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Review Article

Sleep and school education

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ABSTRACT

Sleep has emerged in the past decades as a key process for memory consolidation and restructuring. Given the universality of sleep across cultures, the need to reduce educational inequality, the low implementation cost of a sleep-based pedagogy, and its global scalability, it is surprising that the potential of improved sleep as a means of enhancing school education has remained largely unexploited. Students of various socio-economic status often suffer from sleep deficits. In principle, the optimization of sleep schedules both before and after classes should produce large positive benefits for learning. Here we review the biological and psychological phenomena underlying the cognitive role of sleep, present the few published studies on sleep and learning that have been performed in schools, and discuss potential applications of sleep to the school setting. Translational research on sleep and learning has never seemed more appropriate.

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1. Introduction

Education in the developed world has recently undergone several changes related to advances in computer technology, psychology, neuroscience, sports and nutritional sciences. Just like medical treatment is becoming a personalized endeavor guided by individual traits, education of the richest has never been so specific, resourceful and hopeful. At the same time, the human population in underdeveloped regions continues to increase, making yet more difficult efforts to produce comparable improvements in the educational capacities of these societies. Even in so-called developed societies, poverty and reduced educational opportunities constitute a long-term risk factor for child outcomes [62]. The growing educational inequality across the globe [65] is a serious problem for future generations. In this context, science-based strategies to boost learning are most welcome, yet must be scalable to large populations, lest them be irrelevant.

Due to their critical importance for learning, the improvement of basic physiological needs such as sleep, nutrition and exercise have obvious potential for a scalable change in education. Sleep is particularly promising as a highly efficacious pedagogical variable, due to its wide applicability. Also, measures to mobilize sleep for education often can be implemented at relatively low cost. Children living in overcrowded environments, youth exposed to unrelenting television and internet stimulation, and adults working night shift jobs all suffer from sleep deficits. Teachers typically consider sleep among students something to be resisted and opposed, taking it as a clear sign of disengagement from the learning process. Yet, a wealth of converging evidence in humans as well as in animal models shows that sleep deprivation impairs learning (Fig. 1A), and that a wide range of learning benefits can

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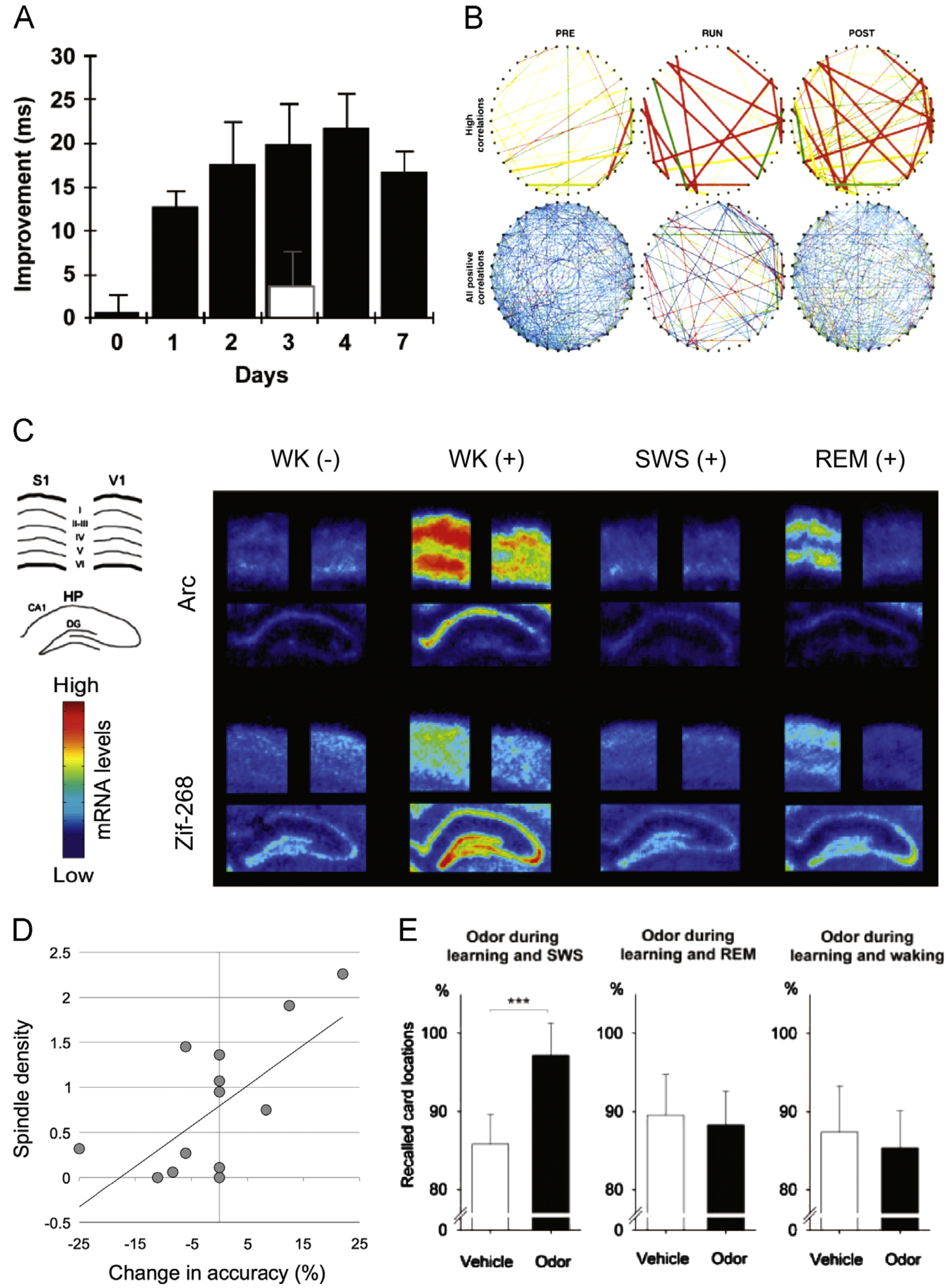

Fig. 1. Psychological and neurophysiological evidence towards translational research on sleep and school learning: (A) Sleep-dependent perceptual learning in humans (adapted from [79]). Overnight incremental improvements over time (black bars) do not occur in subjects deprived of sleep on the first night after training, and allowed to sleep on the following nights (white bar). (B) Pairwise neuronal correlations not present during pre-training NREM sleep (PRE) are established during maze running (RUN) and sustained during post-training NREM sleep (POST) [100]. (C) Transcriptional up-regulation of Arc and ZIf-268, two immediate-early genes with key plasticity roles, occurs after exposure to novel objects during waking WK (+), and subsequently during REM (+), but not during SWS (+). Shown are pseudo-colorized autoradiograms of rat brain frontal sections subjected to in situ hybridization for Zif-268 mRNA. Triplet on the top left indicates hippocampus (HP), primary somatosensory (S1) and visual (V1) cortices. Adapted from [72]. (D) Sleep spindle density is strongly correlated to nap-dependent learning among preschoolers. Adapted from [37]. (E) Memories for card-pair locations learnt in the presence of a specific odor, were enhanced if the odor was re-exposed to the subject during post-learning slow wave sleep. Re-exposure of the contextual odor during post-learning slow wave sleep is thought to reactivate the memory for the card-pairs thereby promoting the consolidation of these memories. Re-exposure of the odor during REM sleep or waking was ineffective. Adapted from [64].

come from optimizing both pre-training and post-training sleep [15,35,79,90,93,98].

2. Sleep and learning

Sleep consists of the cyclic occurrence of rapid-eye-movement (REM) and non-REM (NREM) sleep periods. A typical nocturnal sleep period includes 4–5 NREM–REM sleep cycles of approximately 90 min duration. The first NREM–REM sleep cycles are dominated by slow wave sleep (which represents the deepest form of NREM sleep), whereas during late sleep, REM sleep periods become more intense and extended. The need for sleep varies with age, with younger children sleeping 10–12 h per night whereas 9 h might be sufficient around puberty. Sleep plays a beneficial role on both the encoding and the consolidation of