The reduction in slow wave activity was specific to NREM sleep. This could act as an exacerbating factor in alcoholics' cognitive decline.

[792] Colrain, I. M., Turlington S., & Baker F. C. (2009). Impact of alcoholism on sleep architecture and EEG power spectra in men and women. Sleep. 32(10), 1341 - 1352.

http://www.eurekalert.org/pub_releases/2009-10/aaos-aeo092309.php

Why sleep deprivation causes cognitive impairment, and how to fix it

A mouse study has found a molecular pathway in the brain that is the cause of cognitive impairment due to sleep deprivation, and points to a way of preventing the cognitive deficits caused by sleep deprivation. The study showed that mice deprived of sleep had increased levels of the enzyme phosphodiesterase 4 (PDE4) and reduced levels of cAMP, crucial in forming new synaptic connections in the hippocampus. Treatment with phosphodiesterase inhibitors rescued the sleep deprivation-induced deficits in cAMP signaling, synaptic plasticity and hippocampus-dependent memory, counteracting some of the memory consequences of sleep deprivation.

[1485] Vecsey, C. G., Baillie G. S., Jaganath D., Havekes R., Daniels A., Wimmer M., et al. (2009). Sleep deprivation impairs cAMP signalling in the hippocampus. Nature. 461(7267), 1122 - 1125.

http://www.eurekalert.org/pub_releases/2009-10/uop-fsp102609.php

Poor sleep linked to later development of Alzheimer's

A mouse study has found that amyloid-beta significantly increases during periods of sleep deprivation. The discovery follows observation that peptide levels in both mice and humans increase significantly during the day and drop at night. When mice were only allowed to sleep four hours a day for 21 days, they had higher amyloid-beta plaque build-up in their brain than similar-aged mice with regular sleeping habits. The circadian fluctuation was found to reflect the activity of orexin, a hormone that regulates wakefulness. The findings suggest insomnia, late-night habits, and irregular sleep schedules during mid-life may be linked to the later development of Alzheimer's disease.

Kang, J-E. et al. 2009. Amyloid- Dynamics Are Regulated by Orexin and the Sleep-Wake Cycle. Science, Published Online September 24

http://www.the-scientist.com/blog/display/55996/

Insomniacs have to work harder

A study of 12 people with chronic primary insomnia (average age 39.4 years), and nine good sleepers, has found that the insomniacs increased brain activation relative to good sleepers during the working memory task, particularly in areas responsible for visual-spatial attention and coordination of cognitive processes. This activation may explain how PIs maintain performance on the task despite their sleep difficulties. PIs also were found to have decreased activation in visual and motor areas, which may suggest that PIs have higher baseline activation in these regions relative to good sleepers.

By the way, insomniacs might like to know that a recent study found 81% of 118 chronic insomniacs reported improved sleep after completing a five-week online cognitive behavioural therapy program, including 35% who rated themselves as much or very much improved (see http://www.eurekalert.org/pub_releases/2009-06/aaos-ocb052209.php).

Orff, H.J. et al. 2009. Insomnia Patients Show Increased Cerebral Activation when Compared to Good Sleepers during an NBack Working Memory Task. Presented on June 9 at SLEEP 2009, the 23rd Annual Meeting of the Associated Professional Sleep Societies; Abstract ID: 0779.

http://www.eurekalert.org/pub_releases/2009-06/aaos-is060209.php

Older adults less affected by sleep deprivation than younger adults

A study involving 33 older adults (59-82) and 27 younger adults (19-38) has found that while the younger adults all showed significance deterioration on three different cognitive tasks after 36 hours of sleep deprivation, the older adults did not. The finding may be due to only the healthiest older adults being chosen, suggesting that older adults who remain the healthiest late in life may be less vulnerable to a variety of stressors, not just sleep loss.

It's worth noting that sleep deprivation affects some people more than others. A recent study has found that those with the short variant of the PERIOD3 (PER3) gene compensate for sleep loss by "recruiting" extra brain structures to help with cognitive tasks. Those with the long variant however, showed reduced activity in brain structures normally activated by the task. These participants also showed reduced brain activity in the right posterior inferior frontal gyrus after a normal waking day, a finding consistent with previous research suggesting that people with the long gene variant perform better on executive tasks earlier, but not later, in the day (see http://www.eurekalert.org/pub_releases/2009-06/sfn-gph062409.php).

Wang, R.L. et al. 2009. Older Adults are Less Vulnerable to Sleep Deprivation than Younger Adults during Cognitive Performance. Presented on June 10 at SLEEP 2009, the 23rd Annual Meeting of the Associated Professional Sleep Societies; Abstract ID: 0420.

http://www.eurekalert.org/pub_releases/2009-06/aaos-oal060209.php

Childhood sleep problems persisting through adolescence may affect cognitive abilities

A longitudinal study involving 916 twins whose parents reported their children's sleep problems from age 4 until 16, of whom 568 completed tests of executive functioning at 17, indicates that those whose sleep problems persisted through adolescence had poorer executive functioning at age 17 than children whose problems decreased to a greater extent. Sleep problems as early as age 9, but particularly around age 13, showed significant associations with later executive functions. Some problems appear to be more important than others: changes in levels of 'sleeping more than other children' and 'being overtired' were most important, and nightmares and 'trouble sleeping' the least. However, a child's level of sleep problems early in life don't appear to be an important factor.

[930] Friedman, N. P., Corley R. P., Hewitt J. K., & Wright K. P. (2009). Individual Differences in Childhood Sleep Problems Predict Later Cognitive Executive Control. Sleep. 32(3), 323 - 333.

http://www.eurekalert.org/pub_releases/2009-03/aaos-csp022709.php

Treating sleep apnea in Alzheimer's patients helps cognition

A study of 52 men and women with mild to moderate Alzheimer's disease and obstructive sleep apnea (OSA) has found significant improvement in patients' neurological test scores after continuous positive airway pressure (CPAP) treatment. CPAP also reduced daytime sleepiness, a common complaint of Alzheimer's patients and their caregivers. The prevalence of OSA in patients with dementia has been estimated to be as high as 70 to 80%.

Ancoli-Israel, S. et al. 2008. Cognitive Effects of Treating Obstructive Sleep Apnea in Alzheimer's Disease: A Randomized Controlled Study. Journal of the American Geriatrics Society, 56 (11), 2076-2081.

http://www.eurekalert.org/pub_releases/2008-12/uoc--tsa120308.php

Landmark study links sleep, memory problems in elderly African-Americans

A study of older African-Americans (aged 65-90) has found that those who have trouble falling asleep are at higher risk of having memory problems, most particularly in short-term and working memory.

[242] Gamaldo, A. A., Allaire J. C., & Whitfield K. E. (2008). The Relationship Between Reported Problems Falling Asleep and Cognition Among African American Elderly. Research on Aging. 30(6), 752 - 767.

http://www.eurekalert.org/pub_releases/2008-10/ncsu-lsl101308.php

One sleepless night increases dopamine

A study has found that sleep deprivation increases the level of the hormone dopamine in two brain structures: the striatum, which is involved in motivation and reward, and the thalamus, which is involved in alertness. The rise in dopamine following sleep deprivation may promote wakefulness to compensate for sleep loss. However, since the amount of dopamine correlated with feelings of fatigue and impaired performance on cognitive tasks, it appears that the adaptation is not sufficient to overcome the cognitive deterioration induced by sleep deprivation and may even contribute to it. Amphetamines increase dopamine levels.

[483] Thanos, P. K., Ferre S., Jayne M., Volkow N. D., Wang G. - J., Telang F., et al. (2008). Sleep Deprivation Decreases Binding of [11C]Raclopride to Dopamine D2/D3 Receptors in the Human Brain. J. Neurosci.. 28(34), 8454 - 8461.

http://www.eurekalert.org/pub_releases/2008-08/sfn-osn081808.php

Memory loss linked to sleep apnea

Sleep apnea occurs when a blocked airway repeatedly halts the sleeper's breathing, resulting in loud bursts of snoring and chronic daytime fatigue. Memory loss and difficulty focusing are also common complaints. While sleep loss is a common cause for such impairment, memory problems continue despite treatment for the sleep disorder, implying a long-lasting brain injury. Now a new imaging study has found significant tissue loss in brain regions that help store memory (mammillary bodies). It’s hypothesized that repeated drops in oxygen might be the cause, but further research is needed.

[958] Kumar, R., Birrer B. V. X., Macey P. M., Woo M. A., Gupta R. K., Yan-Go F. L., et al. (2008). Reduced mammillary body volume in patients with obstructive sleep apnea. Neuroscience Letters. 438(3), 330 - 334.

http://www.eurekalert.org/pub_releases/2008-06/uoc--mll060608.php

More sleep improves cognition in Alzheimer patients with OSA

A study involving 52 participants with an average age of 77.8 years who had Alzheimer disease and obstructive sleep apnea (OSA) has found that it was increases in total sleep time in those given continuous positive airway pressure treatment that was associated with improvements in cognition, rather than improvement in oxygen levels. This suggests that the cognitive dysfunction associated with OSA in patients with dementia may be in part an effect of short sleep time.

The findings were presented at SLEEP 2008, the 22nd Annual Meeting of the Associated Professional Sleep Societies (APSS).

http://www.eurekalert.org/pub_releases/2008-06/aaos-iit050708.php

Green tea compounds beat OSA-related brain deficits

A study has found that rats intermittently deprived of oxygen during 12-hour “night” cycles, mimicking the experience of humans with obstructive sleep apnea, performed significantly better on a spatial memory task if they’d been treated with the polyphenols in green tea (administered through drinking water) than if they didn't receive such chemicals. Their brains also showed less oxidative stress.

[464] Burckhardt, I. C., Gozal D., Dayyat E., Cheng Y., Li R. C., Goldbart A. D., et al. (2008). Green tea catechin polyphenols attenuate behavioral and oxidative responses to intermittent hypoxia. American Journal of Respiratory and Critical Care Medicine. 177(10), 1135 - 1141.

http://www.eurekalert.org/pub_releases/2008-05/ats-gtc051308.php

REM sleep deprivation reduces neurogenesis

And in another sleep study, rats deprived of REM sleep for four days showed reduced cell proliferation in the dentate gyrus of the hippocampus, where most adult neurogenesis takes place. The finding indicates that REM sleep is important for brain plasticity.

[507] Guzman-Marin, R., Suntsova N., Bashir T., Nienhuis R., Szymusiak R., & McGinty D. (2008). Rapid eye movement sleep deprivation contributes to reduction of neurogenesis in the hippocampal dentate gyrus of the adult rat. Sleep. 31(2), 167 - 175.

http://www.eurekalert.org/pub_releases/2008-02/aaos-fdo012808.php

Insufficient sleep in early childhood associated with developmental delay

A long-term study of nearly 1500 young children (from 5 months to six years) found four sleep duration patterns; 6% slept less than 10 hours per night throughout early childhood, and 4.8% did so until around 41 months, when it increased. Short sleep duration was found to significantly increase the risk of low performance on the Peabody Picture Vocabulary Test–Revised (given at 5 years), suggesting that language acquisition and the consolidation of new words into memory could be significantly impeded by chronically shortened sleep duration throughout childhood. An increased risk of poorer performance on the Block Design subtest (given at 6 years) was also evident even among those who had increased their sleep duration, suggesting that there is a critical period in early childhood where the lack of sleep is particularly detrimental on various aspects of development even if the sleep duration normalizes later on.

[244] Touchette, É., Petit D., Séguin J. R., Boivin M., Tremblay R. E., & Montplaisir J. Y. (2007). Associations Between Sleep Duration Patterns and Behavioral/Cognitive Functioning at School Entry. Sleep. 30(9), 1213 - 1219.

http://www.eurekalert.org/pub_releases/2007-09/aaos-jsl082407.php

Memory problems and sleep disturbance linked in older women

A large long-running study, involving older women (average age 69) found that the nearly 25% of women who experienced cognitive decline over the 15 year period were twice as likely as women without memory problems to experience sleep disturbances, specifically problems staying asleep, and also problems falling asleep and being awake for more than 90 minutes during their sleep cycle. Women who declined on one of the two cognitive tests were also nearly twice as likely to nap more than two hours a day. However, cognitive decline was not associated with total sleep time. The association between sleep disturbances and poor cognitive function is of course well-known, but these findings raise the possibility that cognitive decline may increase the risk of sleep problems, rather than vice versa.

[679] Yaffe, K., Blackwell T., Barnes D. E., Ancoli-Israel S., Stone K. L., & For the Study of Osteoporotic Fractures Group (2007). Preclinical cognitive decline and subsequent sleep disturbance in older women. Neurology. 69(3), 237 - 242.

http://www.eurekalert.org/pub_releases/2007-07/aaon-oww071007.php

African-American and poor children more affected by sleep problems

A study involving 166 8- and 9-year-old African-American and European-American children from varying socioeconomic backgrounds has found that sleep disruption has greater effects on cognitive performance for children from lower-income homes and African-American children. When socioeconomic status was taken into consideration, African-American and European-American children's performance on cognitive tests was similar when they slept well. But when sleep was disrupted, African-American children's performance was worse. Similarly, children from lower and higher socioeconomic backgrounds performed similarly on tests when they slept well and their sleep schedules were consistent. But when their sleep was disrupted, children from higher-income homes did better than children from lower-income homes.

[1061] Buckhalt, J. A., El-Sheikh M., & Keller P. (2007). Children's sleep and cognitive functioning: race and socioeconomic status as moderators of effects. Child Development. 78(1), 213 - 231.

http://www.eurekalert.org/pub_releases/2007-02/sfri-csp013107.php

Sleep deprivation affects neurogenesis

A rat study has found that rats deprived of sleep for 72 hours had higher levels of the stress hormone corticosterone, and produced significantly fewer new brain cells in a particular region of the hippocampus. Preventing corticosterone levels from rising also prevented the reduction in neurogenesis.

[642] Mirescu, C., Peters J. D., Noiman L., & Gould E. (2006). Sleep deprivation inhibits adult neurogenesis in the hippocampus by elevating glucocorticoids. Proceedings of the National Academy of Sciences. 103(50), 19170 - 19175.

http://news.bbc.co.uk/2/hi/health/6347043.stm

Memory improves after sleep apnea therapy

Patients with obstructive sleep apnea (OSA) often complain of forgetfulness. A study of 58 memory-impaired patients with clinically diagnosed OSA has found that 68% of those who used continuous positive airway pressure (CPAP) machines for an average of more than 6 hours a night regained normal memory after three months. Memory improvement varied based on CPAP adherence: 21% of poor users (fewer than 2 hours/night of CPAP use), 44% of moderate users (2 to 6 hours/night) demonstrated normal memory performance after three months. However, evidence suggests this optimal level of CPAP adherence is uncommon following 3 months of treatment.

[151] Zimmerman, M. E., Arnedt T. J., Stanchina M., Millman R. P., & Aloia M. S. (2006). Normalization of Memory Performance and Positive Airway Pressure Adherence in Memory-Impaired Patients With Obstructive Sleep Apnea*. Chest. 130(6), 1772 - 1778.

http://www.eurekalert.org/pub_releases/2006-12/acoc-mia120606.php

Childhood sleep apnea linked to brain damage, lower IQ

It's long been known that sleep apnea, characterized by fragmented sleep, interrupted breathing and oxygen deprivation, harms children's learning ability and school performance. Now a new study involving 19 children with severe obstructive sleep apnea has identified damage in the hippocampus and the right frontal cortex, and linked that to observable deficits in performance on cognitive tests. Children with OSA had an average IQ of 85 compared to 101 in matched controls. They also performed worse on standardized tests measuring executive functions, such as verbal working memory (8 versus 15) and word fluency (9.7 versus 12). Obstructive sleep apnea affects 2% of children in the United States, but it is unclear how many of these suffer from severe apnea.

[1442] Halbower, A. C., Degaonkar M., Barker P. B., Earley C. J., Marcus C. L., Smith P. L., et al. (2006). Childhood Obstructive Sleep Apnea Associates with Neuropsychological Deficits and Neuronal Brain Injury. PLoS Med. 3(8), e301 - e301.

Full text available at
http://www.plosmedicine.org/article/info:doi/10.1371/journal.pmed.0030301

http://www.eurekalert.org/pub_releases/2006-08/jhmi-csa081506.php

Morning grogginess worse for cognition than sleep deprivation

People who awaken after eight hours of sound sleep have more impaired thinking and memory skills than they do after being deprived of sleep for more than 24 hours. The impairment is worst in the first three minutes, and the most severe effects have generally dissipated by ten minutes, but measurable effects can last up to two hours. This is consistent with reports indicating that cortical areas like the prefrontal cortex take longer to come "online" after sleep than other parts of the brain. The findings have implications for medical, safety and transportation workers who are often called upon to perform critical tasks immediately after waking, as well as for anyone abruptly woken to face an emergency situation.

Wertz, A.T., Ronda, J.M., Czeisler, C.A. & Wright, K.P.Jr. 2006. Effects of Sleep Inertia on Cognition. Journal of the American Medical Association, 295,163-164.

http://www.eurekalert.org/pub_releases/2006-01/uoca-mgm121905.php

Losing sleep inhibits neurogenesis

A new sleep study using rats restricted rather than deprived them of sleep, to mimic more closely the normal human experience. The study found that the sleep-restricted rats had a harder time remembering a path through a maze compared to their rested counterparts. The sleep-restricted rats showed reduced survival rate of new hippocampus cells — learning spatial tasks increases the production of new cells in the hippocampus. This study shows that sleep plays a part in helping those new brain cells survive. However, the sleep-restricted rats that were forced to use visual and odor cues to remember their way through the maze did better on the task than their rested counterparts, implying that some types of learning don't require sleep.

[994] Hairston, I. S., Little M. T. M., Scanlon M. D., Barakat M. T., Palmer T. D., Sapolsky R. M., et al. (2005). Sleep Restriction Suppresses Neurogenesis Induced by Hippocampus-Dependent Learning. J Neurophysiol. 94(6), 4224 - 4233.

http://www.eurekalert.org/pub_releases/2006-01/aps-lsu010506.php

Breathing problems during sleep may affect mental development in infants and young children

Two new studies have found evidence that children who have problems breathing during sleep tend to score lower on tests of mental development and intelligence than do other children their age. The first study found that at one year of age, infants who have multiple, brief breathing pauses (apnea) or slow heart rates during sleep scored lower on mental development tests than did other infants of the same age. The second study found that 5-year-old children who had frequent snoring, loud or noisy breathing during sleep, or sleep apneas observed by parents scored lower standard tests measuring executive function (attention and planning), memory, and general intelligence. More than 10 percent of young children have habitual snoring, the mildest form of sleep-disordered breathing (SDB). The effects of poor sleep are often overlooked or misinterpreted in children -- rather than appearing sleepy, children may in fact seem to be more active or even hyperactive.

[1245] Gottlieb, D. J., Chase C., Vezina R. M., Heeren T. C., Corwin M. J., Auerbach S. H., et al. (2004). Sleep-disordered breathing symptoms are associated with poorer cognitive function in 5-year-old children☆. The Journal of Pediatrics. 145(4), 458 - 464.

[470] Hufford, D., Hunt C. E., Corwin M. J., Baird T., Tinsley L. R., Palmer P., et al. (2004). Cardiorespiratory events detected by home memory monitoring and one-year neurodevelopmental outcome⁎. The Journal of Pediatrics. 145(4), 465 - 471.

http://www.eurekalert.org/pub_releases/2004-10/nhla-bpd100604.php

More on effects of sleep loss and fatigue on memory and learning

Just to confirm what we all know (I hope): a study of medical residents from five U.S. academic health centers has found that sleep loss and fatigue affect learning, job performance and personal relationships. Specifically, residents reported adverse effects on their abilities to learn, either in short-term or long-term memory of material; on their motivation to learn; and on their higher-order thinking skills (cognitive abilities and complex thinking).

[1165] Papp, K. K., Stoller E. P., Sage P., Aikens J. E., Owens J., Avidan A., et al. (2004). The effects of sleep loss and fatigue on resident-physicians: a multi-institutional, mixed-method study. Academic Medicine: Journal of the Association of American Medical Colleges. 79(5), 394 - 406.

http://www.eurekalert.org/pub_releases/2004-05/cwru-mrr050404.php

Sleep deprivation affects working memory

A recent study investigated the working memory capacities of individuals who were sleep-deprived. For nine days, 7 of the 12 participants slept four hours each night, and 5 slept for eight hours. Each morning, participants completed a computer task to measure how quickly they could access a list of numbers they had been asked to memorize. The list could be one, three, or five items long. Then participants were presented with a series of single digits and asked to answer "yes" or "no" to indicate whether each digit was one they had memorized. Those who slept eight hours a night steadily increased their working memory efficiency on this task, but those who slept only four hours a night failed to show any improvement in memory efficiency. Motor skill did not change across days for either group of participants.

Casement, M.D., Mullington, J.M., Broussard, J.L., & Press, D.Z. 2003. The effects of prolonged sleep restriction on working memory performance. Paper presented at the annual meeting of the Society for Neuroscience, New Orleans, LA.

http://www.eurekalert.org/pub_releases/2003-11/sfn-sfb_1111003.php

Strategies for sleep improvement

Learning to shape your brain activity for improved sleep & learning

We know that sleep quality affects cognitive performance. Now an exciting new study has showed that people can learn to control certain aspects of their brainwave rhythm in a way that increased relaxation, reduced the time taken to fall asleep, and, after doing it for two weeks, increased memory performance. The training involved ten sessions of neurofeedback training.

[433] Hoedlmoser, K., Pecherstorfer T., Gruber G., Anderer P., Doppelmayr M., Klimesch W., et al. (2008). Instrumental Conditioning of Human Sensorimotor Rhythm (12–15 Hz) and Its Impact on Sleep as Well as Declarative Learning. Sleep. 31(10), 1401 - 1408.

http://www.eurekalert.org/pub_releases/2008-10/aaos-lts092908.php

Subliminal & sleep learning

Subliminal learning achieved notoriety back in 1957, when James Vicary claimed moviegoers could be induced to buy popcorn and Coca-Cola through the use of messages that flashed on the screen too quickly to be seen. The claim was later shown to be false, but though the idea that people can be brainwashed by the use of such techniques has been disproven (there was quite a bit of hysteria about the notion at the time), that doesn't mean the idea of subliminal learning is crazy.

Ten years ago, researchers demonstrated that subliminal messages do indeed affect human cognition — and showed the limits of that influence [1]. The study demonstrated that, to have an effect on a person's decision, the subliminal message had to be received very very soon before that decision (a tenth of a second or less), and the person had to be forced to make the decision very quickly. Moreover, there was no memory trace detectable, indicating no permanent record was stored in memory.

But even such brief, low-level learning seems to require some level of attention. A study [2] found that subliminal learning doesn't occur if the subliminal stimuli are presented during what has been termed an "attentional blink" You may recall when I've discussed multi-tasking, I've said that we can't do two things at the same time — that tasks have to "queue" for attention. When a bottleneck occurs in the system, this attentional "blink" occurs.

But low-level sensory processing, which is an automatic process, isn't affected by the attentional blink, so the finding that subliminal learning is affected by the blink indicates that subliminal stimuli require some high-level cognitive processing.

This finding has been confirmed by other studies. One such study [3] also has implications for reading. Participants in the study were shown either words or pronounceable nonwords and asked to perform either a lexical task (to identify whether the word they saw was a real word or a nonsense word) or a pronunciation task on the words. Unbeknownst to the participants however, they had been first presented with a subliminal word that either matched or didn't match the target word. People performed the tasks faster when the subliminal word was identical to the target word. However (and this is the interesting bit), the researchers then applied a magnetic pulse (transcranial magnetic stimulation) to the key brain regions of the brain before presenting the subliminal information. By applying TMS to one brain area or the other, they found they could selectively disrupt the subliminal effect for either the lexical or pronunciation task. In other words, it seems that, even when the stimulus is subliminal, the brain takes into account the conscious task instructions. Our expectations shape our processing of subliminal stimuli.

Another study [4] suggests that motivation is important, and also, perhaps, that some stimuli are more suitable than others. The study found that thirsty people could be encouraged to drink more, and also pay more for their drink, after being exposed to subliminal smiling faces. Subliminal frowning faces had the opposite effect. However, how much, and whether, the faces had an effect on drinking, depended on the person’s thirst. Those who weren’t thirsty weren’t affected at all. Smiles and frowns are of course stimuli to which we are very responsive.

So clearly, although it is possible to be unconsciously affected by stimuli that can’t be consciously detected, the effect is both small and fleeting. However, that doesn’t mean more long-term effects can’t be experienced as a result of information we’re not conscious of.

Psychologists make a distinction between explicit memory and implicit memory. Explicit memory is what you’re using when you remember or recognize something — it’s what we tend to think of as "memory". Implicit memory, on the other hand, is a concept that reflects the fact that sometimes people act in ways that are clearly affected by earlier experiences they have had, even though they are not consciously recalling such experiences.

Another study [5] that used erotic images (because, like smiling and frowning faces, these are particularly potent stimuli, making it easy to see a response) found that when your eyes are presented with erotic images in a way that keeps you from becoming aware of them, your brain can still detect them — evidenced by the way people respond to the images according to their gender and sexual orientation.

The study is more evidence that the brain processes more visual information than we are conscious of — which is an important part in the process of determining what we’ll pay attention to. But the researchers believe that the information is probably destroyed at an early stage of processing — in other words, as with subliminal stimuli, there is probably no permanent record of the experience.

Which leads me to sleep learning. This was a big idea when I was young, in the science fiction I read — the idea that you could easily master new languages by being instructed while you were asleep.

Well, the question of whether learning can take place during sleep (and I'm not talking about the consolidation of learning that's occurred earlier) is one that has been looked at in animal studies. It has been shown that simple forms of learning are indeed possible during sleep. However, the way in which associations are formed is clearly altered even for simple learning, and complex forms of learning do not appear to be possible.[6]

As far as humans are concerned, the evidence is that any learning during sleep must occur during the lightest stage of sleep, when you still have some awareness of the world around you, and that what you are learning must be already familiar (presented previously while you were awake and paying attention) and not requiring any understanding.

All the evidence suggests that, although information can be processed without conscious awareness, there are severe limitations on that information. If you want to "know" something in the proper meaning of the word — be able to recall it, think about it — you need to actively engage with the information. No free lunches, I'm afraid!

But that doesn't mean unconscious influences don't have important implications for learning and memory. A paper provided online in the Scientific American Mind Matters blog describes how a single, 15-minute intervention erased almost half the racial achievement gap between African American and white students. And this is entirely consistent with a number of studies showing how our cognitive performance is affected by what we think of ourselves (which is affected by what others think of us).

This article first appeared in the Memory Key Newsletter for March 2007

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Sleep and cognition in children

A U.S. survey provides evidence that both children and adolescents tend to be getting less sleep than needed.

Depression, lower self-esteem, and lower grades, have all been found to be correlated with sleep deprivation in middle-school children.

Sleep disturbance in infants and young children has also been found to be associated with lower cognitive performance.

We all know that lack of sleep makes us more prone to attentional failures, more likely to make mistakes, makes new information harder to learn, old information harder to retrieve ... We all know that, right? And yet, so many of us still go to bed too late to get the sleep we need to function well. Of course, some of us go to sleep early enough, we just can't get to sleep fast enough, or are prone to waking in the night. (Personally, I can count the times I've slept through the night without waking in the last fifteen years on my fingers).

I talk about the effect of sleep on memory elsewhere; I want to talk here about a sleep problem that we don't tend to think about so much — the sleep deficit children are running.

A survey commissioned by the National Sleep Foundation found that 3-to-6-year-olds in the U.S. get about 10.4 hours sleep nightly, while experts recommend 11 to 13 hours. 1st graders to 5th graders who should be getting 10 to 11 hours are averaging just 9.5 hours.

And a study of middle-school children (11 to 14 year olds) found a direct correlation between sleep deprivation and depression, lower self-esteem, and lower grades. "The fewer hours of sleep that children got, the more depressed they were, the higher number of depressive symptoms [they had], and the lower their self-esteem and the lower their grades."

The second largest growth spurt occurs during these years (usually 10-14 for girls; 11-16 for boys), so this is a time when a lot of sleep is needed. But it's also a time when children become more capable and more independent; when they're likely to start taking on a lot more activities, work harder and longer, and are monitored less by their parents and caregivers. So ... it's not surprising, when we stop and think about it, that a lot of these children are starting to pick up the bad habits of their parents — not getting enough sleep.

Which also points, in part, to the solution: if you're a parent, remember that your children are, as always, modeling themselves on you. And sleep habits usually reflect a household pattern. If you're a teacher, remember you need to educate the family, not just the child.

The National Institutes of Health (NIH) have identified adolescents and young adults (ages 12 to 25 years) as a population at high risk for problem sleepiness based on "evidence that the prevalence of problem sleepiness is high and increasing with particularly serious consequences."

Sleep disturbance in infants and young children has also been found to be associated with lower cognitive performance. Previous studies have looked at the severe end of the spectrum of sleep disorders — obstructive sleep apnea. More alarmingly, a new study of 205 5-year-old children found even mild sleep-disordered breathing symptoms (frequent snoring, loud or noisy breathing during sleep) were associated with poorer executive function and memory skills and lower general intelligence.

Before you panic, please note that some 30% of the participants had SBD symptoms, so it's hardly uncommon (although there may have been a bias towards children with these symptoms; it does seem surprisingly high). You might also like to note that I personally had a blocked nose my entire childhood (always breathed through my mouth, and yes, of course I snored) and it didn't stop me being top of the class, so ...

Nor is the research yet developed enough to know precisely what the connection is between SBD and cognitive impairment. However, it does seem that, if something can be done about the problem, it is probably worth doing (in my case, taking me off dairy would probably have fixed the problem! but of course noone had any idea of such factors back then).

Here's a few links that may be of interest to parents and teachers:

ScienCentral article on the middle-school study:
http://sciencentral.com/articles/view.htm3?article_id=218392389

The NSF Sleep in America poll
http://www.sleepfoundation.org/hottopics/index.htm?secid=16

a look at the school start times debate (I find this fairly amazing actually, because here in New Zealand, our children usually start school around 9am; the thought of kids starting school at 7.30 sends me into a spin!)
http://www.sleepfoundation.org/hottopics/index.htm?secid=18&id=206

The National Sleep Foundation also has a site for children who want to learn about sleep and healthy sleep habits: www.SleepforKids.org For children from 7 up; with educational games and activities, as well as a downloadable copy of NSF's new Sleep Diary designed especially for children.

Biological clocks and memory

I've always been interested in the body's clocks — and one of the most interesting things is that it is clocks, in the plural. It appears the main clock is located in a part of the brain structure called the hypothalamus (a very important structure in the brain, although not one of much importance to learning and memory). The part of the hypothalamus that regulates time is called the suprachiasmatic nuclei. These cells contain genes that switch on, off, and on again over a 24-hour period, and send electrical pulses and hormones through the body. This is the body's master clock.

But it is not the only clock in the body. Each organ in the body uses the time signal from the master clock to set its own clock. As a consequence, different systems in the body operate on different schedules. Thus blood pressure peaks at one particular time of the day, and levels of the stress hormone cortisol rise and fall in accordance with the clock that governs this.

The effect of this is that certain physical disorders are more likely to occur at particular times, and, more significantly, that certain medications may be far more effective at certain times.

What does all this have to do with learning and memory?

Well, not a whole lot of research has been done on the effects of time of day on cognitive performance, but what has been done is reasonably consistent. It seems clear that, for many people (but not all), there are significant time of day effects. The most reliable is that, in general, teenagers and young adults perform best (mentally) in the afternoon, while older adults (seniors) perform best in the morning.

Having said that, let's qualify it a little.

Let's start with a table. Now, this represents the findings of one study [4], so let's not get carried away with the illusion of precision cast by actual numbers. Nevertheless, it is interesting. These percentages represent the preferences reported by the young and old participants in the study. These preferences correlated with improved performance on a memory test.

	Young	Old

Definite morning	0%	34%
Moderate morning	8%	49%
No preference	57%	10%
Moderate evening	29%	6%
Definite evening	6%	1%

Now the first thing to note is how marked the differences are between young and old. Of particular interest is how many of the younger adults had no preference. Compare this with that of older adults. The second finding of particular note is how pronounced the preference for the morning is in older adults — 83% preferred morning. And, most interesting of all, is a finding from another study by the same researchers [5]: when tested at their preferred time, older adults performed comparably to younger adults on a memory task. Younger adults, by contrast, seem able to perform well at all times.

There is also some evidence [3] that the deleterious effect of interference (the intrusion of irrelevant words, objects, events) is worse for older adults at those times of day when their performance is poorer. Older adults are more vulnerable to interference than younger adults.

The findings for teenagers and young adults may also apply to children. One study [2] found that below-grade-level students who received reading instruction in the afternoon improved their performance more than those students who received instruction in the morning.

But it must always be remembered that this general principle that morning is better for the aged, and afternoon better for the young, does not apply to each and every individual. As the table tells us, time of day affects some people more than others, and time preference is an individual matter, not entirely predicted by age. This is underscored by a study [1] that found improved performance when students were taught at times that matched their preferences. There was also some evidence that, for some students at least, achievement was greater when they were taught during their teacher's ideal time of day.

None of this is an argument that you should resign yourself to learning only at your preferred time of day! But you could use the information to modify your strategies. For example, by scheduling difficult work for your optimal time (assuming you have an optimal time, and are not one of those fortunate people who have no strong preference). You can also try and counteract the effect by, for example, drinking coffee during your nonoptimal time of day (this was found to be effective in one study with older adults [6]).

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Time of day effects in immediate and delayed memory

Journal Article:

Folkard, S. & Monk, T.H. (1978). Time of day effects in immediate and delayed memory. In M. M. Gruneberg, P. E. Morris & R.N. Sykes (eds.). Practical aspects of memory. London: Academic Press.

- The time of day doesn't appear to significantly affect your ability to remember (retrieve information).
- Time of day does appear to affect your ability to make good memory codes (learn).

In other words, what's important is the time of day you hear/see/read something, not when you try and remember it.

- information learned in the morning shows better immediate retention, but worse long-term retention
- short-term memory appears to improve as arousal levels fall

Three experiments investigated whether the time of day had an effect on short-term or long-term memory.

In the first experiment, the material used was a factual article from a New Scientist magazine. Short-term memory (as measured by 10 multi-choice questions) was best if the article had been read at 8am, and lowest if it had been read at 8pm. Surprisingly, there was a slight, short-lived improvement after lunch (during the post-lunch dip in arousal level), and another one after 8pm (at a similar dip in arousal). Long-term memory (as measured by performance on a category instance task) was apparently not affected by time of day. Nor was reading speed.

In the second experiment, the subjects listened to a story, at either 9am or 3pm. Their recall was tested immediately and again a week later. It was found that short-term recall was better if the story was heard at 9am but long-term recall was better if it had been heard at 3pm. It didn't seem to matter whether testing occurred at 9am or 3pm, nor did it matter whether the test occurred at the same time of day as the story was heard.

In the third experiment, the subjects were shift workers. The subjects, who were nurses, were shown a ten minute film on the use of radium therapy. The times used were more extreme this time: 8.30pm and 4am. Long-term recall was tested at four weeks. Long-term recall was consistently better if the film had been seen at 8.30pm than if it had been seen at 4am, but there was no effect on immediate recall. However, in the group least adjusted to shift work (part-time nurses and those on their first night shift), short-term recall was better if the film had been seen at 4am, while among the most adjusted group the reverse was true (short-term recall was best if the film had been seen at 8.30pm). Again, the time of testing made no difference.

Overall then, the experiments found that the time at which the information was presented consistently influenced immediate and delayed retention in opposite directions. It is not clear why there should be a differential effect. There was no evidence that retrieval efficiency was affected by the time of day.

An interesting implication of this work is that the recommendation from studies early this century, that academic work is better taught in the morning and physical subjects in the afternoon (based on findings that immediate memory was better in mid-morning, and perceptual-motor activity in the afternoon), may have been ill-founded.

Circadian rhythm - news reports

Chronic jet lag has long-lasting effects on cognition

A hamster study indicates that chronic jet lag changes the brain in ways that cause long-lasting memory and learning problems.

Twice a week for four weeks, female hamsters were subjected to six-hour time shifts equivalent to a New York-to-Paris airplane flight. Cognitive tests taken during the last two weeks of jet lag and a month after recovery from it revealed difficulty learning simple tasks that control hamsters achieved easily. Furthermore, the jet-lagged hamsters had only half the number of new neurons in the hippocampus that the control hamsters had.

The findings support earlier research indicating that chronic jet lag impairs memory and learning and reduces the size of the temporal lobe, and points to the loss of brain tissue as being due to reduced neurogenesis in the hippocampus. Although further research is needed to clarify this, indications are that the problem is not so much fewer neurons being created, but fewer new cells maturing into working cells, or perhaps new cells dying prematurely.

Hamsters are excellent subjects for circadian rhythm research because their rhythms are so precise.

[2013] Gibson, E. M., Wang C., Tjho S., Khattar N., & Kriegsfeld L. J. (2010). Experimental 'Jet Lag' Inhibits Adult Neurogenesis and Produces Long-Term Cognitive Deficits in Female Hamsters. PLoS ONE. 5(12), e15267 - e15267.

http://www.physorg.com/news/2010-11-jet-lagged-coincidence.html

Traffic noise disturbs sleep, affects morning performance

A sleep lab study has revealed that traffic noise during sleep produces significantly slower reaction times on a vigilance task in the morning.

It's not just a matter of quantity; quality of sleep matters too. A study involving 72 adults (average age 40), whose sleep was monitored for 11 consecutive nights, has revealed that reaction times on a morning psychomotor vigilance task was significantly slower after exposure to recorded traffic noise during sleep. The slowing was directly related to the frequency and sound-pressure level of the nightly noise. Traffic noise has been identified as one cause of "environmental sleep disorder," which involves an environmental disturbance that causes a complaint of insomnia or daytime sleepiness. Other common causes include bright light and temperature extremes. The researchers also note that nighttime traffic noise may have even stronger effects on the performance of people who are more susceptible to sleep disturbances. Risk groups include children, shift workers, the elderly and people with chronic medical conditions. White noise, produced by fans, sound machines, and special applications for computers and smart phones, can be used to mask other noise.

Elmenhorst, E. et al. 2010. Nocturnal traffic noise and morning cognitive performance. Presented at SLEEP 2010, the 24th annual meeting of the Associated Professional Sleep Societies LLC, in San Antonio, Texas.

www.physorg.com/news195194598.html

Frequent episodes of jet lag without sufficient recovery time may reduce cognitive function

A study of 20 flight attendants suggests that people who undergo repeated, frequent episodes of jet lag without sufficient recovery time between trips may develop actual tissue changes in the brain in an area that's involved in spatial orientation and related aspects of cognitive function. The extent to which this is due to sleep deprivation rather than time shifts per se is unknown. These findings may also be relevant to shift workers, medical trainees and others who work long hours.

[347] Cho, K. (2001). Chronic 'jet lag' produces temporal lobe atrophy and spatial cognitive deficits. Nat Neurosci. 4(6), 567 - 568.

Mice brains shrink during winter, impairing spatial memory

A study involving adult male white-footed mice may help us understand seasonal dysfunctions such as seasonal affective disorder. The study found that those mice kept in artificial light conditions mimicking winter (8 hours of light per day) had impaired spatial memory compared to mice kept in “summer” conditions (16 hours per day). They also had, on average, smaller brains, with a proportionally smaller hippocampus, as well as changes in dendritic spine density in that region. Other types of memory did not appear to be affected.

[853] Pyter, L. M., Reader B. F., & Nelson R. J. (2005). Short Photoperiods Impair Spatial Learning and Alter Hippocampal Dendritic Morphology in Adult Male White-Footed Mice (Peromyscus leucopus). J. Neurosci.. 25(18), 4521 - 4526.

http://www.eurekalert.org/pub_releases/2005-05/osu-mbs051205.php

Morningness a predictor of better grades in college

A survey of 824 undergraduate students has found that those who were evening types had lower average grades than those who were morning types.

The finding was presented at SLEEP 2008, the 22nd Annual Meeting of the Associated Professional Sleep Societies (APSS).

http://www.eurekalert.org/pub_releases/2008-06/aaos-map050708.php

Circadian clock may be critical for remembering what you learn

We know circadian rhythm affects learning and memory in that we find it easier to learn at certain times of day than others, but now a study involving Siberian hamsters has revealed that having a functioning circadian system is in itself critical to being able to remember. The finding has implications for disorders such as Down syndrome and Alzheimer's disease. The critical factor appears to be the amount of the neurotransmitter GABA, which acts to inhibit brain activity. The circadian clock controls the daily cycle of sleep and wakefulness by inhibiting different parts of the brain by releasing GABA. It seems that if it’s not working right, if the hippocampus is overly inhibited by too much GABA, then the circuits responsible for memory storage don't function properly. The effect could be fixed by giving a GABA antagonist, which blocks GABA from binding to synapses. Recent mouse studies have also demonstrated that mice with symptoms of Down syndrome and Alzheimer's also show improved learning and memory when given the same GABA antagonist. The findings may also have implications for general age-related cognitive decline, because age brings about a degradation in the circadian system. It’s also worth noting that the hamsters' circadian systems were put out of commission by manipulating the hamsters' exposure to light, in a technique that was compared to "sending them west three time zones." The effect was independent of sleep duration.

[688] Ruby, N. F., Hwang C. E., Wessells C., Fernandez F., Zhang P., Sapolsky R., et al. (2008). Hippocampal-dependent learning requires a functional circadian system. Proceedings of the National Academy of Sciences. 105(40), 15593 - 15598.

http://www.eurekalert.org/pub_releases/2008-10/su-ccm100808.php

Meditation's cognitive benefits

A critical part of attention (and working memory capacity) is being able to ignore distraction. There has been growing evidence that meditation training (in particular mindfulness meditation) helps develop attentional control, and that this can start to happen very quickly.

For example:

- after an eight-week course that included up to 30 minutes of daily meditation, novices improved their ability to quickly and accurately move and focus attention.
- three months of rigorous training in Vipassana meditation improved attentional control.
- after eight weeks of Mindfulness Training, Marine reservists during pre-deployment showed increased working memory capacity and decreased negative mood (this training also included concrete applications for the operational environment and information and skills about stress, trauma and resilience in the body).
- after a mere four sessions of 20 minutes, students produced a significant improvement in critical cognitive skills — and a dramatic improvement when conditions became more stressful (provided by increasingly challenging time-constraints).

There seem to be several factors involved in these improvements: better control of brainwaves; increased gray matter density in some brain regions; improved white-matter connectivity.

Thus, after ten weeks of Transcendental Meditation (TM) practice, students showed significant changes in brainwave patterns during meditation compared to eyes-closed rest for the controls. These changes reflected greater coherence and power in brainwave activity in areas that overlap with the default mode network (the brain's 'resting state'). Similarly, after an eight-week mindfulness meditation program, participants had better control of alpha brainwaves. Relatedly, perhaps, experienced Zen meditators have shown that, after interruptions designed to mimic spontaneous thoughts, they could bring activity in most regions of the default mode network back to baseline faster than non-meditators.

Thus, after an 8-week mindfulness meditation program, participants showed increased grey-matter density in the left hippocampus, posterior cingulate cortex, temporo-parietal junction, and cerebellum, as well as decreased grey-matter density in the amygdala. Similarly, another study found experienced meditators showed significantly larger volumes of the right hippocampus and the right orbitofrontal cortex, and to a lesser extent the right thalamus and the left inferior temporal gyrus.

These areas of the brain are all closely linked to emotion, and may explain meditators' improved ability in regulating their emotions.

Thus, long-term meditators showed pronounced differences in white-matter connectivity between their brains and those of age-matched controls, meaning that meditators' brains were better able to quickly relay electrical signals. The brain regions linked by these white-matter tracts include many of those mentioned as showing increased gray matter density. Another study found that a mere 11 hours of meditation training (IBMT) produced measurable changes in the integrity and efficiency of white matter in the corona radiata (which links to the anterior cingulate cortex, an area where attention and emotion are thought to be integrated).

It's an interesting question, the extent to which poor attentional control is a reflection of poor emotional regulation. Obviously there is more to distractability than that, but emotion and attention are clearly inextricably entwined. So, for example, a pilot study involving 10 middle school students with ADHD found that those who participated in twice-daily 10 minute sessions of Transcendental Meditation for three months showed a dramatic reduction in stress and anxiety and improvements in ADHD symptoms and executive function.

The effects of emotion regulation are of course wider than the effects on attention. Another domain they impact is that of decision-making. A study involving experienced Buddhist meditators found that they used different brain regions than controls when making decisions in a 'fairness' game. The differences reflected less input from emotional reactions and more emphasis on the actual benefits.

Similarly, brain scans taken while experienced and novice meditators meditated found that periodic bursts of disturbing noise had less effect on brain areas involved in emotion and decision-making for experienced meditators compared to novices — and very experienced meditators (at least 40,000 hours of experience) showed hardly any activity in these areas at all.

Attention is also entwined with perception, so it's also interesting to observe that several studies have found improved visual perception attendant on meditation training and/or experience. Thus, participants attending a three-month meditation retreat, showed significant improvements in making fine visual distinctions, and ability to sustain attention.

But such benefits may depend on the style of meditation. A study involving experienced practitioners of two styles of meditation (Deity Yoga (DY) and Open Presence (OP)) found that DY meditators were dramatically better at mental rotation and visual memory tasks compared to OP practitioners and controls (and only if they were given the tasks immediately after meditating). Similarly, a study involving Tibetan Buddhist monks found that, during "one-point" meditation, monks were significantly better at maintaining their focus on one image, when two different images were presented to each eye. This superior attentional control was not found during compassion-oriented meditation. However, even under normal conditions the monks showed longer stable perception compared to meditation-naïve control subjects. And three months of intense training in Vipassana meditation produced an improvement in the ability of participants to detect the second of two visual signals half a second apart (the size of the improvement was linked to reduced brain activity to the first target — which was still detected with the same level of accuracy). Similarly, three months of intensive meditation training reduced variability in attentional processing of target tones.

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You can read about these studies in more detail in the aggregated news reports on meditation. Three studies were mentioned here without having appeared in the news reports:

Lutz, A., Slagter, H. A., Rawlings, N. B., Francis, A. D., Greischar, L. L., & Davidson, R. J. (2009). Mental Training Enhances Attentional Stability: Neural and Behavioral Evidence. J. Neurosci., 29(42), 13418-13427. doi:10.1523/JNEUROSCI.1614-09.2009

Tang, Y.-Y., Lu, Q., Geng, X., Stein, E. A., Yang, Y., & Posner, M. I. (2010). Short-term meditation induces white matter changes in the anterior cingulate. Proceedings of the National Academy of Sciences, 107(35), 15649 -15652. doi:10.1073/pnas.1011043107

Travis, F., Haaga, D., Hagelin, J., Tanner, M., Arenander, A., Nidich, S., Gaylord-King, C., et al. (2010). A self-referential default brain state: patterns of coherence, power, and eLORETA sources during eyes-closed rest and Transcendental Meditation practice. Cognitive Processing, 11(1), 21-30. doi:10.1007/s10339-009-0343-2

Meditation's cognitive benefits - news reports

[Running faster changes brain rhythms associated with learning]

A mouse study finds that gamma waves in the hippocampus, critically involved in learning, grow stronger as mice run faster.

I've always felt that better thinking was associated with my brain working 'in a higher gear' — literally working at a faster rhythm. So I was particularly intrigued by the findings of a recent mouse study that found that brainwaves associated with learning became stronger as the mice ran faster.

In the study, 12 male mice were implanted with microelectrodes that monitored gamma waves in the hippocampus, then trained to run back and forth on a linear track for a food reward. Gamma waves are thought to help synchronize neural activity in various cognitive functions, including attention, learning, temporal binding, and awareness.

We know that the hippocampus has specialized 'place cells' that record where we are and help us navigate. But to navigate the world, to create a map of where things are, we need to also know how fast we are moving. Having the same cells encode both speed and position could be problematic, so researchers set out to find how speed was being encoded. To their surprise and excitement, they found that the strength of the gamma rhythm grew substantially as the mice ran faster.

The results also confirmed recent claims that the gamma rhythm, which oscillates between 30 and 120 times a second, can be divided into slow and fast signals (20-45 Hz vs 45-120 Hz for mice, consistent with the 30-55 Hz vs 45-120 Hz bands found in rats) that originate from separate parts of the brain. The slow gamma waves in the CA1 region of the hippocampus were synchronized with slow gamma waves in CA3, while the fast gamma in CA1 were synchronized with fast gamma waves in the entorhinal cortex.

The two signals became increasingly separated with increasing speed, because the two bands were differentially affected by speed. While the slow waves increased linearly, the fast waves increased logarithmically. This differential effect could have to do with mechanisms in the source regions (CA3 and the medial entorhinal cortex, respectively), or to mechanisms in the different regions in CA1 where the inputs terminate (the waves coming from CA3 and the entorhinal cortex enter CA1 in different places).

In the hippocampus, gamma waves are known to interact with theta waves. Further analysis of the data revealed that the effects of speed on gamma rhythm only occurred within a narrow range of theta phases — but this 'preferred' theta phase also changed with running speed, more so for the slow gamma waves than the fast gamma waves (which is not inconsistent with the fact that slow gamma waves are more affected by running speed than fast gamma waves). Thus, while slow and fast gamma rhythms preferred similar phases of theta at low speeds, the two rhythms became increasingly phase-separated with increasing running speed.

What's all this mean? Previous research has shown that if inputs from CA3 and the entorhinal cortex enter CA1 at the same time, the kind of long-term changes at the synapses that bring about learning are stronger and more likely in CA1. So at low speeds, synchronous inputs from CA3 and the entorhinal cortex at similar theta phases make them more effective at activating CA1 and inducing learning. But the faster you move, the more quickly you need to process information. The stronger gamma waves may help you do that. Moreover, the theta phase separation of slow and fast gamma that increases with running speed means that activity in CA3 (slow gamma source) increasingly anticipates activity in the medial entorhinal cortex (fast gamma source).

What does this mean at the practical level? Well at this point it can only be speculation that moving / exercising can affect learning and attention, but I personally am taking this on board. Most of us think better when we walk. This suggests that if you're having trouble focusing and don't have time for that, maybe walking down the hall or even jogging on the spot will help bring your brain cells into order!

Pushing speculation even further, I note that meditation by expert meditators has been associated with changes in gamma and theta rhythms. And in an intriguing comparison of the effect of spoken versus sung presentation on learning and remembering word lists, the group that sang showed greater coherence in both gamma and theta rhythms (in the frontal lobes, admittedly, but they weren't looking elsewhere).

So, while we're a long way from pinning any of this down, it may be that all of these — movement, meditation, music — can be useful in synchronizing your brain rhythms in a way that helps attention and learning. This exciting discovery will hopefully be the start of an exploration of these possibilities.

[2337] Chen, Z., Resnik E., McFarland J. M., Sakmann B., & Mehta M. R. (2011). Speed Controls the Amplitude and Timing of the Hippocampal Gamma Rhythm. PLoS ONE. 6(6), e21408 - e21408.

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http://www.eurekalert.org/pub_releases/2011-06/uoc--bra062411.php

Long-term meditation fights age-related cognitive decline

Another study adds to the weight of evidence that meditating has cognitive benefits. The latest finding points to brain-wide improvements in connectivity.

Following on from research showing that long-term meditation is associated with gray matter increases across the brain, an imaging study involving 27 long-term meditators (average age 52) and 27 controls (matched by age and sex) has revealed pronounced differences in white-matter connectivity between their brains.

The differences reflect white-matter tracts in the meditators' brains being more numerous, more dense, more myelinated, or more coherent in orientation (unfortunately the technology does not yet allow us to disentangle these) — thus, better able to quickly relay electrical signals.

While the differences were evident among major pathways throughout the brain, the greatest differences were seen within the temporal part of the superior longitudinal fasciculus (bundles of neurons connecting the front and the back of the cerebrum) in the left hemisphere; the corticospinal tract (a collection of axons that travel between the cerebral cortex of the brain and the spinal cord), and the uncinate fasciculus (connecting parts of the limbic system, such as the hippocampus and amygdala, with the frontal cortex) in both hemispheres.

These findings are consistent with the regions in which gray matter increases have been found. For example, the tSLF connects with the caudal area of the temporal lobe, the inferior temporal gyrus, and the superior temporal gyrus; the UNC connects the orbitofrontal cortex with the amygdala and hippocampal gyrus

It's possible, of course, that those who are drawn to meditation, or who are likely to engage in it long term, have fundamentally different brains from other people. However, it is more likely (and more consistent with research showing the short-term effects of meditation) that the practice of meditation changes the brain.

The precise mechanism whereby meditation might have these effects can only be speculated. However, more broadly, we can say that meditation might induce physical changes in the brain, or it might be protecting against age-related reduction. Most likely of all, perhaps, both processes might be going on, perhaps in different regions or networks.

Regardless of the mechanism, the evidence that meditation has cognitive benefits is steadily accumulating.

The number of years the meditators had practiced ranged from 5 to 46. They reported a number of different meditation styles, including Shamatha, Vipassana and Zazen.

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Mindfulness meditation changes how decisions are made

Another recent meditation study has found that experienced Buddhist meditators use different brain regions than controls when making decisions in a ‘fairness’ game.

The study involved 26 experienced Buddhist meditators and 40 control subjects. Scans of their brains while they played the "ultimatum game," in which the first player proposes how to divide a sum of money and the second can accept or reject the proposal, revealed that the two groups engaged different parts of the brain when making these decisions.

Consistent with earlier studies, controls showed increased activity in the anterior insula (involved in disgust and emotional reactions to unfairness and betrayal) when the offers were unfair. However the Buddhist meditators showed higher activity instead in the posterior insula (involved in interoception and attention to the present moment). In other words, rather than dwelling on emotional reactions and imaginary what-if scenarios, the meditators concentrated on the interoceptive qualities that accompany any reward, no matter how small.

The meditators accepted unfair offers on more than half of the trials, whereas controls only accepted unfair offers on a quarter of the trials.

Moreover, those controls who did in fact play the game ‘rationally’ (that is, mostly accepting the unfair offers) showed activity in the dorsolateral prefrontal cortex, while rational meditators displayed increased activity in the somatosensory cortex and posterior superior temporal cortex.

The most intriguing thing about all this is not so much that regular meditation might change the way your brain works (although that is undeniably interesting), but as a more general demonstration that we can train our brain to work in different ways. Something to add to the research showing how brain regions shift in function in those with physical damage to their brains or sense organs (eg, in those who become blind).

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Mindfulness meditation may help attention through better control of alpha rhythms

New research suggests that meditation can improve your ability to control alpha brainwaves, thus helping you block out distraction.

As I’ve discussed on many occasions, a critical part of attention (and working memory capacity) is being able to ignore distraction. There has been growing evidence that mindfulness meditation training helps develop attentional control. Now a new study helps fill out the picture of why it might do so.

The alpha rhythm is particularly active in neurons that process sensory information. When you expect a touch, sight or sound, the focusing of attention toward the expected stimulus induces a lower alpha wave height in neurons that would handle the expected sensation, making them more receptive to that information. At the same time the height of the alpha wave in neurons that would handle irrelevant or distracting information increases, making those cells less receptive to that information. In other words, alpha rhythm helps screen out distractions.

In this study, six participants who completed an eight-week mindfulness meditation program (MBSR) were found to generate larger alpha waves, and generate them faster, than the six in the control group. Alpha wave activity in the somatosensory cortex was measured while participants directed their attention to either their left hand or foot. This was done on three occasions: before training, at three weeks of the program, and after the program.

The MBSR program involves an initial two-and-a-half-hour training session, followed by daily 45-minute meditation sessions guided by a CD recording. The program is focused on training participants first to pay close attention to body sensations, then to focus on body sensations in a specific area, then being able to disengage and shifting the focus to another body area.

Apart from helping us understand why mindfulness meditation training seems to improve attention, the findings may also explain why this meditation can help sufferers of chronic pain.

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Mindfulness meditation training changes brain structure in 8 weeks

After 8 weeks practicing mindfulness meditation, measurable changes occurred in brain regions associated with memory and emotion.

Brain images of 16 participants in an 8-week mindfulness meditation program, taken two weeks before and after the program, have found measurable changes in brain regions associated with memory, sense of self, empathy and stress. Specifically, they showed increased grey-matter density in the left hippocampus, posterior cingulate cortex, temporo-parietal junction, and cerebellum, as well as decreased grey-matter density in the amygdala. Similar brain scans of a control group of non-meditators (those on a waiting list for the program) showed no such changes over time.

Although a number of studies have found differences in the brains of experienced meditators and those who don't practice meditation, this is the first to demonstrate that those differences are actually produced by meditation.

The Mindfulness-Based Stress Reduction program involved weekly meetings that included practice of mindfulness meditation and audio recordings for guided meditation practice.

Participants reported spending an average of 27 minutes each day practicing mindfulness exercises.

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The protective effects of mindfulness training

Mindfulness Training had a positive effect on both working memory capacity and mood in a group of Marine reservists during the high-stress pre-deployment interval.

Mindfulness Training had a positive effect on both working memory capacity and mood in a group of Marine reservists during the high-stress pre-deployment interval. While those who weren't given the 8-week MT program, as well as those who spent little time engaging in mindfulness exercises, showed greater negative mood and decreased working memory capacity over the eight weeks, those who recorded high practice time showed increased capacity and decreased negative mood. A civilian control group showed no change in working memory capacity over the period. The program, called Mindfulness-based Mind Fitness Training (MMFT™), blended mindfulness skills training with concrete applications for the operational environment and information and skills about stress, trauma and resilience in the body. The researchers suggest that mindfulness training may help anyone who must maintain peak performance in the face of extremely stressful circumstances.

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Visual perception heightened by meditation training

Another study confirms the effects of meditation training on visual perception.

Another study showing the cognitive benefits of meditation has revealed benefits to perception and attention. The study involved 30 participants attending a three-month meditation retreat, during which they attended group sessions twice a day and engaging in individual practice for about six hours a day. The meditation practice involved sustained selective attention on a chosen stimulus (e.g., the participant's breath). By midway through the retreat, meditators had become better at making fine visual distinctions, and better able to sustain attention during the half-hour test, compared to matched controls. Those who continued practicing meditation after the retreat still showed improvements in perception when they were retested about five months later.

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Brief meditative exercise helps cognition

Great news for those who crave the benefits of meditation but find the thought a bit intimidating! Adding to evidence that long-term mindfulness meditation practice promotes executive functioning and the ability to sustain attention, a small study has found cognitive benefits from as little as four sessions of 20 minutes.

Great news for those who crave the benefits of meditation but find the thought a bit intimidating! While a number of studies have demonstrated that long-term mindfulness meditation practice promotes executive functioning and the ability to sustain attention, now a small study involving 49 students has found that as little as four sessions of 20 minutes produced a significant improvement in critical cognitive skills, compared to those who spent an equal amount of time listening to Tolkien's The Hobbit being read aloud. Both groups showed similar improved levels of mood, but only the meditation group improved their cognitive scores. While this group improved on all cognitive tasks, they did dramatically better when under stressful conditions, such as provided by increasingly challenging time-constraints, and particularly in the areas of attention and vigilance. Mindfulness training, as given here, focuses on breathing, letting go one's thoughts, releasing sensory events that distract. It should be noted that no one is suggesting four days training produces a permanent effect! But it is encouraging to think that benefits might be achieved so quickly. The training also reduced fatigue and anxiety.

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More on how meditation can improve attention

Another study adds to research showing meditation training helps people improve their ability to focus and ignore distraction. The new study shows that three months of rigorous training in Vipassana meditation improved people's ability to stabilize attention on target tones, when presented with tones in both ears and instructed to respond only to specific tones in one ear. Marked variability in response time is characteristic of those with ADHD.

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Meditation may increase gray matter

Adding to the increasing evidence for the cognitive benefits of meditation, a new imaging study of 22 experienced meditators and 22 controls has revealed that meditators showed significantly larger volumes of the right hippocampus and the right orbitofrontal cortex, and to a lesser extent the right thalamus and the left inferior temporal gyrus. There were no regions where controls had significantly more gray matter than meditators. These areas of the brain are all closely linked to emotion, and may explain meditators' improved ability in regulating their emotions.

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Meditation technique can temporarily improve visuospatial abilities

And continuing on the subject of visual short-term memory, a study involving experienced practitioners of two styles of meditation: Deity Yoga (DY) and Open Presence (OP) has found that, although meditators performed similarly to nonmeditators on two types of visuospatial tasks (mental rotation and visual memory), when they did the tasks immediately after meditating for 20 minutes (while the nonmeditators rested or did something else), practitioners of the DY style of meditation showed a dramatic improvement compared to OP practitioners and controls. In other words, although the claim that regular meditation practice can increase your short-term memory capacity was not confirmed, it does appear that some forms of meditation can temporarily (and dramatically) improve it. Since the form of meditation that had this effect was one that emphasizes visual imagery, it does support the idea that you can improve your imagery and visual memory skills (even if you do need to ‘warm up’ before the improvement is evident).

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Transcendental Meditation reduces ADHD symptoms among students

A pilot study involving 10 middle school students with ADHD has found that those who participated in twice-daily 10 minute sessions of Trancendental Meditation for three months showed a dramatic reduction in stress and anxiety and improvements in ADHD symptoms and executive function. The effect was much greater than expected. ADHD children have a reduced ability to cope with stress.
A second, recently completed study has also found that three months practice of the technique

resulted in significant positive changes in brain functioning during visual-motor skills, especially in the circuitry of the brain associated with attention and distractibility. After six months practice, measurements of distractibility moved into the normal range.

Grosswald, S. J., Stixrud, W. R., Travis, F., & Bateh, M. A. (2008, December). Use of the Transcendental Meditation technique to reduce symptoms of Attention Deficit Hyperactivity Disorder (ADHD) by reducing stress and anxiety: An exploratory study. *Current Issues in Education* [On-line], *10*(2). Available: http://cie.ed.asu.edu/volume10/number2/

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Meditation speeds the mind's return after distraction

Another study comparing brain activity in experienced meditators and novices has looked at what happens when people meditating were interrupted by stimuli designed to mimic the appearance of spontaneous thoughts. The study compared 12 people with more than three years of daily practice in Zen meditation with 12 others who had never practiced meditation. It was found that, after interruption, experienced meditators were able to bring activity in most regions of the default mode network (especially the angular gyrus, a region important for processing language) back to baseline faster than non-meditators. The default mode network is associated with the occurrence of spontaneous thoughts and mind-wandering during wakeful rest. The findings indicate not only the attentional benefits of meditation, but also suggest a value for disorders characterized by excessive rumination or an abnormal production of task-unrelated thoughts, such as obsessive-compulsive disorder, anxiety disorder and major depression.

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Improved attention with mindfulness training

More evidence of the benefits of meditation for attention comes from a study looking at the performance of novices taking part in an eight-week course that included up to 30 minutes of daily meditation, and experienced meditators who attended an intensive full-time, one-month retreat. Initially, the experienced participants demonstrated better executive functioning skills, the cognitive ability to voluntarily focus, manage tasks and prioritize goals. After the eight-week training, the novices had improved their ability to quickly and accurately move and focus attention, while the experienced participants, after their one-month intensive retreat, also improved their ability to keep attention "at the ready."

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Brain scans show how meditation affects the brain

An imaging study comparing novice and experienced meditators found that experienced meditators showed greater activity in brain circuits involved in paying attention. But the most experienced meditators with at least 40,000 hours of experience showed a brief increase in activity as they started meditating, and then a drop to baseline, as if they were able to concentrate in an effortless way. Moreover, while the subjects meditated inside the MRI, the researchers periodically blasted them with disturbing noises. Among the experienced meditators, the noise had less effect on the brain areas involved in emotion and decision-making than among novice meditators. Among meditators with more than 40,000 hours of lifetime practice, these areas were hardly affected at all. The attention circuits affected by meditation are also involved in attention deficit hyperactivity disorder.

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Meditation may improve attentional control

Paying attention to one thing can keep you from noticing something else. When people are shown two visual signals half a second apart, they often miss the second one — this effect is called the attentional blink. In a study involving 40 participants being trained in Vipassana meditation (designed to reduce mental distraction and improve sensory awareness), one group of 17 attended a 3 month retreat during which they meditated for 10–12 hours a day (practitioner group), and 23 simply received a 1-hour meditation class and were asked to meditate for 20 minutes daily for 1 week prior to each testing session (control group). The three months of intense training resulted in a smaller attentional blink and reduced brain activity to the first target (which was still detected with the same level of accuracy. Individuals with the most reduction in activity generally showed the most reduction in attentional blink size. The study demonstrates that mental training can result in increased attentional control.

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Meditation skills of Buddhist monks yield clues to brain's regulation of attention

Recent research has suggested that skilled meditation can alter certain aspects of the brain's neural activity. A new study has now found evidence that certain types of trained meditative practice can influence the conscious experience of visual perceptual rivalry, a phenomenon thought to involve brain mechanisms that regulate attention and conscious awareness. Perceptual rivalry arises normally when two different images are presented to each eye, and it is manifested as a fluctuation in the "dominant" image that is consciously perceived. The study involved 76 Tibetan Buddhist monks with training ranging from 5 to 54 years. Tested during the practice of two types of meditation: a "compassion"-oriented meditation (contemplation of suffering within the world), and "one-point" meditation (involving the maintained focus of attention on a single object or thought). Major increases in the durations of perceptual dominance were experienced by monks practicing one-point meditation, but not during compassion-oriented meditation. Additionally, under normal conditions the monks showed longer stable perception (average 4.1 seconds compared to 2.6 seconds for meditation-naïve control subjects). The findings suggest that processes particularly associated with one-point meditation can considerably alter the normal fluctuations in conscious state that are induced by perceptual rivalry.

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The role of consolidation in memory

"Consolidation" is a term that is bandied about a lot in recent memory research. Here's my take on what it means.

Becoming a memory

Initially, information is thought to be encoded as patterns of neural activity — cells "talking" to each other. Later, the information is coded in more persistent molecular or structural formats (e.g., the formation of new synapses). It has been assumed that once this occurs, the memory is "fixed" — a permanent, unchanging, representation.

With new techniques, it has indeed become possible to observe these changes (you can see videos here). Researchers found that the changes to a cell that occurred in response to an initial stimulation lasted some three to five minutes and disappeared within five to 10 minutes. If the cell was stimulated four times over the course of an hour, however, the synapse would actually split and new synapses would form, producing a (presumably) permanent change.

Memory consolidation theory

The hypothesis that new memories consolidate slowly over time was proposed 100 years ago, and continues to guide memory research. In modern consolidation theory, it is assumed that new memories are initially 'labile' and sensitive to disruption before undergoing a series of processes (e.g., glutamate release, protein synthesis, neural growth and rearrangement) that render the memory representations progressively more stable. It is these processes that are generally referred to as “consolidation”.

Recently, however, the idea has been gaining support that stable representations can revert to a labile state on reactivation.

Memory as reconstruction

In a way, this is not surprising. We already have ample evidence that retrieval is a dynamic process during which new information merges with and modifies the existing representation — memory is now seen as reconstructive, rather than a simple replaying of stored information

Reconsolidation of memories

Researchers who have found evidence that supposedly stable representations have become labile again after reactivation, have called the process “reconsolidation”, and suggest that consolidation, rather than being a one-time event, occurs repeatedly every time the representation is activated.

This raises the question: does reconsolidation involve *replacing* the previously stable representation, or the establishment of a new representation, that coexists with the old?

Whether reconsolidation is the creating of a new representation, or the modifying of an old, is this something other than the reconstruction of memories as they are retrieved? In other words, is this recent research telling us something about consolidation (part of the encoding process), or something about reconstruction (part of the retrieval process)?

Hippocampus involved in memory consolidation

The principal player in memory consolidation research, in terms of brain regions, is the hippocampus. The hippocampus is involved in the recognition of place and the consolidation of contextual memories, and is part of a region called the medial temporal lobe (MTL), that also includes the perirhinal, parahippocampal, and entorhinal cortices. Lesions in the medial temporal lobe typically produce amnesia characterized by the disproportionate loss of recently acquired memories. This has been interpreted as evidence for a memory consolidation process.

Some research suggests that the hippocampus may participate only in consolidation processes lasting a few years. The entorhinal cortex, on the other hand, gives evidence of temporally graded changes extending up to 20 years, suggesting that it is this region that participates in memory consolidation over decades. The entorhinal cortex is damaged in the early stages of Alzheimer's disease.

There is, however, some evidence that the hippocampus can be involved in older memories — perhaps when they are particularly vivid.

A recent idea that has been floated suggests that the entorhinal cortex, through which all information passes on its way to the hippocampus, handles "incremental learning" — learning that requires repeated experiences. "Episodic learning" — memories that are stored after only one occurrence — might be mainly stored in the hippocampus.

This may help explain the persistence of some vivid memories in the hippocampus. Memories of emotionally arousing events tend to be more vivid and to persist longer than do memories of neutral or trivial events, and are, moreover, more likely to require only a single experience.

Whether or not the hippocampus may retain some older memories, the evidence that some memories might be held in the hippocampus for several years, only to move on, as it were, to another region, is another challenge to a simple consolidation theory.

Memory more complex than we thought

So where does all this leave us? What **is** consolidation? **Do** memories reach a fixed state?

My own feeling is that, no, memories don't reach this fabled "cast in stone" state. Memories are subject to change every time they are activated (such activation doesn't have to bring the memory to your conscious awareness). But consolidation traditionally (and logically) refers to encoding processes. It is reasonable, and useful, to distinguish between:

- the initial encoding, the "working memory" state, when new information is held precariously in shifting patterns of neural activity,
- the later encoding processes, when the information is consolidated into a more permanent form with the growth of new connections between nerve cells,
- the (possibly much) later retrieval processes, when the information is retrieved in, most probably, a new context, and is activated anew

I think that "reconsolidation" is a retrieval process rather than part of the encoding processes, but of course, if you admit retrieval as involving a return to the active state and a modification of the original representation in line with new associations, then the differences between retrieval and encoding become less evident.

When you add to this the possibility that memories might "move" from one area of the brain to another after a certain period of time (although it is likely that the triggering factor is not time *per se*), then you cast into disarray the whole concept of memories becoming stable.

Perhaps our best approach is to see memory as a series of processes, and consolidation as an agreed-upon (and possibly arbitrary) subset of those processes.

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Adult Neurogenesis

Neurogenesis occurs in two main areas in the adult brain: the hippocampus and the olfactory bulb.

The transformation of a new cell into a neuron appears to crucially involve a specific protein called WnT3, that's released by support cells called astrocytes.

A chemical called BDNF also appears critical for the transformation into neurons.

Most recently, T-cells have also been revealed as important for neurogenesis to occur.

The extent and speed of neurogenesis can also be enhanced by various chemicals. Nerve growth factors appear to enhance the proliferation of precursor cells (cells with the potential to become neurons), and the prion protein that, damaged, causes mad cow disease, appears in its normal state to speed the rate of neurogenesis.

The integration of the new neuron into existing networks appears to need a brain chemical called GABA.

Indications are that moderate alcohol may enhance neurogenesis, but excess alcohol certainly has a negative effect. Most illegal drugs have a negative effect, but there is some suggestion cannabinoids may enhance neurogenesis. Antidepressants also seem to have a positive effect, while stress and anxiety reduce neurogenesis. However, positive social experiences, such as being of high status, can increase neurogenesis. Physical activity, mental stimulation, and learning, have all been shown to have a positive effect on neurogenesis.

What is neurogenesis?

Neurogenesis — the creation of new brain cells — occurs of course at a great rate in the very young. For a long time, it was not thought to occur in adult brains — once you were grown, it was thought, all you could do was watch your brain cells die!

Adult neurogenesis (the creation of new brain cells in adult brains) was first discovered in 1965, but only recently has it been accepted as a general phenomenon that occurs in many species, including humans (1998).

Where does adult neurogenesis occur?

It's now widely accepted that adult neurogenesis occurs in the subgranular zone of the dentate gyrus within the hippocampus and the subventricular zone (SVZ) lining the walls of the lateral ventricles within the forebrain. It occurs, indeed, at a quite frantic rate — some 9000 new cells are born in the dentate gyrus every day in young adult rat brains — but under normal circumstances, at least half of those new cells will die within one or two months.

The neurons produced in the SVZ are sent to the olfactory bulb, while those produced in the dentate gyrus are intended for the hippocampus.

Adult neurogenesis might occur in other regions, but this is not yet well-established. However, recent research has found that small, non-pyramidal, inhibitory interneurons are being created in the cortex and striatum. These new interneurons appear to arise from a previously unknown class of local precursor cells. These interneurons make and secrete GABA (see below for why GABA is important), and are thought to play a role in regulating larger types of neurons that make long-distance connections between brain regions.

How does neurogenesis occur?

New neurons are spawned from the division of neural precursor cells — cells that have the potential to become neurons or support cells. How do they decide whether to remain a stem cell, turn into a neuron, or a support cell (an astrocyte or oligodendrocyte)?

Observation that neuroblasts traveled to the olfactory bulb from the SVZ through tubes formed by astrocytes has led to an interest in the role of those support cells. It's now been found that astrocytes encourage both precursor cell proliferation and their maturation into neurons — precursor cells grown on glia divide about twice as fast as they do when grown on fibroblasts, and are about six times more likely to become neurons.

Adult astrocytes are only about half as effective as embryonic astrocytes in promoting neurogenesis.

It’s been suggested that the role of astrocytes may help explain why neurogenesis only occurs in certain parts of the brain — it may be that there’s something missing from the glial cells in those regions.

The latest research suggests that the astrocytes influence the decision through a protein that it secretes called Wnt3. When Wnt3 proteins were blocked in the brains of adult mice, neurogenesis decreased dramatically; when additional Wnt3 was introduced, neurogenesis increased.

How are these new neurons then integrated into existing networks? Mouse experiments have found that the brain chemical called GABA is critical. Normally, GABA inhibits neuronal signals, but it turns out that with new neurons, GABA has a different effect: it excites them, and prepares them for integration into the adult brain. Thus a constant flood of GABA is needed initially; the flood then shifts to a more targeted pulse that gives the new neuron specific connections that communicate using GABA; finally, the neuron receives connections that communicate via another chemical, glutamate. The neuron is now ready to function as an adult neuron, and will respond to glutamate and GABA as it should.

The creation and development of new neurons in the adult brain is very much a "hot" topic right now — it's still very much a work-in-progress. However, it is clear that other brain chemicals are also involved. An important one is BDNF (brain-derived neurotrophic factor), which seems to be needed during the proliferation of hippocampal precursor cells to trigger their transformation into neurons.

Other growth factors have been found to stimulate proliferation of hippocampal progenitor cells: FGF-2 (fibroblast growth factor-2) and EGF (epidermal growth factor).

Recently it has been discovered that the normal form of the prion protein which, when malformed, causes mad cow disease, is also involved in neurogenesis. These proteins, in their normal form, are found throughout our bodies, and particularly in our brains. Now it seems that the more of these prion proteins that are available, the faster neural precursor cells turn into neurons.

The immune system's T cells (which recognize brain proteins) are also critically involved in enabling neurogenesis to occur. Among mice given environmental enrichment, only those with healthy T-cells had their production of new neurons boosted.

Factors that influence neurogenesis

A number of factors have been found to affect the creation and survival of new neurons. For a start, damage to the brain (from a variety of causes) can provoke neurogenesis.

Moderate alcohol consumption over a relatively long period of time can also enhance the formation of new nerve cells in the adult brain (this may be related to alcohol's enhancement of GABA's function). Excess alcohol, however, has a detrimental effect on the formation of new neurons in the adult hippocampus. But although neurogenesis is inhibited during alcohol dependency, it does recover. A pronounced increase in new neuron formation in the hippocampus was found within four-to-five weeks of abstinence. This included a twofold burst in brain cell proliferation at day seven of abstinence.

Most drugs of abuse such as nicotine, heroine, and cocaine suppress neurogenesis, but a new study suggests that cannabinoids also promote neurogenesis. The study involved a synthetic cannabinoid, which increased the proliferation of progenitor cells in the hippocampal dentate gyrus of mice, in a similar manner as some antidepressants have been shown to do. The cannabinoid also produced similar antidepressant effects. Further research is needed to confirm this early finding.

If antidepressants promote neurogenesis, it won't be surprising to find that chronic stress, anxiety and depression are associated with losing hippocampal neurons. A rat study has also found that stress in early life can permanently impair neurogenesis in the hippocampus.

Showing the other side of this picture, perhaps, an intriguing rat study found that status affected neurogenesis in the hippocampus, with high-status animals having around 30% more neurons in their hippocampus after being placed in a naturalistic setting with other rats.

Also, a study into the brains of songbirds found that birds living in large groups have more new neurons and probably a better memory than those living alone.

Both physical activity and environmental enrichment ("mental stimulation") have been shown to affect both how many cells are born in the dentate gyrus of rats and how many survive. Learning that uses the hippocampus has also been shown to have a positive effect, although results here have been inconsistent.

Inconsistent results from studies looking at neurogenesis are, it is suggested, largely because of a confusion between proliferation and survival. Neurogenesis is measured in terms of these two factors, which researchers often fail to distinguish between: the generation of new brain cells, and their survival. But these are separate factors, that are independently affected by various factors.

The inconsistency found in the effects of learning may also be partly explained by the complex nature of the effects. For example, during the later phase of learning, when performance is starting to plateau, neurons created during the late phase were more likely to survive, but neurons created during the early phase of more rapid learning disappeared. It's speculated that that this may be a "pruning" process by which cells that haven't made synaptic connections are removed from the network.

And finally, rodent studies suggest a calorie-restricted diet may also be of benefit.

It's not all about growing new neurons

A few years ago, we were surprised by news that new neurons could be created in the adult brain. However, it's remained a tenet that adult neurons don't grow — this because researchers have found no sign that any structural remodelling takes place in an adult brain. Now a mouse study using new techniques has revealed that dramatic restructuring occurs in the less-known, less-accessible inhibitory interneurons. Dendrites (the branched projections of a nerve cell that conducts electrical stimulation to the cell body) show sometimes dramatic growth, and this growth is tied to use, supporting the idea that the more we use our minds, the better they will be.

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