The incredible, shrinking sleep-learning connection

Jerome M. Siegel
Neurobiology Research 151A3, V.A. Greater Los Angeles Health System, Sepulveda, CA 91343; and Department of Psychiatry, UCLA David Geffen School of Medicine, 16111 Plummer Street, North Hills, CA 91343. ***JSiegel@ucla.edu***
http://www.npi.ucla.edu/sleepresearch

Abstract: Initial claims that REM sleep is important in the consolidation of all memories have been revised and reduced to the claim that sleep has a role only in the consolidation of procedural learning. Now, Walker hypothesizes that sleep has no role in the "stabilization phase of consolidation" but only in the "enhanced learning" phase of procedural learning. Evidence for this vague, truncated hypothesis remains as inconsistent as that for prior claims.

The idea that REM sleep is important for memory consolidation is attractive, since it would explain the vivid imagery of dreams as a repetition of the events of the prior day to enable the laying down of permanent memory traces. Unfortunately, dream reports do not support this idea. Most dreams concern emotions and activities that did not occur during prior days. Furthermore, most dreams are not subsequently recalled unless they are immediately rehearsed in waking following the dream (Rechtschaffen & Siegel 2000).

Those working on the role of sleep in human learning have modified their hypotheses to include non-REM sleep as well as REM sleep. Many studies of the relationship between human sleep and learning have focused on sleep's role in learning of word recognition and associations between words and events – tasks mimicking most of what goes on in school; this is what learning

and memory researchers call *declarative learning*. Dr. Carlyle Smith, a leader in the sleep-memory consolidation field, after reviewing his own studies and many negative studies in the world literature, recently concluded that sleep is not important in declarative memory. He was quoted as saying "Declarative memory is such a large part of our memory that everybody would like to find [a link]. Yet no matter what I have done – I have deprived people of sleep, I have deprived people of REM sleep, I have deprived them of non-REM sleep – I have never seen any difference between people who got a good night's sleep and those who didn't" *(Los Angeles Times,* Feb. 3, 2003; see Smith 2001). Walker appears to accept this conclusion in his review, stating "a clear understanding of the role of sleep in declarative memory formation remains to be established in humans" (sect. 2.2, para. 6). However, if one accepts this conclusion, the domain of the sleep–learning connection is dramatically reduced.

In addition to redefining the role of sleep in human memory consolidation, this conclusion also has important implications for animal studies that have been used to support a role for sleep in memory consolidation. Several studies have claimed to see evidence of "replay" of neuronal activity during REM sleep or non-REM sleep. Most of these studies have seen this replay in the hippocampus (Lee & Wilson 2002; Louie & Wilson 2001; Pavlides & Winson 1989). However, it is well known that the hippocampus is critical for declarative leaning but of little importance in procedural learning (Eichenbaum 1999). Thus, even if one dismisses the technical problems with these studies (see Siegel 2001), their relevance to procedural learning and hence to the sleep-learning field is questionable.

A hallmark of sleep learning theories is the variability of hypotheses from study to study, even within studies by the same group. For example, studies of the consolidation of human procedural learning make contradictory claims, with some saying that REM but not non-REM sleep is important (De Koninck & Prevost 1991; Pearlman 1971), others stating just the reverse (Gais et al. 2000; Portnoff et al. 1966), others claiming that both sleep states are essential (Stickgold et al. 2000a), and still others making ad hoc claims, such as that "only the amount of stage 2 nonREM sleep obtained during the last quarter of the night" is important (Walker et al. 2002). The statistical reliability of such ad hoc hypotheses is questionable.

The most striking aspect of the current review is the further redefinition of the role of sleep in learning to be so limited and vague as to defy disproof. In earlier formulations, the author's colleagues indicated that memory consolidation occurs in sleep. It was emphasized that "no improvement" occurred in waking, and that therefore sleep is "absolutely required" for performance improvement (Stickgold et al. 2000b). In the current review, Walker subdivides consolidation into a "sleep-independent" process that makes memory "resistant to interference" and a "sleep-dependent" process of "enhancement." The "sleep-independent" process that makes memory "resistant to interference" sounds a lot like what learning theorists refer to simply as "consolidation." The two subdivisions of consolidation created by Walker's reformulation are difficult to separate operationally and this subdivision invites post hoc explanations of any observed effect.

Fatigue, circadian factors, and simply the passage of time have long been known to affect performance. In order to properly control for performance effects, it needs to be shown that sleep disruption produces a long term impairment of consolidation of tasks learned before the interrupted sleep, and that any decrements in performance during retesting were specific for the recently learned task. Similar tasks that had been learned previously should not be comparably affected by deprivation. It also needs to be shown that recovery from the performance decrements during learning that are known to be caused by intense practice were not creating an illusion of consolidation or "enhancement" when retesting after a recovery period. These sorts of controls have not been thoroughly and systematically done in studies claiming a role of sleep in memory consolidation (Siegel 2001; Vertes & Eastman 2000).

The scientific and popular interest in the possibility that sleep is important in memory consolidation does not derive from the hypothesis that sleep is "one of many states" in which memory consolidation occurs. If this were the case, we would be excited over the possibility that consolidation occurs during eating, drinking, and engaging in sexual behavior, and we would be exhorted to increase these activities when learning. Rather, it derives from the idea that sleep has a unique and important role in consolidation. The reformulated sleep–memory consolidation model proposed here advocates a "democratic," equal division of memory consolidation across sleep and waking states, a considerable dilution of the original idea.

Millions of humans have taken MAO inhibitors or tricyclic antidepressants, often for 10–20 years. These drugs profoundly depress or in many cases completely eliminate all detectable aspects of REM sleep. However, there is not a single report of procedural or declarative memory deficits attributable to such treatment. Similarly, well-studied individuals with permanent loss of REM sleep resulting from brain damage show normal learning abilities, including the best studied case of an individual who completed law school after his injury and was the puzzle editor of his city newspaper (Lavie et al. 1984). The "dual process" theories of learning, with both REM and nonREM sleep participating in memory consolidation, as well as REM sleep-based theories, are contradicted by these findings. Yet this literature is ignored in the current review.

It is common knowledge that sleep loss produces sleepiness and impaired concentration. Similarly, it is well established that sleep loss impairs performance of a variety of tasks in subsequent waking. Studies claiming to demonstrate an important role for sleep in memory consolidation have yet to establish that the effects they are observing are independent of these well-known phenomena.

Siegel, J.M. The incredible shrinking sleep-learning connection. Behavioral and Brain Sciences 82-83, 2005.