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SLEEPING BETTER TO LEARN BETTER

Summary of research and recommendations

Text written
under the direction
of Stéphanie Mazza,
with contributions
from Kinga Igloi,
Sabine Plancoulaine,
Amandine Rey and
Rébecca Shankland

This text was produced as part of the work of the "Well-being at School" working group of the Scientific Council for National Education, under the direction of **Stéphanie Mazza,** with contributions from **Kinga Igloi, Sabine Plancoulaine, Amandine Rey, Rébecca Shankland,** and the members of the working group.

Working group « Well-being at school » of the French Scientific Council for Education

Scientific research in psychology and neuroscience highlights the key role of sleep, physical activity, and psychosocial skills in cognitive and academic performance. The working group seeks to identify the most effective interventions in these areas in order to develop concrete recommendations.

Coordination: Stéphanie Mazza, Professor of Neuropsychology at Lyon 1 University.

Véronique Billard, Director of Pedagogy, Réseau Canopé; Vincent Cano, Project Officer, Middle Schools Office (Dgesco); Emily Darlington, Associate Professor at Lyon 1 University; Patrick Debut, Secretary General of the Scientific Council of National Education (CSEN); Ghislaine Dehaene-Lambertz, Research Director at the CNRS in Cognitive Science; Isabelle Goubier, National Education Inspector, Paris Academy; Kinga Igloi, Assistant Professor at the University of Geneva; Marjorie Koubi, Head of the Middle Schools Office (Dgesco); Christine Lequette, Medical Advisor to the Rector of Grenoble; Thomas Leroux, Deputy Director for Educational Policy (Dgesco); Marion Mallet-Petiot, Head of the Primary Schools Office (Dgesco); Christophe Marsollier, Inspector General (IGESR); Stéphanie Mazza, Professor of Neuropsychology at Lyon 1 University; Sophie Mico, School Nurse Advisor to the Rector of Lyon; Brigitte Moltrecht, Technical Advisor (Dgesco); Sofia Nogueira, Deputy Head of the Middle Schools Office (Dgesco); Sabine Plancoulaine, Researcher at Inserm; Amandine Rey, Associate Professor at Lyon 1 University; Benoit Rogeon, Head of the Health and Social Action Office (Dgesco); Rebecca Shankland, Professor of Developmental Psychology at Lumière Lyon 2 University; Anne Valat, Project Officer, CSEN.

Abstract

Too often regarded as a waste of time in modern societies, sleep is far more than a period of rest. It is a vital and fundamental component of development, physical and emotional health, learning, and interpersonal relationships, at every stage of life. While technological advances encourage us to delay our bedtime, our sleep needs have changed very little over the past 100 years. Evidence shows that:

- The body is unable to “store” sleep in anticipation of future deprivation;
- Regular sleep, sufficient in both quantity and quality, is therefore the only guarantee of proper functioning;
- Sleep is important at all ages, but is especially crucial for the brain, metabolic, immune, emotional, and cognitive development of children and adolescents.
- A good sleep is necessary to allow students to learn well. Nighttime sleep or a nap is essential to consolidate what has been learned.
- Lack of sleep in early childhood constitutes a handicap for future learning, as it leaves visible traces upon entry into elementary school.

Thus, a child who sleeps well is more likely to learn well. All stakeholders in the education system should consider sleep as a key factor in academic success and, more broadly, as a driver of student well-being. Although sleep primarily takes place within the private sphere of the family, its main consequences are clearly visible in the classroom: drowsiness, conflicts, lack of attention, hyperactivity, impulsivity, absenteeism, and more. With compulsory schooling starting at age three, all children should be given the opportunity to take a nap within the school setting.

Teachers and researchers are convinced: sleeping well means learning well.

Summary

A few days before the start of the school year, it is common to read or hear in the media that it is time to reset the routines of children and adolescents so that they can begin the new school year well rested. Implicitly, sleep is considered a factor in success. Yet, while diet and physical exercise are often emphasized in the prevention of health problems, sleep is still frequently regarded as a waste of time. It is estimated that more than 30% of children[1] and up to 70% of adolescents do not get enough sleep[2].

In this text, we will highlight the significant impact of sleep deprivation on attention, emotions, and academic performance. The influence of sleep on learning is twofold. Getting a good night's sleep allows students to have optimal cognitive conditions for acquiring new knowledge, and sleeping well after learning helps consolidate this new knowledge.
Several scientific studies show that sleep deprivation in children and adolescents could be addressed through the establishment of good sleep hygiene. Implementing effective behaviours requires a solid understanding of sleep, in order to identify the factors that may promote or hinder it.

Although the issue of insufficient sleep is frequently discussed within educational teams, education professionals often feel ill-equipped and not fully legitimate to address it confidently in the classroom or with families. This review of the literature provides scientific evidence demonstrating how essential sleep is to the conditions for success and well-being in children and adolescents. This synthesis presents, in a non-exhaustive manner, scientific publications and the results of school-based interventions that have been evaluated. It highlights the role of schools, from kindergarten to high school, in sleep education.

1 (Owens, 2014; Trosman & Ivanenco, 2021)
2 (Royant-Parola, Londe, Tréhout, & Hartley, 2021)

1. Sleep across development

Throughout development, sleep undergoes numerous changes. Although sleep duration varies from one newborn to another, at birth infants spend more than two-thirds of their time sleeping. Their sleep is distributed across both day and night, in periods of 3 to 4 hours interspersed with wakefulness. This is referred to as ultradian sleep.

The stages of sleep as we know them in adults are not yet visible. Infants alternate between phases of "quiet sleep" and "active sleep," which will later develop into "slow deep sleep," characterized by slow brain waves and reduced physiological activity, and "REM sleep," characterized by intense brain activity, muscle atonia, and rapid eye movements.

From the age of three, children display a sleep architecture that is fairly similar to that of adults. Slow-wave sleep and REM sleep alternate throughout the night in cycles lasting 90 to 120 minutes (Figure 1). At the end of each cycle, a brief period of wakefulness can be observed, often without awareness. The composition of sleep cycles varies over the course of the night: cycles occurring before 2–3 a.m. are generally richer in deep slow-wave sleep, whereas those later in the night contain longer periods of REM sleep.

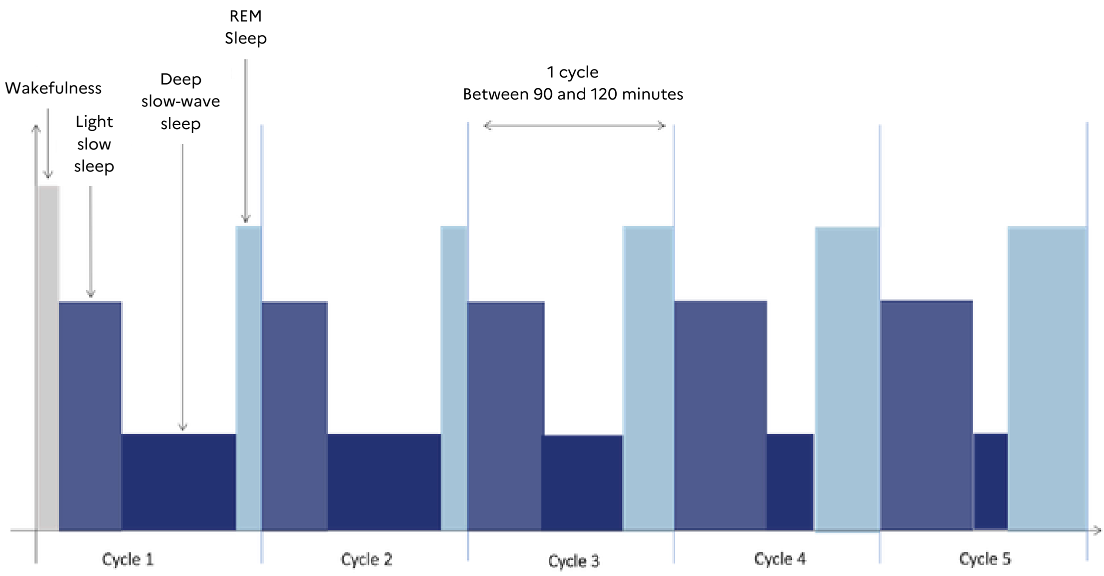

Figure 1. Organization of sleep throughout the night

Between the ages of 3 and 6, total sleep time is substantial, with children sleeping between 10 and 13 hours per 24-hour period[3] (Figure 2). This includes nighttime sleep and an early afternoon nap, which gradually disappears before the age of 6.[4] After the age of 6, sleep becomes almost exclusively nocturnal, and bedtime is progressively delayed. The amount of deep slow-wave sleep remains high, especially in the first half of the night. As children attend school, wake-up times during the week are determined by school schedules. When bedtimes are too late, this can lead in some children to a chronic reduction in sleep duration.

3 (Hirshkowitz et al., 2015)
4 (Staton et al., 2020)

According to Borbély and colleagues[5] the biological regulation of sleep depends on two processes:

- On the one hand, we all feel the need to sleep in the evening and wake up in the morning. This 24-hour cycle, which regulates wakefulness and sleep, is known as the circadian rhythm (from the Latin circa diem, meaning "about a day"). It relies on the activity of neurons in a specific brain region, the suprachiasmatic nucleus, which acts as an internal clock for our organism. This circadian process is also responsible for variations in core body temperature and the secretion of melatonin, both of which contribute to the sleep–wake cycle.

- On the other hand, our need for sleep also varies from one day to the next, depending on our activity during the previous day or days. This "sleep pressure" is controlled by what is known as the homeostatic process, which reflects the accumulation of sleep need during periods of wakefulness.

When these two processes are aligned, individuals experience a strong sleep pressure in the evening following a long day of activity. Although these two processes are independent, they interact to regulate sleep on a day-to-day basis. Thus, lost sleep cannot truly be recovered, just as it is impossible to accumulate sleep in anticipation of future restriction. These mechanisms regulate many biological functions over a 24-hour period, as will be discussed in the following chapters.

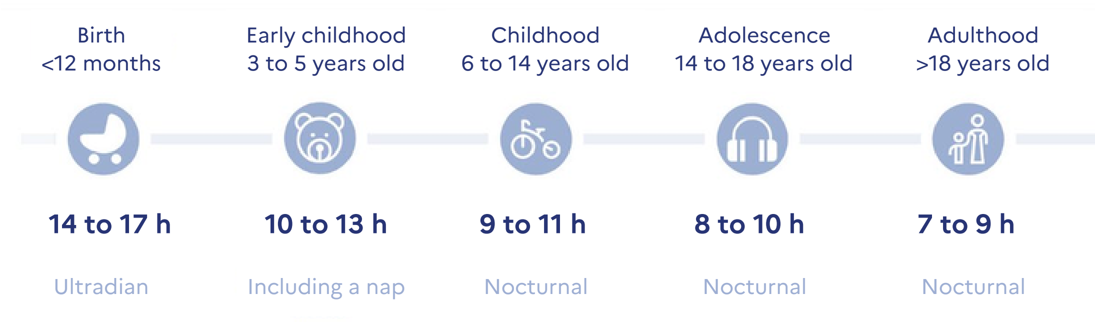

Figure 2. Sleep recommendations for each age group (translated and adapted from www.sleepfoundation.org)

During adolescence, the sleep–wake rhythm undergoes significant changes, which some sleep specialists have described as a "storm"[6] (Figure 3). This upheaval gradually transforms children's sleep into an adult pattern, characterized by later bedtimes, lighter sleep, and shorter duration. During adolescence, circadian regulation changes, physiologically delaying bedtime by about 1.5 hours between the ages of 11 and 20. Adolescents are said to exhibit an "evening chronotype," meaning they cannot help but become night owls. This shift reaches its peak around age 20, after which bedtimes gradually become earlier again and the chronotype becomes more "morning-oriented." In 2004, Roenneberg and colleagues[7] showed that these changes in chronotype are a good marker of the onset and end of adolescence. Deep slow-wave sleep, which accounts for about 25% of a child's sleep, also decreases in proportion to pubertal development[8] Hormonal changes during adolescence are also thought to affect the homeostatic process. Studies have shown that pubertal adolescents tolerate sleep pressure during prolonged wakefulness more easily than pre-pubertal adolescents. As a result, in the evening, adolescents perceive fewer signs of fatigue than children or adults. However, even though they appear more resistant to sleep pressure, their need for sleep does not decrease during adolescence[9]

5 (Borbély & Achermann, 1999; Borbély, Daan, Wirz-Justice, & Deboer, 2016)
6 (Carskadon, 2011; Crawley, Wolfson, & Carskadon, 2018)
7 (Roenneberg et al. 2004)
8 (Carskadon & Acebo, 2002)

The American Academy of Sleep Medicine recommends that adolescents aged 12 to 18 sleep between 8 and 10 hours per night to meet their physiological needs.[10] In reality, however, daily sleep time is estimated to be reduced by an average of 2 hours per night.[11] "Extrinsic" factors also contribute to increasing this sleep restriction, including early school start times, evening screen use (see section 4.3), and extracurricular activities.[12] Although adolescents often try to compensate for their sleep debt by sleeping longer on weekends, this strategy is generally ineffective or even counterproductive.[13] As noted earlier, the sleep–wake cycle follows a 24-hour rhythm (circadian process), and there is no way to store sleep in advance of the coming week. Moreover, sleeping in on Sunday mornings may disrupt the homeostatic process and lead to difficulty falling asleep the following evening.

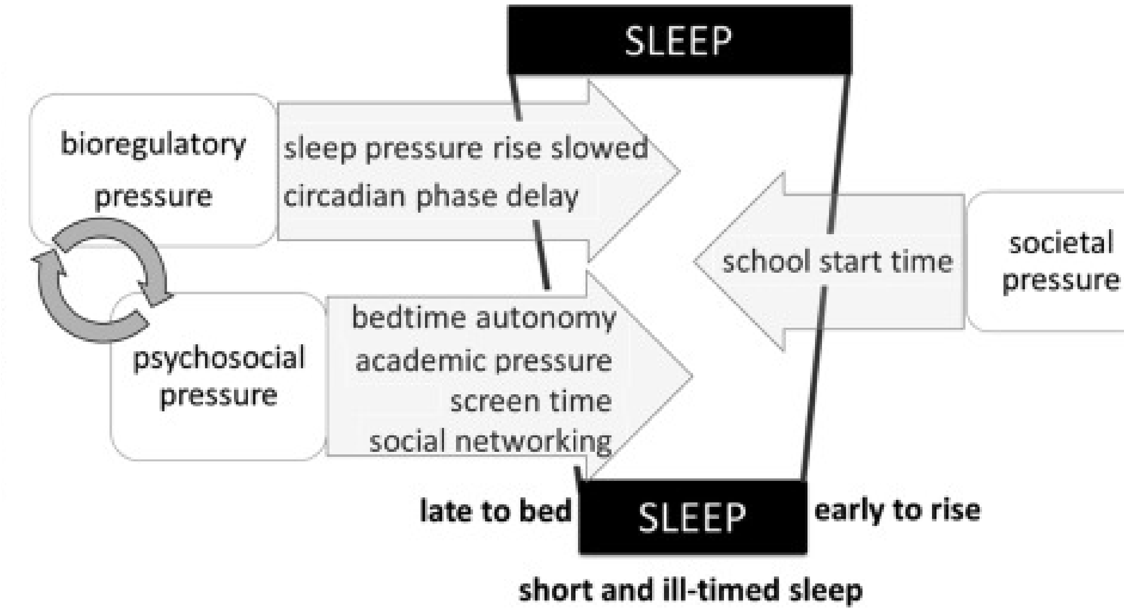

Figure 3. The "Perfect Storm" model (French translation of Carskadon, 2011)

The importance of napping

In adults, several studies have examined the relationship between napping and cognitive functions, emotional processing and self-regulation, as well as health-related factors such as the immune, neuroendocrine, and cardiovascular systems.[14]

Data collected from children are more limited and mainly concern cognition. In 2015, Thorpe and colleagues[15] conducted a review of 26 studies on the effects of nap duration and quality on the development and health of young children. They showed that the results were not entirely consistent, due to two factors: the age of the children and the regularity of their naps. Indeed, beneficial effects on learning and emotional regulation are generally observed in younger children who nap regularly.[16]

9 (Hagenauer et al., 2009; Jenni et al., 2005)
10 (Paruthi et al., 2016)
11 (Gradisar et al., 2011)
12 (Tarokh et al., 2016)
13 (Wittmann et al., 2006)
14 (Faraut, Andrillon, Vecchierini, & Leger, 2017)
15 (Thorpe et al., 2015)

Williams and Horst investigated the influence of napping on the learning of new words from storybooks, thereby simulating a realistic learning environment.[17] Forty-eight 3-year-old children listened to stories containing new words. In this experiment, children were assigned in a quasi-random manner to four conditions depending on whether they habitually napped or not; within each of these two groups, half of the children heard the same story three times, while the other half heard three different stories. Word retention was tested several times: 2.5 hours later, 24 hours later, and 7 days later. As expected, the results showed that repeated readings of the same story facilitated the learning of new words compared with the condition in which three different stories were presented. However, the results also demonstrated strong and lasting effects of napping on word learning. Thus, napping enabled children who had listened to three different stories before sleeping to remember as many words as those who had the advantage of hearing the same story three times.

In a study conducted with children aged 3 to 5 years, researchers asked 40 children to complete a visuospatial learning task (a memory game) in the early afternoon and to recall the learned information after delays of 2 hours and 24 hours.[18] In one condition, children remained awake between learning and the first recall. In the second condition, the same children had the opportunity to take a nap during this interval. The authors showed that napping significantly reduced forgetting at both the 2-hour and 24-hour recall. By analyzing separately children who napped daily and those who no longer napped (or did so less than twice per week), they found that the beneficial effect of napping was greater among habitual nappers.

In China, napping is a common and widely accepted practice at all ages as part of a healthy lifestyle. A recent study conducted with 3,819 Chinese primary school children showed that regular napping had beneficial effects on cognitive functioning, psychological well-being, and emotional and behavioral problems.[19]

It is important to note that even in adulthood we experience a decrease in alertness in the early afternoon. This drop in vigilance is caused by a decrease in core body temperature, which occurs around 1 p.m. in a consistent manner, even in the absence of a meal. This represents a time window conducive to rest, as cognitive abilities are reduced and the body is ready to take a break.

For some children or adolescents whose environmental factors reduce the quality or quantity of nighttime sleep, napping also helps regulate sleepiness.[20] For these reasons, the implementation of napping is considered a health intervention to compensate for the negative consequences of insufficient sleep.[21]

16 (Horváth & Plunkett, 2018; Miller, Seifer, Crossin, & Lebourgeois, 2015; Berger et al., 2012; Kurdziel et al., 2013)
17 (Williams & Horst, 2014)
18 (Kurdziel et al., 2013)
19 (Liu et al., 2019)
20 (Hartzler, 2014; Saletin et al., 2017; Tietzel & Lack, 2001; Vgontzas et al., 2007)
21 (Faraut et al., 2017; Lo et al., 2017)

2. The functions of sleep across development

Sleep is often regarded as a simple mechanism for recovering from fatigue. In this sense, it is commonly considered a waste of time—particularly among adolescents, who are less aware of their need for sleep. However, reducing the role of sleep to this single recovery function is a mistake. Studies show that sleep plays an essential role in many biological functions, the regulation of which must occur every night.

A growing body of research conducted in adults shows that short sleep duration or poor sleep quality affects cardiovascular, metabolic, and cognitive functioning, in addition to exacerbating existing health problems.[22] Only one meta-review currently exists regarding data obtained in children.[23] This meta-review synthesizes the findings of multiple systematic reviews in order to identify robust effects consistently observed across studies. Conducted by Matricciani and colleagues in 2019, it brings together the results of 39 systematic reviews, representing more than 1,000 studies, examining the relationship between sleep and cognition, psychosocial health, cardiometabolic health, and other outcomes such as musculoskeletal pain. The findings indicate substantial and consistent evidence linking children's sleep duration with weight gain and emotional regulation (see Chapter 3). For the other parameters assessed, results are more mixed, partly due to greater variability in how confounding factors are considered across studies.

2.1 Sleep and brain maturation

Sleep undergoes major transformations alongside key stages of brain maturation, from prenatal life through early adulthood.

Brain maturation begins in the posterior sensory regions and continues until around age 25 in the frontal regions at the front of the brain. The slow waves that characterize deep slow-wave sleep contribute to this maturation process. A similar posterior-to-anterior trajectory is observed for these slow waves: they are highly present in the back of the brain during early childhood and gradually spread to central regions and then to the frontal areas as the child grows.[24] Like the number of synapses, deep slow-wave sleep—and especially the slow waves that compose it—increases from birth until around age 10, then declines into adulthood.[25] Consequently, sleep disorders (difficulty falling asleep, frequent awakenings, snoring, sleep apnea, etc.) or sleep deprivation in children and adolescents may alter brain maturation in the medium and long term and increase the risk of cognitive, emotional, and behavioural disorders.[26]

REM sleep also plays a role in brain development and maturation, particularly at the very beginning of life. During this stage, newborns often display small jerky movements of the hands and feet. These movements activate sensorimotor networks, preparing the infant to perform and control certain movements.[27] A similar process is thought to occur with emotional facial expressions (such as the so-called "angel smile") observed in sleeping newborns, even though these expressions are not yet seen during wakefulness.

22 (Pandi-Perumal & Leger, 2006; Gao et al., 2021)
23 (Matricciani et al., 2019)
24 (Shaw et al., 2008; Buchmann et al., 2011; van Noordt & Willoughby, 2021; Kocevska et al., 2017)
25 (Feinberg et al., 1990; Campbell & Feinberg, 2009)
26 (Brooks, Katz, & Stamoulis, 2022; Page, Wakschlag, & Norton, 2021; Jalbrzikowski et al., 2021)
27 (Blumberg et al., 2013; Sokoloff et al., 2021; Tarokh, 2021)

Once brain maturation is complete, sleep continues to support proper brain functioning by contributing to the neural plasticity underlying learning. For example, studies in mice have shown that sleep strengthens connections between neurons within brain networks activated during learning while weakening connections outside these networks.[28] Sleep also enables the nightly removal of toxins produced by neuronal activity. Recent findings in rodents show that during deep slow-wave sleep, the space between neurons expands, allowing cerebrospinal fluid to circulate and clear waste accumulated during wakefulness.[29] Although this mechanism has not yet been directly observed in humans, it may help protect the brain from abnormal accumulation of such waste, as seen in Alzheimer's disease.[30]

2.2 Sleep and growth

Sleep also contributes to growth in both height and weight.[31] It is often said that children grow during their sleep. In reality, both sleep and wakefulness contribute to growth. Growth hormone is secreted both during the day and at night, but at night it is primarily released during deep slow-wave sleep. Around age 18, approximately 70% of this secretion occurs during the first half of the night (before 3–4 a.m.), when deep slow-wave sleep is most abundant.[32]

There is also a strong link between sleep deprivation and weight gain. In children, insufficient sleep is estimated to increase the risk of obesity by 30%,[33] as well as the risk of developing serious metabolic conditions such as type 2 diabetes.[34] This effect appears to be related to the regulation of leptin (the satiety hormone) and ghrelin (the hunger hormone), both of which are linked to the growth hormone cycle. A study in young adults showed that partial sleep deprivation over just two consecutive nights was enough to decrease leptin secretion and increase ghrelin secretion,[35] resulting in a more than 24% increase in perceived hunger. This hormonal imbalance may explain the significant effect of sleep deprivation on weight gain.

Thus, it is not only sleep duration that matters for growth. Good sleep quality, including sufficient deep slow-wave sleep, is also essential.

2.3 Sleep and immunity

Sleep and the immune system have a bidirectional relationship. In the absence of infection, sleep prepares the body for potential infectious threats by acting on various immune system messengers, such as cytokines. This is referred to as "inflammatory homeostasis," whereby the system anticipates possible aggressions. During infection, the immune system triggers an inflammatory response which, depending[36] on its intensity and duration, leads to an increase in both sleep duration and depth. This change in sleep is thought to, in turn, act on the immune system to promote more effective defense mechanisms. It is important to note that most knowledge about the interactions between sleep and the immune system comes from studies conducted in adults, as such studies are not carried out in children for ethical reasons.

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28 (Tononi et al., 2012)
29 (Xi et al., 2013; Herculano-Houzel, 2013)
30 (Winer, 2021)
31 (Copinschi, Leproult, & Spiegel, 2014; Fatima, Doi, & Mamun, 2016)
32 (Van Cauter, Leproult, & Plat, 2000)
33 (Li et al., 2017)
34 (Rudnicka et al., 2017; Dutil & Chaput, 2017; Monzon, Patton, Korenn 2021; Matricciani et al., 2019)
35 (Spiegel et al., 2004)
36 (Besedovsky, Lange, & Haack, 2019; Radogna, Diederich, & Ghibelli, 2010)

For example, in order to better understand the link between sleep and immunity, researchers have exposed healthy volunteers to viruses such as the common cold.[37] They found that reduced sleep duration in the week preceding exposure significantly increased the risk of developing symptoms. Participants who slept on average less than 6 hours per night (about one hour less than the recommended duration) were four times more likely to develop cold symptoms than those who slept sufficiently.[38] Thus, sleep deprivation weakens the immune response, particularly by reducing antibody production in response to infection.[39] Through the same mechanism, insufficient sleep also reduces vaccine effectiveness by lowering the level of antibodies produced following vaccination.[40] A recent longitudinal study conducted with children aged 2 to 5 years showed that shorter sleep duration is associated with higher levels of inflammatory markers.[41] Chronic sleep restriction, by promoting these inflammatory processes, therefore increases the risk of numerous chronic conditions, including obesity, diabetes, cardiovascular diseases, and cancer.

3. Sleep and learning

3.1 Sleep and cognitive functions

To study the consequences of insufficient sleep on children's cognitive development, cohort studies have been conducted, notably in France and Quebec. The Canadian cohort includes 2,120 children followed from birth. Between the ages of 2½ and 6 years, assessments of sleep and various measures of cognitive, socio-emotional, and physical development were carried out.[42] The findings showed that children who slept the least at 2½ years had lower cognitive abilities at age 6 compared to good sleepers. Compared with other children, their performance was lower on standardized tests measuring vocabulary level and non-verbal abilities. These associations remained significant even after accounting for a large number of characteristics potentially related to children's cognitive performance, such as maternal smoking during pregnancy, low birth weight, breastfeeding, maternal age at childbirth, maternal immigrant status, parental education level, family income, and others.[43]

Three major meta-analyses have examined the effects of sleep on the cognitive functioning of school-aged children.[44] The first, conducted in 2012, included 86 studies with a total of 35,936 children; the second, from 2017, brought together 26 studies involving children under 6 years of age (37,853 participants); and the third, published in 2018, was more modest, including 19 studies with a total of 1,760 children. Several studies included in these meta-analyses focused on academic performance. They show that children who obtain sufficient sleep perform better on academic tasks.[45] They also demonstrate a significant overall association between sleep duration and cognitive functioning. Longer sleep duration is associated with better performance on tasks involving executive functions. This translates into better self-control, greater cognitive flexibility, and improved working memory capacity.

37 (Prather et al., 2015)
38 (Cohen et al., 2009)
39 (Spiegel, Sheridan, & Van Cauter, 2002; Lange et al., 2003)
40 (Lange et al., 2011)
41 (Radmanish et al., 2022)
42 (Touchette et al., 2007, 2008)
43 (Touchette et al., 2007)

Executive functions are supported by activity in the prefrontal regions of the brain. These regions are highly energy-demanding during wakefulness and are therefore particularly sensitive to sleep deprivation.[46] During the night, sleep is deepest in these regions, ensuring the restorative processes they require.[47] When sleep is insufficient, brain activity in these areas is altered during wakefulness, their functional connectivity is reduced,[48] and difficulties emerge in executive functioning, emotional regulation, and behavior.

Analyses of various moderating factors show that these findings are observed regardless of children's gender or age. It is important to note that these studies reveal a high degree of heterogeneity in the types and methods used to measure sleep variables, as well as behavioural and cognitive variables, and in the statistical methods employed. Moreover, these studies do not allow for causal conclusions, as experimental studies would.

Experimental studies have therefore attempted to manipulate children's sleep duration in order to measure its impact on cognitive performance. For example, researchers examined the effects of short sleep restriction and short sleep extension on the cognitive functioning of children aged 9 to 12 years.[49] Children were asked to follow their usual sleep schedule for two nights, and their cognitive performance was assessed on the morning of the first day. On the third afternoon, they received a phone call instructing them either to go to bed one hour earlier (sleep extension) or one hour later (sleep restriction) for the next three nights. After the third night of restricted or extended sleep (verified by actigraphy), the children were tested again. The results showed that even a short experimental sleep restriction had detrimental effects on children's cognitive performance, whereas increasing sleep duration improved it.

It has also been shown that children with neuropsychological disorders (i.e., disorders affecting cognitive processes) more frequently experience sleep disturbances than their healthy peers.[50] These difficulties include longer sleep onset latency, more fragmented sleep, and irregular bedtimes that reduce total sleep duration. In turn, these sleep difficulties may exacerbate their cognitive impairments (see box on neurodevelopmental disorders).

44 (Astill et al., 2012; Reynaud et al., 2017; Short et al., 2018)
45 (Dunster et al. ,2018; Sadeh et al. 2003)
46 (Dahl, 1996)
47 Maquet et al., 1990; Tononi & Cirelli, 2003; Tononi & Cirelli, 2006)
48 Koenis et al., 2013; Verweij et al., 2014)
49 (Sadeh et al., 2003)
50 (Aishworiya et al., 2016; Dorris et al., 2008)

3.2 Sleep and learning consolidation

All of these data help us understand how sleep deprivation, by reducing children's cognitive capacities, can impair their ability to learn. However, the influence of sleep does not stop there. Once information has been encoded, the sleep that follows learning enables this knowledge to be consolidated and become less susceptible to forgetting.

In 1885, Hermann Ebbinghaus identified one of the most well-known principles in psychology: the forgetting curve. This curve illustrates the exponential decline in memory retention over time. The more time passes, the more memories fade... By measuring his own recall performance at regular intervals, Ebbinghaus showed that forgetting is particularly pronounced in the first hours after learning: 55.8% of the syllables he had learned were forgotten after one hour, 64.2% after nine hours, 66.3% after one day, 72.2% after two days, 74.6% after six days, and 78.9% after 31 days. While forgetting follows an exponential curve, it is difficult to explain why forgetting amounts to only 2.1% between 9 hours and 1 day, compared with 6.1% between 24 and 48 hours. This inflection in the forgetting curve occurs specifically during Ebbinghaus's sleep period. Using more robust methodologies, several studies have confirmed that when a period of sleep occurs between learning and recall, the amount of retained information is greater. Studies often employing sleep deprivation paradigms, electrophysiology, and brain imaging have shown in both animals and humans that sleep transforms a labile memory into a more stable, long-lasting one that is less sensitive to interference. Thus, even though it is not possible to learn new information while sleeping, sleep plays an active role in memory processes. Thanks to sleep, newly acquired information is integrated with existing knowledge, common elements are identified, and less relevant information is forgotten.[51] It is therefore not surprising to observe an increase in sleep duration —particularly in deep slow-wave sleep and REM sleep—during the night following learning, nor to observe a disruption of this consolidation process in cases of sleep deprivation (for complete reviews, see 52).

Memory consolidation during sleep is made possible by the spontaneous reactivation of brain regions involved at the time of learning. Studies conducted in rodents have shown that neurons activated during the exploration of a maze reactivate during the subsequent sleep period,[53] as if the sleeping animal were mentally replaying its path through the maze. These activations are observed in the hippocampus, the brain region responsible for the temporary storage of new information, as well as in the cortex, where long-term storage occurs. These reactivations may occur at normal speed, sometimes in reverse order, or on a compressed timescale (up to 20 times faster). After this sleep period, rodents are able to find the maze exit more quickly. This phenomenon, known as "neuronal reactivation" or "replay," is thought to transform a new, labile memory trace into a long-term trace that is more easily accessible and less vulnerable to interference. Sleep thus constitutes a unique physiological state in which the absence of external stimulation allows memory traces to be reactivated and consolidated. Using magnetic resonance imaging, similar reactivations during sleep have also been observed in humans. It has also been shown that increasing the amount of slow-wave activity during sleep (through mild electrical stimulation or auditory cues) can enhance learning consolidation.[54]

51 (Diekelmann, Wilhelm, & Born, 2009)
52 (Rasch & Born, 2013; Klinzing et al., 2019)
53 (Ji & Wilson, 2007)
54 (Mölle & Born, 2011)

Given the techniques involved, fewer experimental studies have been conducted in children than in adults; however, existing findings support similar conclusions. In one study, researchers recorded brain activity in children aged 8 to 12 years using magnetoencephalography (a brain imaging technique) to examine the effects of a 90-minute nap on the consolidation of declarative memories (i.e., new associations between unfamiliar objects and their functions).[55] When children learned these new associations, activation was observed in hippocampal regions. After the sleep period, the authors observed changes in activation at the cortical level, particularly in the prefrontal cortex, whereas no comparable changes were found after an equivalent period of wakefulness. They also found that the greater the amount of post-learning slow-wave sleep, the more pronounced these activations were.

3.3 Sleep and behaviours

In children, the manifestations of insufficient sleep can take various forms: irritability, hyperactivity, inattention, and a lowered tolerance threshold, in addition to more typical signs such as drowsiness or apathy.[56]

Researchers have shown that there is an association between sleep duration and different dimensions of behaviour in school-aged children, particularly self-directed behavioural problems (anxiety, depression, social withdrawal) and behavioural problems directed against others (aggressive or antisocial behaviours).[57]

With regard to anxiety and depressive disorders, several studies in adults highlight a bidirectional relationship with sleep. Anxiety and depression are often accompanied by sleep disturbances, and conversely, sleep problems can contribute to the development of anxiety and depressive disorders.[58] Although fewer studies exist, similar reciprocal effects between sleep and psychiatric disorders have also been described in children.[59] Emotional difficulties may lead to sleep problems, which in turn can intensify existing emotional or behavioural disturbances, creating a perpetual negative cycle.[60]

In children, lack of sleep does not manifest solely as drowsiness or reduced activity, as is often the case in adults. It more commonly presents as increased excitation and hyperactivity.[61] In a cohort study of Canadian children, researchers found that those who slept less than 10 hours at age 2½ were four times more likely to exhibit high levels of hyperactivity–impulsivity at age 6 compared with children who slept more, independently of several other factors.[62] Similar findings have been reported in France: children—particularly boys—who slept 10 hours or less per night between ages 2 and 5½ showed higher levels of hyperactivity and impulsivity at age 5½.[63]

55 (Urbain et al., 2016)
56 (Dahl et al., 1996)
57 (Astill et al., 2012)
58 (Alvaro, Roberts, & Harris, 2013)
59 (Vriend et al., 2013)
60 (Chorney et al., 2008)
61 (Aronen et al., 2000; Lavigne et al., 1999; Paavonen, Raikkonen, et al., 2009)
62 (Touchette et al., 2009)
63 (Reynaud et al., 2021)

These hyperactive behaviours are also frequently observed in children with sleep-related breathing disorders. In obstructive sleep apnea, repeated breathing interruptions disrupt sleep cycles, causing nighttime awakenings and reduced oxygen levels. Attention deficits and hyperactivity are common in this condition and are directly linked to sleep disruption. The presence of these behavioural symptoms may sometimes lead to an incorrect diagnosis of attention deficit hyperactivity disorder (ADHD).[64] Neuroimaging studies measuring cortical thickness have shown that children with sleep apnea exhibit significant reductions in grey matter thickness in prefrontal and parietal regions, which are the sites of executive and attentional functions.[65] Treatment of this sleep disorder (particularly through removal of the tonsils and/or adenoids) can substantially reduce their cognitive and behavioural difficulties.[66]

3.4 A link to social and emotional skills

As discussed above, sleep deprivation affects many cognitive functions, particularly executive functions that underlie behavioural adaptation. The increase in internalized disorders (anxiety and depressive symptoms) and externalized disorders (aggressive behavior, conduct problems), as well as risk-taking behaviours in adolescents (such as substance use or risky sports activities),[67] may also be explained by greater difficulty in mobilizing and developing their psychosocial skills.

According to the World Health Organization, psychosocial skills are defined as "the ability of an individual to respond effectively to the demands and challenges of everyday life. It is the ability to maintain a state of subjective well-being that enables appropriate and positive behaviour in interactions with others, one's culture, and one's environment[68]." These skills are generally grouped into three categories (OMS, 2003)[69]:
(1) cognitive psychosocial skills, such as decision-making, problem-solving, and positive self-evaluation; (2) emotional skills, such as the ability to identify, express, and regulate one's emotions; (3) social skills, such as empathy, cooperation, and conflict resolution. These competencies are now recognized as key determinants of health, well-being, and educational success (more information available on the Santé publique France website; for a meta-review, see 70).

A number of studies, conducted from early childhood through adulthood, have shown the detrimental effects of sleep deprivation on all categories of psychosocial skills.

Regarding cognitive psychosocial skills, the effects of insufficient sleep on executive functions —particularly cognitive control and self-regulation[71]—can impact decision-making abilities, which require the capacity to pause and make informed choices. Many studies have shown that sleep deprivation is associated with less health-promoting decisions in adolescents. In a study using functional magnetic resonance imaging (fMRI), researchers examined whether lack of sleep altered adolescents' decision-making in tasks involving potential financial rewards or losses.[72] Forty-six adolescents participated. Behaviourally, those who reported poor sleep took more risks during the task.

64 (Chervin et al., 2002)
65 (Philby et al., 2017)
66 (Chervin et al., 2006)
67 (Short & Weber, 2018)
68 (Organisation Mondiale de la Santé, 1997)
69 (Organisation Mondiale de la Santé, 2003)
70 (Durkal et al., 2011; Santé publique France, 2022)
71 (Anderson et al., 2008; Beebe et al., 2008; Dahl, 1996)
72 (Telzer et al., 2013)

The researchers also observed reduced activation in brain regions associated with cognitive control (prefrontal cortex), alongside increased activation in the regions underlying the emotional system (insula), and weaker connectivity between these two regions. These findings suggest that poor sleep may exacerbate the imbalance—common during adolescence—between affective and cognitive control systems, leading to increased risk-taking in adolescents.[73] Moreover, this study also highlighted the fact that adolescents reported lower perceived competence in completing the task, relating to another cognitive psychosocial skill: positive self-evaluation (self-efficacy belief). However, it is important to note that the relationship between sleep deprivation and impaired inhibitory control may be bidirectional. Adolescents who already exhibit a greater imbalance between reward sensitivity and cognitive control skills may also experience more sleep difficulties, due to poorer emotional regulation, leading to increased anxiety, depressive symptoms, and rumination that delay sleep onset.

Sleep deprivation also affects emotional psychosocial skills.[74] Several studies have shown that insufficient sleep in children and adolescents is associated with greater difficulty in processing emotional information[75] and regulating emotions.[76] These difficulties may contribute to the development of anxiety and depressive symptoms, impulsivity, and challenges in social adjustment.[77] A longitudinal study involving more than 1,000 children followed over six years demonstrated a link between insufficient sleep and socio-emotional difficulties (emotion regulation, anxiety and depressive symptoms) in preadolescence, particularly among girls.[78] Sleep problems in childhood may therefore trigger cascading effects that impact emotional skills, which in turn influence social competencies.

Cognitive and emotional psychosocial skills are essential for children's and adolescents' social abilities. The ability to regulate attention, exert inhibitory control, and manage emotions enables children to build constructive relationships, engage in cooperative behaviour, and adapt appropriately to social situations,[79] whereas difficulties in self-regulation are associated with greater social rejection.

Studies involving children under the age of 6 indicate that sleep influences the development of self-regulation skills.[80] Sleep deprivation, in particular, reduces children's ability to understand others' mental states and to demonstrate empathy,[81] which may limit their capacity to adjust in social interactions and reduce altruistic behaviour. Moreover, in 5-year-old children, sleep deprivation has been shown to reduce engagement in social interactions.[82] Research also indicates that improving both the duration and quality of sleep can enhance relational skills. For example, following a program designed to improve the duration and quality of sleep in children with attention deficit hyperactivity disorder, participants and their parents reported, after 12 weeks, improvements in mood, emotional regulation, relationship quality, and social acceptance of the children concerned.[83] It would therefore be particularly useful to raise awareness about the benefits of sleep within programs aimed at developing psychosocial skills in school settings.

73 (Somerville, Jones, & Casey, 2010; Geier et al., 2010)
74 (Kahn, 2013; Kelly & El-Sheikh, 2013)
75 (Soffer-Dudek et al., 2021)
76 (Baum et al., 2014; Berger et al., 2012; Brand et al., 2016; Williams et al., 2016; Vriend et al., 2015)
77 (Wang et al., 2016; Williams et al., 2016)
78 (Foley & Weinraub,2017)
79 (Blair, 2003; Bierman, Kalvin, & Heinrichs, 2015; Denham et al., 2003; Vaughn et al., 2015)
80 (Kara et al., 2018; Mäkelä et al., 2021; Reynaud et al., 2018)
81 (Tesfaye & Gruber, 2017)
82 (Vaughn et al., 2015)

Le sommeil dans les troubles neuro-développementaux[84]

Neurodevelopmental disorders (NDDs) affect approximately one in eight children. Among these children and adolescents, sleep disturbances and disruptions of the sleep-wake cycle are among the most frequent comorbidities, affecting between 25 and 80% of the population, depending on the NDD. As in children with typical neurodevelopment, poor sleep quality or insufficient sleep has a significant impact on cognition (memory, attention, overall IQ), on daytime behaviour, leading to disturbances such as hyperactivity-impulsivity, and even on language acquisition in children with NDDs.[85]

Sleep disorders in children or adolescents with NDDs also have major repercussions on the health and well-being of the entire family. They have been associated with higher levels of stress, maternal depression, and family disorganization, as well as impacts on work performance and increased parental absenteeism at work.[86] The overall negative effects of sleep and circadian rhythm disturbances on neurodevelopment are such that both affected individuals and their parents—in countries such as England and France—are calling for this issue to be made a research priority in the field of NDDs.[87] Despite the high prevalence of morbidity and additional disability associated with sleep and sleep–wake rhythm disorders in NDDs, these conditions are often under-recognized or trivialized, and therefore left untreated,[88] even though addressing them could help reduce the associated additional impairments.[89]

4. School-based interventions

Interventions on sleep aimed at the general public are numerous, but they do not always represent the most effective lever for achieving lasting behavioural change. As a result, school-based sleep interventions—allowing all children to be reached—are increasing both nationally and internationally. These initiatives may be accompanied by experimental studies conducted through collaboration between researchers and educational teams, across different grade levels.

4.1 Interventions in pre-elementary education (Cycle 1)

Few interventions specifically target children in pre-primary education (Cycle 1), and even fewer have been scientifically evaluated in terms of their impact on children's sleep–wake rhythms. In 2014, a team of American researchers developed and evaluated the "Sweet Dreamzzz Early Childhood Sleep Education Program" in a randomized study targeting families of children aged 3 to 6 years from low socioeconomic backgrounds.[90]

83 (Keshavarzi et al., 2014)
84 Redacted with the contribution of Carmen Schröder, child and adolescent's psychiatrist professor at the Hôpitaux universitaire de Strasbourg
85 (Gruber et al., 2011; Goldman et al., 2012; Johnson et al., 2018; Yavuz-Kodat et al., 2020)
86 (Wiggs & Stores 2001, Jacoby et al. 2015, Pisula & Porebowicz-Dorsmann 2017))
87 (McConachie, Livingstone et al. 2018; McConachie, Mason et al. 2018)
88 (Meltzer, Johnson et al., 2010)
89 (Yuge et al., 2020; McDonagh, Holmes, & Hsu, 2019; Heussler, 2016)

This educational program consisted of two components: parents attended a 45-minute training session, and children participated in approximately 5 hours of classroom-based sleep education sessions over a two-week period. Following implementation, results showed that parents improved their knowledge and perceptions of sleep immediately after the intervention; however, these effects were no longer observed one month later. Children's sleep duration increased by 30 minutes on weekday nights among those who participated in the program, compared with those who did not, although bedtime itself did not change. The authors emphasized the need for repeated exposure to sleep-related information and recommendations. To our knowledge, no other school-based initiatives of this kind targeting young children have yet been scientifically evaluated, although some are currently under development.

4.2 Interventions in elementary education (Cycles 2 and 3)

Interventions targeting students in Cycles 2 and 3 are more numerous than those with pre-elementary pupils. A study conducted in China between 2007 and 2009 involved 525 children aged around 10 years across six schools, where the school day began at 7:30 a.m.[91] The study examined the effects of delaying school start times by 30 or 60 minutes, with corresponding delays in end times. Parents completed standardized questionnaires on their children's sleep. The results showed an increase in sleep duration of 15.6 minutes for students starting school at 8:00 a.m. and 22.8 minutes for those starting at 8:30 a.m. However, in their 2017 systematic review[92] of 11 studies on sleep interventions in school or other settings, the authors highlighted the lack of high-quality evidence in this field.

Other studies have used objective measures of children's sleep before and after interventions. The Canadian program "Sleep for Success" was implemented in primary schools with 46 children aged 7 to 11, compared to a control group of 25 children from another school. The program consisted of six interactive sessions, each lasting two hours, delivered weekly by "sleep experts" (physicians, researchers, or trained teachers). Children who participated in the program increased their sleep duration, improved sleep efficiency, and achieved better results in mathematics and English compared to the control group.[93] This study represents the first scientific evidence from a school-based intervention showing positive effects on both sleep and academic performance.

However, the requirement for "sleep experts" to deliver the programs in class or to train teachers or parents may limit their scalability and widespread implementation.

In France, sleep education is included in school curricula, particularly in Cycle 2 (CP, CE1, CE2), published in the BOEN No. 31 of 30 July 2020 within the subject « Questioning the World » for the theme « Questioning the world of living things, matter and objects » and more specifically in the section 'How to recognise the living world?' for the end-of-cycle learning outcome « Recognising behaviours that promote health ». Sleep is also addressed within the health education pathway, in cycle 2, particularly regarding healthy lifestyle habits and changes in activity rhythms (see BOEN n°5, 4th of February 2016).

90 (Wilson et al., 2014)
91 (Li et al, 2013)
92 (Busch et al., 2017)
93 (Gruber et al., 2016)

Developed through a multidisciplinary collaboration, the educational program "Mémé Tonpyj" was co-designed and evaluated for Cycle 2 students. Teachers, researchers, illustrators, parents, school nurses and physicians, as well as children, contributed to the development of educational materials, including comics, short videos, play-based exercises, lesson plans, and explanatory documents. The program was grounded in scientific evidence while respecting classroom teaching practices. Eight lessons of approximately 50 minutes each were developed, covering topics such as sleep rhythms, the functions of sleep, sleep needs, and the friends or enemies of sleep. The program was designed so that teachers could implement it independently with their students, without requiring the involvement of researchers or external sleep specialists.

Regarding its evaluation, 130 students aged 8 to 9 years from five different schools (two rural and three urban, including one in a priority education network) participated in an experimental study assessing the program's impact. As expected from the literature, children's average sleep duration was below pediatric recommendations. While their sleep needs ranged from 9 to 11 hours at their age, they slept on average 8 hours and 36 minutes per night, with even the 'best sleepers' in the group sleeping no more than 20 minutes above the lower limit of these recommendations. After one month of implementing the sleep education program in class, children's sleep duration increased by more than 30 minutes per night. This increase was even greater among those who initially slept the least (more than 50 minutes of additional sleep). Overall, the program positively improved sleep both in terms of quantity and quality (see Figure 4). These improvements were accompanied by significant gains in academic performance, as well as in attention, inhibition of distractions, and working memory updating. One year after the intervention, the increase in sleep duration observed post-study was still maintained.[94] Finally, although the program did not directly involve parents, more than 80% of them reported improved knowledge about sleep, suggesting that interactions on the topic of sleep had taken place with teachers, and likely within families as well.

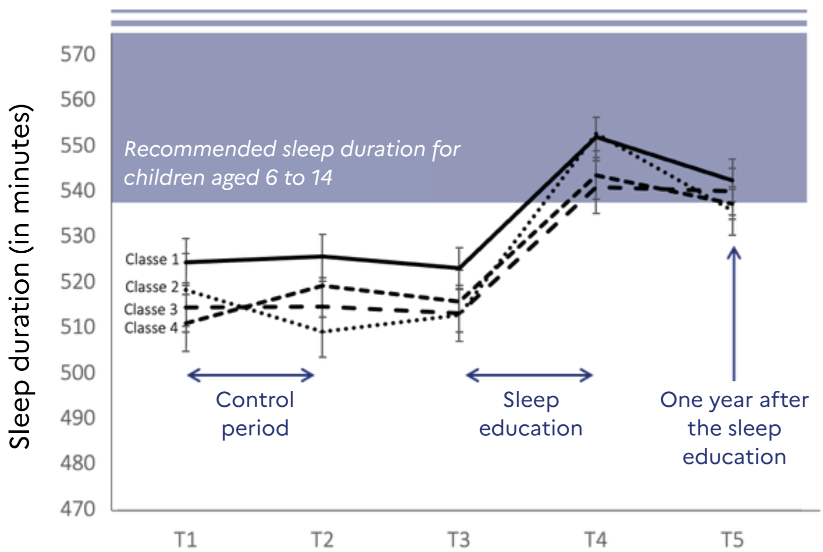

Figure 4. Sleep duration among children in four classes who took part in the evaluation of the Mémé Tonpyj programme and underwent actigraphic monitoring on five occasions (T1 and T2: before and after the control period without sleep education; T3 and T4: before and after the introduction of sleep education; T5: one year after the implementation of sleep education). One class participating in the evaluation did not undergo actigraphic measurements.

94 (Rey et al., 2020)

4.3 Interventions targeting secondary-school students

As mentioned in Section 1, the American Academy of Sleep Medicine estimates that adolescents should sleep between 8 and 10 hours each night to meet their physiological needs. However, adolescents' daily sleep duration is on average reduced by 2 hours per night, even though their actual physiological sleep needs not only do not decrease, but are greater during this period than in adulthood.[95] Moreover, adolescents' sleep–wake rhythms are subject to numerous physiological changes, in addition to many social and school-related constraints. Adolescent and young adult sleep is marked by a physiological phase delay, resulting in a shift in bedtime of around 2 hours.[96]

Current sleep education programs mainly aim to provide adolescents with knowledge about sleep, whether in Australia,[97] Brazil,[98] the United States,[99] Italy,[100] Spain,[101] or China.[102] A 2017 literature review examined 7 studies evaluating school-based sleep interventions among adolescents and young people aged 10 to 19.[103] These interventions typically consisted of one session per week over 4 weeks, conducted within the school by a teacher or specialist, and aimed to provide knowledge about how sleep works and its role in learning and behaviour. Across these studies conducted in Brazil, Australia, New Zealand, and Hong Kong between 2009 and 2015, results from 1,879 adolescents who received a sleep intervention at school were compared with those from 2,843 adolescents who did not benefit from this intervention. Although the number of studies included in this meta-analysis was limited, the results suggest an increase in sleep duration during both weekdays and weekends, as well as improved mood among adolescents who participated in the intervention compared to the other group. Long-term effects remain to be demonstrated.

Among the factors contributing to adolescents' phase delay, evening screen use is often highlighted. A literature review of 67 studies published between 1999 and 2014 showed that 90% of studies examining the impact of screens on sleep confirmed that evening use delays sleep onset by about 30 minutes and reduces sleep duration by approximately 50 minutes for adolescents.[104] Some studies have therefore asked adolescents to modify their screen use, for example by reducing evening screen time, but without providing educational content about sleep.[105] In 2019, a Swiss research team proposed an intervention targeting screen use among adolescents aged 12 to 19. Their evening screen use and sleep habits were collected for one month. During this period, the first two weeks were used to establish their habits and uses (baseline), and the following two weeks corresponded to the intervention phase. During this intervention phase, after receiving general information about the relationship between sleep and screens and the impact of sleep on daytime functioning, adolescents were asked not to use screens after 9 p.m. on evenings before school days. A total of 183 adolescents agreed to participate in the intervention phase. Results showed that reducing screen time after 9 p.m. led to an earlier bedtime by 19 minutes and an increase in sleep duration of 17 minutes compared to baseline. This increase in sleep duration was accompanied by improved vigilance performance. However, adherence was very low, with only 25% of participants agreeing to follow this constraint.

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95 (Illingworth, 2020)
96 (Carskadon, 2011)
97 (Kira et al., 2014; Blunden et al., 2012; Bonnar et al., 2015)
98 (Azevedo et al., 2008; Beijamini et al., 2011; de Sousa, Araujo & Azevedo, 2007)
99 (Wolfson et al., 2015)
100 (Cortesi et al., 2004)
101 (Diaz-Morales et al., 2012)
102 (Wing et al., 2011)
103 (Chung et al., 2017)
104 (Hale & Guan, 2015)
105 (Bartel et al., 2018; Perrault et al., 2019)

Studies have also evaluated the impact of delaying school start times on sleep and performance. In a 2016 meta-analysis, Minges and Redeker reviewed six studies (three pre-post studies without control groups, two randomized controlled trials, and one quasi-experimental model).[106] School start times were delayed by 25 to 60 minutes, resulting in an increase in sleep duration of 25 to 77 minutes per weeknight. Some studies also reported reductions in daytime sleepiness, depression, caffeine consumption, tardiness, and difficulty staying awake.

A 2008 study conducted in New Zealand asked students aged 15 or 16 to complete a questionnaire about their sleep habits. A total of 131 students aged 15 who started school at 9 a.m., and 184 students aged 16 whose start time was delayed to 10:30 a.m., took part. Results showed that, compared to students starting at 10:30 a.m., those starting at 9 a.m. had shorter sleep duration and reported greater sleepiness. Students with the later start time found it easier to wake up in the morning. However, the small sample size and age differences between experimental groups are two limitations of this study. Another study conducted over three years with 9,000 adolescents across eight schools found that starting school after 8:30 a.m. allowed more than 60% of adolescents to sleep at least 8 hours per night during the week.[107] Adolescents with shorter sleep duration reported more depressive symptoms and higher consumption of caffeine and addictive substances. Delaying school start times (to 8:35 a.m. or later) was associated with improved grades in subjects such as mathematics, English, science, and social studies, as well as better results on national and state exams. Students were also more punctual and less frequently late. Finally, the number of car accidents among teenage drivers aged 16 to 18 decreased by 70% when school start times were shifted from 7:35 a.m. to 8:55 a.m.

More recently, a 4-year observational study using an A-B-A design was conducted in a U.S. high school. This design involves three assessment phases. Participants are exposed to condition A for a given period, and the effects of this condition are measured. The same participants are then exposed to another condition (B) for the same period, before being subjected to condition A again. During the first year (condition A), school started at 8:50 a.m.; during the next two years (condition B), it was delayed to 10 a.m.; and in the final year (condition A), it returned to 8:50 a.m. Measures of student health (absences due to illness) and academic performance (national exam results) were collected. The delay in start times led to a reduction of more than 50% in illness-related absences after two years, and returning to the earlier schedule cancelled this improvement. Starting school at 10 a.m. was also associated with increased academic progress.

Overall, the available evidence supports findings from recent non-experimental studies and argues in favor of policies that delay school start times to improve sleep. However, it is important to note that studies remain limited in number or methodological quality. There is therefore a need for rigorous randomized studies and consistent results, particularly using objective sleep measures alongside consistent indicators of health and academic performance.

106 (Minges & Redeker, 2016)
107 (Wahlstrom et al., 2014)

Le sommeil et les écrans

Among the factors contributing to delayed bedtimes, increased screen use has become a central focus of attention. International studies conducted over the past ten years report that evening screen use contributes to increasing sleep debt among adolescents.[108] Screens are present in the bedrooms of 75% of children and adolescents aged 6 to 17.[109] Most studies exploring their effects on sleep show a negative association between screen time and both sleep onset and sleep duration: later bedtimes and reduced total sleep time.[110] A cross-sectional study conducted in the United States on a representative sample of children (aged 6 to 17) showed that the mere presence of a screen in the bedroom at night (phone, computer, or television) was sufficient to predict insufficient sleep duration for the child's age (Buxton et al., 2015).
Another rapidly growing behaviour is the simultaneous use of multiple screens in the evening. A study conducted in Philadelphia found that adolescents used an average of four screens simultaneously after 9 p.m. (television, phone, game console, computer, etc.), and that this multitasking activity was twice as common among adolescents who sleep less than 8 hours per night.[111]

The impact of screens on sleep is multifactorial. Among the most frequently reported factors are delayed bedtimes due to time spent on screens, hyperarousal generated by the activity or the content viewed,[112] as well as the effect of blue light on the circadian clock.[113] The impact of blue light is particularly significant, as it reduces the peak of melatonin and therefore leads to delayed sleep onset and increased alertness. A study conducted with 300 Swiss adolescents showed that reducing screen use after 9 p.m. significantly increased sleep duration and reduced daytime sleepiness[114] (see previous section).
It should be noted that sleep measures in these studies are often self-reported. It has been shown that data collected through sleep diaries and questionnaires differ from objectively collected data, particularly with an overestimation of sleep duration.[115]

For more information on screens, the brain, and children, see the "La main à la pâte" foundation resource: fondation-lamap.org/sequence-d-activites/le-temps-du-sommeil .

108 (LeBourgeois et al., 2017; Moore & Meltzer, 2008)
109 (Buxton et al., 2015)
110 (Hale & Guan, 2015; LeBourgeois et al., 2017)
111 (Calamaro, Masson, & Ratcliffe, 2009)
112 (Cain & Gradisar, 2010)
113 (Chang et al., 2015)
114 (Perrault et al., 2019)
115 (Short et al., 2012)

5. Studies limitations

It is important to emphasize that, due to the complexity of the protocols required to study sleep, studies conducted in children are fewer than those carried out in adult populations. Information on sleep habits is often collected through questionnaires or sleep diaries completed by adolescents or, for younger children, by their parents. This can lead to memory biases, particularly when questionnaires are not filled in daily, as well as social desirability bias. To avoid this, the ideal approach is to objectively measure sleep (both duration and quality) using sensors, ranging from wrist-worn actigraphs used over several days to electroencephalographic recordings conducted in hospital settings or at home. Similarly, intervention protocols involving sleep deprivation are rarely conducted in children for ethical reasons. As a result, most studies involving children are correlational in nature—that is, they examine associations between variations, such as sleep duration, and different cognitive or behavioral measures. This may partly explain why findings observed in adults are not always replicated in children.

Finally, studies do not account for all known factors that influence sleep. This is the case, for example, for socioeconomic status, the number of children in the family, the age of siblings, parental sleep characteristics, and so on. These factors strongly influence children's sleep habits, yet they are not always specified in studies and are therefore rarely included in meta-analyses, which limits the interpretation and strength of conclusions. It should also be noted that the children included in studies often cover a wide age range (for example, from 5 to 12 years old), even though optimal sleep duration varies considerably across this same period.

6. Perspectives and recommendations

Here are several forward-looking points that may foster reflection, as well as future pedagogical and research work.

6.1. Sleep can be learned

The implementation of appropriate behaviours cannot occur without learning. Whether it concerns diet or physical activity, publicity campaigns and awareness initiatives—particularly in schools—are well established ("Eat, move…"). However, regarding sleep, France has not yet fully taken into account the importance of this aspect of our lives for our health. As a central element of children's living environment, schools play an important role in improving the health and well-being of all children, notably through the development of health-promoting schools, where various actions reinforce one another and contribute to reducing health inequalities.[116] School is therefore recognized as a priority setting for interventions targeting students, as well as for engaging and reaching the broader population, since educational environments are considered by the World Health Organization (WHO) to be a hub for community-based health promotion.[117]

116 (Basch, 2011; Langford et al., 2014)

School curricula now include health education. Article L541-1 of the French Education Code states: “Health promotion actions for pupils are part of the missions of the national education system. All members of the educational community contribute to this mission, which is primarily carried out by medical staff, nurses, social workers, and school psychologists working together in a coordinated manner. In this regard, pupils benefit throughout their schooling from prevention and information initiatives, as well as compulsory medical check-ups and screenings, which form part of their health pathway within the school system. Pupils also benefit from health promotion actions that constitute a health education pathway conducted under the conditions set out in the penultimate paragraph of II of Article L. 121-4-1. These actions notably promote academic success and reduce health inequalities.”

Circular No. 2016-008 of January 28, 2016 further specifies that: “The mission of schools in the field of health is to: provide each pupil with the knowledge, skills, and culture enabling them to take responsibility for their own health in an autonomous and responsible manner, in line with the emancipatory mission of schools (health education is one component of citizenship education); implement, in every school and educational institution, prevention projects focused on health issues, particularly those likely to affect academic success; and create a school environment conducive to the health and academic success of all pupils.” Thus, discussing sleep in the classroom is already part of school curricula, particularly in Cycles 2 and 3, and many teachers address this topic during lessons or dedicated health education sessions. However, the tools available to them remain scarce and have not been scientifically validated.

It is this need that led to the co-development of the educational toolkit mentioned in Section 4.2 (www.memetonpyj.fr). Although sleep is not explicitly included in middle or high school curricula, it can serve as an educational topic across various subjects, such as life and earth sciences, visual arts, or physical education. Nevertheless, it seems important that sleep be given a more explicit place in curricula, particularly in early childhood education (Cycle 1) and in secondary education.

6.2. Sleep isn’t just a night-time affair : the role of napping

In France, for many years, a majority of education professionals working in early childhood education (Cycle 1) have been aware of the need to address children’s need for naps. Arrangements and practices regarding sleep represent an important challenge for educational teams, who must deal with a lack of financial resources, practical constraints, and parents’ preferences. Some schools have found this balance and manage to offer a nap to all children from the youngest to the middle sections, and in some cases even to older children with specific needs. Others, due to constraints of space, staff, or number of children, are forced to eliminate naps before their spontaneous cessation at the beginning of the middle section of kindergarten, without taking into account differences in age or individual needs. Conversely, some schools have implemented mandatory naps, in which all children must participate, regardless of their individual sleep needs. Offering a nap to a child who no longer needs one is frequently associated with disturbances in nighttime sleep, whereas a nap for those who still need it does not affect nighttime sleep. Moreover, as we have seen, the effect of naps on learning is mainly present in habitual nappers, and once again, sleep responds to a need.

117 (OMS, 2008)

Even if the nap is not mandatory, its organization must allow for sufficient flexibility to take into account each child's needs, which evolve between ages 2 and 6. Thus, it cannot be imposed on a child who does not need it, and conversely it cannot be collectively removed during the school year (it should not be forgotten that a child in the middle section born in December and one in the small section born in January will have similar physiological needs). Let's not forget: a child who sleeps is a child who learns and consolidates what they have learned!

The coordination of nighttime sleep and naps is particularly crucial during this transitional phase toward exclusively nighttime sleep. This cannot be achieved without frequent, bidirectional communication between parents and educational teams. And above all, let us not forget: napping does not stop overnight; this need gradually fades and, at certain times in a child's life, may temporarily respond to sleep difficulties occurring at home (illness, stress, birth of a sibling, etc.).

The appropriate time for a nap is at the very beginning of the afternoon, as soon as possible after lunch. Falling asleep is a crucial moment. When supported by a calm and reassuring activity (reading, music, etc.), it allows children to reduce their level of arousal and facilitates falling asleep. It is not necessary for this bedtime routine to last long, but it must help reassure the child. The time needed to fall asleep varies from one child to another; it is often suggested that a child who has not fallen asleep after 20 minutes can be allowed to get up. It is important to recall that falling asleep within 20 minutes is only possible if the child arrives calm and ready to sleep.

As we have seen, a sleep cycle lasts about 90 minutes (not including the time to fall asleep). In kindergarten, the nap should allow for a full cycle. The environment is also important: the dormitory must be comfortable and welcoming. It is always more difficult to sleep in a group, in an unfamiliar environment. To help the child feel comfortable in their sleeping space, preparation can be made to personalize it. While silence is important in the dormitory, darkness is not necessary. Natural light will help the child distinguish between nighttime sleep and nap sleep, which will support the establishment of their circadian rhythm. The more naps are considered normal and, above all, beneficial by the educational team, the more the child will become aware of the importance of sleep. It should not be seen as something reserved for "little ones" or as a solution to behavioural problems, but rather as an opportunity to learn better. Thus, it will be important to ensure that children who sleep do not feel frustrated at having missed part of the classroom activities.

Managing the diversity of needs is a real challenge for educational teams. Observing signs of fatigue, inattention, or hyperactivity during the day will help them adapt to the evolution of the child's sleep–wake rhythm, as will the implementation of cross-disciplinary training. To support these practices, work on official guidelines governing naps should be undertaken.
The high frequency of sleep disorders in children with neurodevelopmental disorders should also encourage educational teams to organize rest periods for these children whenever the need arises (at any age). These children should be able to benefit from rest time at the beginning of the afternoon, particularly when behavioural disorders affect the quality of nighttime sleep. These rest periods will allow these children to regain the resources necessary for learning and for interacting with their peers and the educational team.

6.3. Paying particular attention to adolescents

Although our discussion regarding napping is focused on children in kindergarten, its effect seems perceptible at all ages. Let us not forget that our internal temperature is a good reflection of our level of alertness, and that it shows a dip at the beginning of the afternoon at all ages. NASA even promotes it: a 26-minute nap in adults is said to increase alertness by 54%.[118] Several large companies create work schedules based on the employee's chronotype, in order to respect the needs of night owls and early risers, with the aim of increasing their well-being and, consequently, their productivity.

Experiments conducted with adolescents point in the same direction: when school start times are delayed, so as to better align them with their naturally later wake-up times, their academic performance improves. International studies show strong effects of delaying schedules. A reflection at the level of middle and high schools could be undertaken to encourage this shift in school activities, favouring a later start to teaching rather than having idle periods during the day. The implementation of such a measure is nevertheless complex and would need to be tested in France, notably due to geographical and economic disparities. Changing school schedules, particularly in rural areas, implies modifying transport schedules, sports and social activities, as well as other extracurricular activities.

6.4. The training of pedagogical teams

Initial and ongoing training of educational teams is an essential condition for sleep to become an effective lever for learning. Cross-disciplinary and cross-level training bringing together teachers, specialised assistants of early childhood education, and activity leaders would, in addition to providing knowledge about sleep, make it possible to establish in schools, in partnership with families, a collective reflection to adapt to the specific needs of children, particularly the youngest who enter school from the age of 3.

At the same time, pedagogical advisors and inspection bodies should be able to benefit from training enabling them to support educational teams, notably by relying on institutional framework documents.

School nurses are regularly consulted by educational teams on the issue of sleep. They are also in direct contact with adolescents who have difficulties staying awake in class. They should be able to benefit from extended training on normal and pathological sleep, in order, on the one hand, to identify sleep disorders and their consequences on physical, psychological, and cognitive development, and, on the other hand, to propose individual or group support in connection with the school physician. In collaboration with student health services, they could also offer annual awareness initiatives within the framework of the Health-Promoting School.

118 (Rosekind et al., 1995)

Key takeaways

- Sleep is a fundamental element of children's and adolescents' development, learning, and well-being.
- It is estimated that more than 30% of children and up to 70% of adolescents do not get enough sleep.
- From the age of three, children have a sleep architecture quite similar to that of adults. Their sleep need is 10 to 13 hours every 24 hours. This includes nighttime sleep and a nap of about 1.5 hours.
- Napping is a physiological need; it depends on the child's maturation, which is why its removal happens gradually before the age of 6.
- Early childhood sleep is associated with academic performance. Children who sleep well before age 3 have better performance at age 6.
- During adolescence, sleep need is about 8 to 10 hours. Bedtime is later due to a physiological phase delay. Because of school start times, adolescents are in a chronic sleep debt of about 2 hours per night.
- Sleep duration and quality are linked to cognitive performance. Executive functions are especially affected by sleep deprivation (planning abilities, inhibition, mental flexibility, etc.).
- Thanks to sleep, newly learned information is consolidated. During deep slow-wave sleep, neural networks activated during learning reactivate to replay what has been learned. This reactivation allows transfer of information into long-term memory.
- Sleep helps sorting: it consolidates essential information and allows forgetting of irrelevant information.
- Sleep-deprived children are not always sleepy. On the contrary, hyperactivity, impulsivity, and irritability are frequently associated with sleep debt.
- Lack of sleep leads to growth disorders and weight gain. It is a risk factor for childhood obesity.
- Sleep disorders affect between 25% and 80% of children with neurodevelopmental disorders (NDD).
- Sleep disorders worsen learning difficulties, as well as behavioral problems in children with NDD.
- Evening screen use delays sleep onset in children and adolescents.
- Sleep deprivation also impacts children's and adolescents' ability to use their psychosocial skills.
- Sleep deprivation does not need to be severe to cause cognitive or behavioral problems. One hour less of sleep over three nights already produces a deficit.
- Sleep deprivation in children and adolescents can be improved through good sleep hygiene. This requires them to have good knowledge about sleep in order to identify factors that promote or hinder it.
- Implementing sleep education programs in classrooms can sustainably increase sleep duration and quality.
- The importance of sleep is not sufficiently mentioned in school curricula, even though health promotion actions are part of the missions of the national education system.

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education.gouv.fr

Contact presse
01 55 55 30 10
spresse@education.gouv.fr

Contact Conseil scientifique de l'éducation nationale
csen@education.gouv.fr
re seau - canope.fr/conseil -scientif ique - de - leducation - nationale