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Early to bed: how sleep benefits children's memory

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Children learn differently than adults: they have smaller knowledge bases and thus must rely more on rote learning. Incomplete development of cortical circuits and other cognitive systems leads to additional differences. Now a study argues that differences in sleep-dependent memory processing may be another important source of these differences.

The differences between children and adults are legion, and how they approach and learn from new situations is clearly one of them. Purely psychological studies, ranging from the work of Piaget in the 1950s and 1960s to the ongoing work of Spelke and Carey [1], have focused on the developmental trajectory of learning capacities and the dependence of each incremental improvement on the ones preceding it. Other studies focus on the continuing development of the cerebral cortex as key to changes in learning style and intellectual development [2]. Now, a study by Wilhelm *et al*. suggests a very different source of these differences [3].

The last decade has produced a wealth of converging evidence demonstrating that sleep plays a critical role in the 'evolution' of memories [4]. Once encoded, sleep-dependent memory processing can not only stabilize memories – a process classically referred to as memory consolidation – but can also enhance them and integrate them into existing memory networks, extracting key elements for retention, abstracting the gist from multi-item memories, discovering the rules governing such collections of item memories, and even modifying them in ways that facilitate the subsequent discovery of creative insights [4]. Over time, through such processing, memories evolve into forms that optimize their future utility.

Of course, not every memory undergoes all of these forms of sleep-dependent processing, and the mechanisms that determine which ones are employed for a given memory remain poorly understood. In their recent study, Wilhelm *et al*. suggest that at least some of the differences in how adults and children process newly acquired information result from age-dependent differences in the forms of sleep-dependent processing applied to such memories [3]. Specifically, their findings suggest that children, 8–11 years of age, show greater sleep-dependent extraction of explicit, or declarative, knowledge of the rules that govern an implicit procedural task than do adults, 18–35 years old.

Participants were trained to press eight colored buttons as quickly as possible as each one lit up in what turned out to be a repeating 8-button sequence. Training consisted of 50 repetitions of the 8-key sequence, arranged into 10 blocks of 40 key-presses each. Although never explicitly told of the repeating pattern, both children and adults improved at least their procedural skill on the task, becoming 25% faster as training progressed.

When participants were asked 10–12 hours later to indicate their declarative knowledge, or conscious awareness, of the sequence by pointing out the sequence on the keypad, such knowledge was clearly demonstrated. What was so striking about the results was that children, but not adults, showed remarkably greater declarative knowledge after a night of sleep than after a day of wakefulness. Whereas adults, after a day or night, and children, after a day, could report, on average, only 4 or 5 keys from the 8-key sequence, after a night of sleep all but 2 of the 15 children reported the entire 8-key sequence. Thus, the authors conclude, 'children showed greater gains in explicit [declarative] sequence knowledge after sleep than adults'.

A possible explanation of this age difference in declarative knowledge is found in the structure of their sleep. Children not only obtained significantly more sleep than the adults (9.8 vs 6.5 hr), but spent more than twice as much of that time in deep, slow wave sleep (SWS; 39% vs 17%; 217 vs 64 min). In addition, the number of keys in the sequence that individual subjects could report correlated with the amount of slow wave activity during the intervening night both for the adults and, in a second experiment, for the children. Thus, the increased declarative knowledge of the sequence seen in children may well result from their increased slow wave sleep during this night.

There are, as is so often the case, uncertainties that remain. No measure of declarative knowledge was obtained at the end of training, so whether sleep, compared to wakefulness, led to increased knowledge or less forgetting is unclear. In addition, the extent of procedural learning during training of the sequence is only partially known. Improvement in speed comes both from gaining knowledge of the 8-key sequence and from a more general improvement in speed. The separate contribution of these two processes was measured in the children, where only 40% of the overall improvement was found to be sequence specific. Unfortunately, no such breakdown was obtained for adults, so the extent of their procedural learning of the sequence is unknown. Knowing that they went into the night with knowledge equivalent to that of the children would have been reassuring, as would information on the performance improvements that should have been present in both groups overnight [5]. The latter would have also told us whether there was a trade-off between sleep-dependent gains in declarative and procedural knowledge, as has been observed elsewhere [6]. Despite all this, the results remain intriguing.

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The suggestion that increased SWS in children might lead to better extraction or maintenance of declarative as opposed to non-declarative (e.g., procedural) knowledge has its counterpart in the suggestion found in a recent paper [7] that further decreases in SWS with aging might underlie the difficulty to retain new declarative memories experienced by the elderly (and not so elderly!). Even childhood naps may be part of this story. Among 15-month-old infants, only those who napped after a learning task retained knowledge of it the next morning [8]. Together, they suggest that the developmental changes in sleep architecture, with more naps, SWS, and REM sleep in children than adults, reflects parallel changes in how sleep guides the evolution of memories across the life cycle, in part enhancing explicit fact memory in children, but more abstract knowledge in adults. Perhaps sleep makes children smarter, but adults wiser.

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