The Effects of Sleep Deprivation on Brain and Behavior

by Sarah Ledoux

Sleep deprivation is a commonplace occurrence in modern culture. Every day there seems to be twice as much work and half as much time to complete it in. This results in either extended periods of wakefulness or a decrease in sleep over an extended period of time. While some people may like to believe that they can train their bodies to not require as much sleep as they once did, this belief is false (1).

Sleep is needed to regenerate certain parts of the body, especially the brain, so that it may continue to function optimally. After periods of extended wakefulness or reduced sleep neurons may begin to malfunction, visibly affecting a person's behavior. Some organs, such as muscles, are able to regenerate even when a person is not sleeping so long as they are resting. This could involve lying awake but relaxed within a quite environment. Even though cognitive functions might not seem necessary in this scenario the brain, especially the cerebral cortex, is not able to rest but rather remains semi-alert in a state of "quiet readiness" (2). Certain stages of sleep are needed for the regeneration of neurons within the cerebral cortex while other stages of sleep seem to be used for forming new memories and generating new synaptic connections. The effects of sleep deprivation on behavior have been tested with relation to the presence of activity in different sections of the cerebral cortex.

The temporal lobe of the cerebral cortex is associated with the processing of language. During verbal learning tests on subjects who are fully rested functional magnetic resonance imaging scans show that this area of the brain is very active. However, in sleep deprived subjects there is no activity within this region (3), (4), (5). The effects of this inactivity can be observed by the slurred speech in subjects who have gone for prolonged periods with no sleep (6).

Even severely sleep deprived people are still able to perform to some degree on a verbal learning test. This implies that some other area of the brain must become active to compensate for the loss of temporal lobe functioning. In fact, activity can be seen in the parietal lobe that is not present during verbal learning tests using rested subjects (5).

Greater activity within this region corresponded to better performance by subjects in research studies (7). Still, sleep deprived people do not perform as well on these tests as do fully rested subjects (3), (4). One possible reason for the poorer performance after missing sleep, aside from unregenerated neurons, could be the fact that since the parietal lobe is not usually used to performing tasks such as these it is not as adept at carrying them out. Therefore, when control switches from the temporal lobe to the parietal lobe some speed and accuracy is naturally lost. Interestingly, sleep deprived subjects have been shown to have better short-term memory abilities than their well-rested counterparts (6). Since memory is associated with this region of the cerebral cortex the fact that it is already active in sleep deprived people could make it easier for new synapses to be created, thus forming new short-term memories more easily.

While activity is seen within the parietal lobes of rested people as they think through math problems no corresponding activity is visible within the brains of sleep-deprived subjects. Also, no new area of the brain becomes active while the sleep deprived people work on math problems. Since sleep deprived people can still complete math problems, albeit with less speed and accuracy than a well-rested individual, this data implies that a region of the brain already in use is used for this task (1).

The frontal lobe is the most fascinating section of the brain with relation to sleep deprivation. Its functions are associated with speech as well as novel and creative thinking (5). Sleep deprived test subjects have difficulties thinking of imaginative words or ideas. Instead, they tend to choose repetitious words or clichéd phrases. Also, a sleep-deprived individual is less able to deliver a statement well. The subject may show signs of slurred speech, stuttering, speaking in a monotone voice, or speaking at a slower pace than usual (6). Subjects in research studies also have a more difficult time reacting well to unpredicted rapid changes. Sleep deprived people do not have the speed or creative abilities to cope with making quick but logical decisions, nor do they have the ability to implement them well. Studies have demonstrated that a lack of sleep impairs one's ability to simultaneously focus on several different related tasks, reducing the speed as well as the efficiency of one's actions (8). A person may be able to react to a complex scenario when suddenly presented with it but, similar to the verbal tests, the subject will most likely pick an unoriginal solution. If presented with a similar situation multiple times with slight variations in the information presented the subject chooses the same solution, even though it might not be as applicable to the new scenario (9).

Part of the frontal lobe, the prefrontal cortex, has several functions specifically coupled with it. Judgment, impulse control, attention, and visual association have all been related to this region of the cerebral cortex (8). A recent study has shown that the prefrontal cortex, usually the most active area of the brain in rested individuals, becomes more active as a person remains awake for long periods of time (3), (4). This region regenerates during the first stage of sleep, giving a person the ability to feel somewhat refreshed after only a short nap (5). The length of the first stage of sleep cycle is somewhat dependent upon how long the person had previously been awake. The longer the period of wakefulness, the longer the brain remains in the first stage of sleep. When the brain enters into the REM stage of sleep the prefrontal cortex is active once more.

The implications of this data seem to be fairly important in supporting the location of the I-function within the brain. The prefrontal cortex is active whenever a person is awake, no matter how little sleep they have had. Also, this area is active while dreaming. Since the individual is aware of him or herself during both of these instances, but is not aware during the stages of sleep when the prefrontal cortex is shut down, it seems logical that the I-function is located within this region. This indicates that the I-function is what is resting and regenerating during the first stage of sleep. It would be interesting to study prefrontal cortex activity while a person is conscious, but unaware of his or her actions, due to an influence such as drugs or alcohol. According to the results of the sleep deprivation studies little or no activity should be seen in the prefrontal cortex at anytime when the individual is unaware of his or herself.

One of the symptoms of prolonged sleep deprivation is hallucinations (10). This could also be related to the I-function since it is the system that integrates the input from all other areas of the brain. If the neurons composing the I-function become too taxed then the picture in the head that the I-function produces may be more dissimilar from reality than usual. The neurons, under pressure to continue functioning but unable to perform optimally, create an image useful enough for a person to see most of his or her surroundings. Metabolic activity in the prefrontal cortex can drop as much as eleven percent after a person has missed sleep for only twenty four hours (8). As a person loses more sleep or continues to receive less-than-adequate amounts of sleep the neurons become even more taxed and the I-function may begin to generate even less coherent images possibly resulting in temporary insanity.

Another piece of evidence supporting the location of the I-function is that mammals have REM sleep whereas cold-blooded animals do not and mammals have a neocortex, located within the prefrontal cortex, while cold-blooded animals do not. REM sleep stimulates areas of the brain used for learning and memory (10). When a person is taught a new skill his or her performance does not improve until he or she receives at least eight hours of sleep (11). An extended period of sleep ensures that the brain will be able to complete the full sleep cycle, including REM sleep. The necessity of sleep for learning could be due to the fact that sleep increases the production of proteins while reducing the rate at which they are broken down (10). Proteins are used to regenerate the neurons within the brain. Without them new synapses may not be able to be formed, thus limiting the amount of information a sleep-deprived individual can maintain.

One of the possible side effects of a continued lack of sleep is death. Usually this is the result of the fact that the immune system is weakened without sleep. The number of white blood cells within the body decreases, as does the activity of the remaining white blood cells. The body also decreases the amount of growth hormone produced (8). The ability of the body to metabolize sugar declines, turning sugar into fat. One study stated that people who sleep less than four hours per night are three times more likely to die within the next six years (11). Although the longest a human has remained awake was eleven days rats that are continually deprived of sleep die within two to five weeks, generally due to their severely weakened immune system (10), (11), (12).

In a way sleep deprivation studies help us to study the relationship between the brain and behavior in a very unique way by observing how a person's behavior changes as the brain shuts down. By taking images of the brain showing where activity is located it is possible to correlate the behavior exhibited by a subject with his or her brain patterns. Just like a person cannot jog for three continuous days a person's brain cannot operate without rest breaks. Since different regions of the brain rest during different stages of the sleep cycle, sleep cannot be cut short. In fact, if the brain does not receive a break it will soon begin to shut down for periods of microsleep. This is essentially several seconds of actual sleep; delta waves that interrupt the regular EEG of an awake person thereby impairing his or her continuity of cognitive function. Microsleep generally happens directly before performance failure occurs (8). Without sleep our brains deteriorate, and if the argument that brain=behavior is true, then our behavior will also suffer accordingly.

WWW Sources

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