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# Sleep and Memory: Can We Enhance Intelligence?

REM sleep, stage II sleep, and slow wave sleep are all important in the consolidation of memory.[1 2 3] Studies involving trampolining,[4] intensive learning of a foreign language,[5] and Morse code learning[6] all demonstrated increases in REM sleep following successful learning. This knowledge is interesting, but the question is whether or not it can be put to real benefit. Is there a way to aid in the learning process to improve upon our ability to learn?

Specific EEG waveforms during REM sleep may be important in the process of memory consolidation. Sawtooth waves in the theta frequency seen during REM sleep may occur right before a burst of rapid eye movements.[7] During prior wakefulness, the process of temporarily storing a memory trace in the hippocampus also occurs at this theta frequency.[8] The actual pattern of hippocampal neuronal firing seen during waking learning may later be witnessed during subsequent REM sleep.[9] This process has been witnessed in rats running wheels and learning mazes as well as in zebra finches learning new songs.[10]

Assuming the quality and amount of sleep is normal, can memory be enhanced? One study has demonstrated enhanced learning when auditory clicks are presented while learning and then during bursts of rapid eye movements in REM sleep.[11] Neuronal excitation may be enhanced when auditory clicks are presented during the sleep spindles of stage II sleep especially during the ascent from slow wave sleep to REM sleep.[12] Another study used weak electrical current direct cortical stimulation through the scalp over thirty minute periods to modulate excitability in the frontal lobes during slow wave sleep. The study claims that the direct cortical stimulation significantly improved memory in regards to memorizing word pairs.[13]

Theoretically, a device could be devised that could enhance normal learning. This device would presumably provide a stimulus during the learning of conscious awareness, and then again during the occurrence of certain neurophysiologic waveforms of sleep.

Transcranial magnetic stimulation (TMS) could be provided both during waking learning and during sleep. However, as TMS may be expensive, potentially epileptogenic, and of limited availability, simpler and cheaper tools may potentially be used to enhance memory consolidation. Auditory cues given both during waking learning and during these specific neurophysiologic waveforms of sleep may also conceivably enhance learning. Short auditory snippets, similar to various cell phone ring tones, or short clips of well known songs, each unique and each lasting several seconds in duration could be played while learning a specific task, procedure, fact, or relationship to be remembered by the subject. A different auditory snippet could be used for each specific thing to be learned, but the same auditory snippet would be used if the same information is rehearsed more than once, so that a specific auditory snippet is specific to each task, procedure, fact, relationship, or other such thing to be remembered. The auditory snippets could also be given first during learning and then during sleep, specifically during the sawtooth waves of REM sleep, the actual phasic eye movements of REM sleep, during the sleep spindles of stage II sleep especially for the stage II sleep seen following slow wave sleep just prior to the onset of REM sleep, or during the incline of slope of the slow waves of slow wave sleep.[14 15]

It is also conceivable that visual, somatosensory, or olfactory stimuli could be provided during waking learning and later during sleep in a similar fashion as that described for auditory snippets. Born has demonstrated that the olfactory scent of a rose provided during learning and then again during SWS enhanced learning as retested the following day.[16] In a similar way, various combinations of sensory modalities or sensory modalities together with TMS may also prove to be promising.

Is the enhancement of the normal learning process really possible? Only time will tell. It isn't clear if we will all soon be wearing electrode grids or hearing auditory snippets while we learn and while we sleep so that we can all learn at a superhuman rate. In the meantime, watching how the research pans out will sure be interesting.

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