

Time for the Sleep Community to Take a Critical Look at the Purported Role of Sleep in Memory Processing

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Abstract: We have previously presented a wealth of data refuting the proposal that memories are processed or consolidated in sleep. Our objections have been largely ignored, creating the impression that the hypothesized role for sleep in memory processing is an established fact rather than a highly controversial and unresolved issue. We briefly review the main arguments against a role for sleep in learning/memory.

I (ROBERT VERTES) INITIALLY BECAME INVOLVED IN THE ISSUE OF SLEEP AND MEMORY PROCESSING IN 1995 WHEN ASKED BY PETER SHIROMANI TO participate in a forum on this topic for the Sleep Research Society Bulletin. There were 8 participants in the forum and I was the only taking the ‘con’ position – no relationship between sleep and memory. Interestingly, the debate still rages 10 years later and the ‘con position’ is still seemingly a minority view.

Undoubtedly the reason this issue continues to be ‘hot’ in the sleep field, and possibly in the neurosciences in general, is that it speaks both to the function of sleep and to the nature of memory processing. The present exchange is further testament to its significance and follows on target articles in Behavioral and Brain Sciences^{1,2} as well as pro-con debates in Science³⁻⁵, Neuron^{6,7} and at the APSS 17th Annual Meeting in 2003. As they say, the issue has legs.

The present ‘debate’ was sparked by an editorial by Robert Stickgold⁸ in SLEEP on an article in that issue by Schabus et al⁹ on paired associate learning and sleep spindles in humans. I approached Dr. White about responding to Stickgold’s editorial and he instead suggested a 4-person exchange in the form of a debate.

Regarding Stickgold’s editorial, I was particularly troubled by his opening statement, as follows: “The study of sleep-dependent memory consolidation has moved beyond the question of whether it exists to questions of its extent and of the mechanisms supporting it”. He then proceeded to cite evidence justifying this statement. Surprisingly, there was no mention of opposing views or a discussion of data inconsistent with the sleep-memory consolidation (S-MC) hypothesis. It seemed that the controversial nature of this issue should have at least been acknowledged, but apparently to do so would have undermined Stickgold’s position that the door is closed on this debate and only the fine points need be resolved.

In a similar manner, Walker and Stickgold⁷ recently characterized our position^{1,4} that sleep does not function to process memory as an “extreme stance”. It is unclear why voicing reasoned opposition to the S-MC hypothesis is viewed as ‘extreme’ – possibly only if adherents to this view are convinced that the issue has moved beyond hypothesis testing to established doctrine. Obviously, we do not think this is the case.

Jerry Siegel and I have previously discussed this issue in depth.^{1,4,6} In the following, we will briefly highlight and expand upon what we believe are some of the major shortcomings of the S-MC hypothesis.

1. By all accounts, sleep does not serve a role in declarative memory.^{10,11} As reviewed by Smith¹², with few exceptions, reports have shown that depriving subjects of REM sleep does not disrupt learning/memory, or exposure to intense learning situations does not produce subsequent increases in REM sleep. Smith¹² concluded: “REM sleep is not involved with consolidation of declarative material.” The study by Schabus et al.⁹ (see above) is another example that the learning of declarative material is unaffected by sleep. They reported⁹ that subjects showed no significant difference in the percentage of word-pairs correctly recalled before and after 8 hours of sleep. Or as Stickgold⁸ stated in his editorial, “Performance in the morning was essentially unchanged from the night before”. It would seem important for Stickgold/Walker to acknowledge that the debate on sleep and memory has been reduced to a consideration of procedural memory – to the exclusion of declarative memory. If there are exceptions, they should note.

2. Several lines of evidence indicate that REM sleep is not involved in memory processing/consolidation – or at least not in humans. Perhaps the strongest argument for this is the demonstration that the marked suppression or elimination of REM sleep in individuals with brainstem lesions or on antidepressant drugs has no detrimental effect on cognition. A classic case is that of an Israeli man who at the age of 19 suffered damage to the brainstem from shrapnel from a gunshot wound, and when examined at the age of 33 he showed no REM sleep.³ The man, now 55, is a lawyer, a painter and interestingly the editor of a puzzle column for an Israeli magazine. Recently commenting on his ‘famous’ patient, Peretz Lavie stated that “he is probably the most normal person I know and one of the most successful ones”.¹⁴ There are several other well documented cases of individuals with greatly reduced or absent REM sleep that exhibit no apparent cognitive deficits.⁶ It would seem that these individuals would be a valuable resource for examining the role of sleep in memory.

3. As recently proposed by Walker and Stickgold⁷ and Walker,² procedural learning in humans involves two processes, consolidation and enhancement. Consolidation refers to a short term post-acquisition strengthening of labile traces and enhancement to delayed ‘improvements’ in learning without further practice on a task. While some reports indicate that the consolidation/enhancement of procedural skills is dependent on sleep, others clearly do not.¹⁵⁻²⁰ This has been acknowledged by Walker and Stickgold.⁷ Interestingly, the latter studies include a recent report by Stickgold and colleagues¹⁹ on auditory learning. Atienza et al¹⁹ (2004)

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trained 20 subjects on an auditory discrimination task, deprived half of them of sleep, and reported that both groups (sleep and non-sleep deprived) showed the same degree of improvement on 48- and 72-hour re-test. In effect, the loss of sleep in no way altered the time course of improvement on the task. These findings are consistent with those of previous reports showing that sleep does not differentially affect the consolidation/enhancement of sensory^{15,16,20} or motor skills,^{17,18} and together suggest that the consolidation or enhancement of procedural skills is a time dependent and not a state dependent process – changes occur slowly over time independent of state. Sleep would serve no unique role in these processes.

4. Although we find the notion of enhancement to be counterintuitive (improvements in learning with the mere passage of time), the question arises regarding the contribution of ‘enhancement’, compared to practice on tasks, to overall improvements on them. In this regard, Walker et al²¹ described gains in performance on a finger tapping task with overnight sleep (enhancement), but importantly also noted that these gains were significantly less than those previously reported with practice on this task.²² In effect, if enhancement does occur, what is its contribution, relative to practice, to the mastery of skills? By way of example, on non tournament days, professional golfers typically practice for about 2-5 hours/day, roughly hitting about 300-500 golf balls/day – and conservatively about 90,000 to 100,000 balls/year.²³ If some incremental improvement (enhancement) were to occur on this skill during sleep, how significant could it be compared to the fine motor learning/programming that undoubtedly occurs with 300-500 swings of a golf club over a day. My guess is that sleep contributes very little – or why hit 500 golf balls a day. Hit 10 a day and let sleep take over.

5. Finally, rather than invoking convoluted scenarios for how sleep might contribute to learning/memory, that include attributing highly specific roles for general events of sleep (PGO waves, theta rhythm, sleep spindles)²⁴⁻²⁶ or claiming that patterns of waking activity spontaneously re-emerge and are hence strengthened in sleep (for review see references 6,26, and 27), more parsimonious explanations would suffice. For instance, the findings of a recent study by Gottselig et al²⁰ indicate that cognitive improvements in sleep result from the absence of distractions during sleep. They reported that subjects showed the same degree of improvement on an auditory sequence task following periods of either restful waking or sleep, and attributed improvement in both instances to the lack of interference from competing events.

In conclusion, we believe it is important for the sleep community to cast a critical eye on claims that sleep serves a role in memory processing. As briefly reviewed above, it is widely acknowledged that sleep is not involved in declarative memory, and as evidenced by the intact cognitive functions of individuals lacking REM sleep, REM is not critical for cognitive processing in sleep. This reduces the debate to non-REM sleep and procedural learning/memory, or more specifically, to the current focus on sleep and ‘enhancement’ – the post acquisition improvement on procedural tasks. Although some studies have reported that ‘enhancement’ is dependent on sleep, several others have either failed to demonstrate ‘enhancement’ (in sleep or waking) or shown that it is not differentially affected by sleep. It seems likely that current interest in sleep and memory will eventually wain and dissipate, as did the last wave of research on this topic in 1960-1970s, for lack of substantive support for sleep in memory processing/consolidation.

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