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A Flourishing Brain in the 21st Century: A Scoping Review of the Impact of Developing Good Habits for Mind, Brain, Well-Being, and Learning

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ABSTRACT— Emerging scientific knowledge such as the role of epigenetics and neuroplasticity—the brain's capability to constantly rewire with every action, experience, and thought—is fundamentally changing our understanding of the potential impact we can have on our brain. Our brain is formed by our habits in interaction with our body, the environment, influenced by our lifestyle, successes, failures, and traumas. Neuroplasticity proves that every student's brain is a work in progress, and it is never too late to take better care of one's cognitive fitness. This review presents a repertoire of good habits (GHs). Combined, we suggest that these GHs provide conditions for optimal brain health, by acting as a "Mental Vaccine" which enhances the brain's resilience to brain health-degrading challenges. We argue that schools have a crucial role to play in empowering students to increase their own stress resilience, well-being, and learning by developing their own GHs profile.

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Adolescents' development and well-being are shaped by brain-based differences, which reciprocate with social contexts (Schriber & Guyer, 2016; VanderWeele, 2020). Over the last decade, there has been a substantial increase in the prevalence of mental health disorders among adolescents (Monaco, 2021). These include mental and psychosomatic disorders such as anxiety and depression or sleep problems with adverse effects on motivation to engage and learn in school. This highlights the pressing need to facilitate an evidence-based optimal brain development program from child to adult (Frith, 2019). This article presents research evidence from a multidimensional range of good habits (GHs) which include *healthy eating, exercising, rest and sleep, optimism, managing stress, making autonomous decisions, variety and challenge, social interactions with friends, learning new things, and repetition*. We suggest that these GHs together provide conditions for optimal brain health for the individual and a foundation for lifelong learning. The combination may also present an individual boost, a mental vaccine. Research highlights links between the adoption of behavioral strategies and positive health effects (Embry, 2002; Schwartz & Baruch, 2012). We define optimal brain health as consisting of five cognitive functions which affect lifelong learning: *attention, processing speed, memory, flexibility, and problem-solving*. Different lifestyle factors such as exercise, food, and rest are determinants of a person's lifelong brain health (Gorelick et al., 2017; Mattson, 2015). While a mental vaccine may seem like an overly ambitious description, it reflects the idea that GHs have a generative impact on the development of molecules, genes, and brain plasticity, which in turn affect behavioral outcomes (Ramus, 2006; Sweatt, 2016). Generating deep insights about the health of the brain, the most enigmatic organ in the human body, will have an impact on both individuals and future societies (Wang, Pan, & Li, 2020).

The links between the brain's chemical base and its impact on the development of the individual brain plasticity and health derive from two Nobel laureates in medicine; Arvid Carlsson, who found that the brain is controlled by chemistry (Carlsson, 2001), and Elizabeth Blackburn, whose research shows that our cells are listening to our thoughts (Blackburn & Epel, 2017). The vision for the GHs is that these habits will serve as a holistic platform, which combines neuroscience, psychology, and pedagogy together. In this article, we seek to present practical applications of published research about brain abilities and development which have an impact on learning (Goswami, 2006). We suggest that the integration of the GHs will have positive consequences for pedagogical activities and inspire well-being and lifelong learning in forward-looking schools and societies (Dubinsky et al., 2019).

Adolescence is an important and exciting period for young people to develop skills and gain experiences that help prepare them for healthy, meaningful, and inventive adulthood (Dahl, Allen, Wilbrecht, & Suleiman, 2018). Young people are deeply impacted by their social, physical, and intellectual milieus, and the mixed messages they often receive (Schriber & Guyer, 2016), which is why it is essential to give them the opportunity to develop a comprehensive understanding of key factors which underpin lifelong development. Furthermore, adolescence is a period of dramatic developmental transitions—from puberty-related changes in hormones, bodies, and brains to navigate in an increasingly complex social world (Laube, van den Bos, & Fandakova, 2020). The brain is central to this development, which is why it is essential that the brain is nurtured. Brain health is a multifaceted concept used to describe brain physiology, cognitive function, mental health, and well-being (Fusar-Poli et al., 2020). Cognitive development heavily intertwines with the adolescent-specific changes in synaptic density in the prefrontal cortex (Delevich, Wren Thomas, & Wilbrecht, 2019). Adolescence represents a unique period of prolonged maturation and developmental programming of higher-order cognitive processes. These consist of decision-making, working memory, learning, and social interaction, as well as physical and cognitive activity that can potentially influence multiple facets of brain health. Despite the intense and complex maturation of the brain during adolescence, there is limited knowledge about teachers' and students' awareness of aspects that improve the brain health and learning (Dubinsky et al., 2019; Lindgren, Haraldsson, & Håman, 2019). While there is a lot of scientific knowledge, the major challenge is how to incorporate this knowledge in everyday life of students and adolescents. This article aims to dismantle this challenge and contribute with an evidence-based overview to support teachers and students toward improving brain health and related learnings.

METHODS AND AIMS

This article presents a scoping review (Daudt, van Mossel, & Scott, 2013; Peters et al., 2021) of peer-reviewed research published between 2000 and 2020. Publications were sourced from PubMed and Google Scholar using search terms with synonyms that included healthy eating, exercising, rest/sleep, optimism, managing stress, making autonomous decisions, variety/challenges, social interactions/friends, learning new things/repetition, adolescents, optimal brain health, and learning.

The scoping review search for the habits (1–10) in combination with the basic keywords (learning, optimal, brain, health), set within the time parameters between the years 2000 and 2020 and sorted according to relevance, generated more than 200,000 references (please see Table 1). We decided to select a combination of references from Google Scholar and PubMed using the first 300 proposed publications, based on significance for each of the habits, plus the basic keywords. This generated 3,000 abstracts that were scrutinized. In turn, this process resulted in 64 articles being thoroughly reviewed and subsequently cited as references in this article. While articles were selected on the basis of relevance and impact citations, there is no assumption that the evidence reviewed is exhaustive. Due to space constraints, the research cited in this article does not represent all reviewed publications.

We focus on the combined impact on the brain and immune system, reflected in cognitive functions such as learning, thinking, decision-making, and attention. In the interaction between the central nervous system and the immune system, studies show that thoughts, emotional patterns, and the psychological dynamics are strongly interrelated with the immune response on learning (Bilbo & Schwarz, 2012; Slavich, 2020). It means that if a person is aware of how they can influence and regulate their situation, they gain a sense of control and self-awareness. Becoming literate in the GHs presents an opportunity for a person to develop a growing mind and lifelong learning. To the best of our knowledge, no studies have described the relation between brain health, learning, and the range of skill trajectories the GHs represent.

Table 1
Summary of the Original Results Using the Presented Search Terms in Google Scholar and PubMed

Habit	*Google Scholar search results*[a]	*PubMed search results*[a]
1. Healthy eating	20,900	469
2. Exercising	20,600	177
3. Rest/sleep	21,000	631
4. Optimism	18,400	342
5. Managing stress	18,500	113
6. Making autonomous decisions	21,300	328
7. Variety/challenges	20,900	744
8. Social interactions/friends	20,800	530
9. Learning new things	21,600	325
10. Repetition	20,500	198

[a]The number of references for the basic keywords: learning, optimal, brain, health + each habit separately.

The overall objective of integrating the GHs as a form of health-promoting school development is to support students' well-being and knowledge development by giving them knowledge and tools to understand how they can fine-tune their own brain. We anticipate that this material will be useful to teachers, students, researchers, and stakeholders interested in the adolescent brain, mind, and cognitive development.

RESULTS AND DISCUSSION

The aim of the GHs is to support flexible brain development and plasticity by optimizing individual brain health (La Rosa, Parolisi, & Bonfanti, 2020). Brain plasticity plays a key role in the dynamic evolvement of brain functions to adequately meet the challenges presented by society and the environment. Hence, the influence of GHs on brain plasticity is an important mediator of its effect on brain health. It involves the modulation of neuronal connections through complex epigenetic interactions between genes and the environment (McEwen, 2016). Learning, memory, and the underlying neural processes play an important part in this plasticity. Comprehension of the integrated effects of the GHs requires an understanding of how the external environment, which is primarily social during the adolescent years, influences and shapes brain development. Work from the past years has shown that adolescence represents a crucial period of enhanced brain plasticity, specifically in areas associated with experience-dependent associative learning. The onset of puberty is hypothesized to mark a shift in plasticity toward brain areas involved in learning and complex cognitive functions (Schriber & Guyer, 2016). In the brain throughout the teens, enhanced cortical maturation and plasticity are supported by observations of extensive experience-dependent pruning and remodeling of cortical connections (Shaw, Dupree, & Neigh, 2020). Moreover, facilitated associative learning and learning from reinforcement, that is, associative learning from positive and negative behavioral outcomes, are associated with increased hippocampal plasticity during adolescence (DePasque & Galván, 2017). During reinforcement learning, the extent to which the outcome deviates positively or negatively is used to adapt existing action–outcome associations in an experience-dependent manner. However, in adolescents, positive memory bias is associated with improved learning and enhanced functional connectivity between two brain regions, the hippocampus and striatum (Davidow et al, 2016; DePasque & Galván, 2017). These findings suggest that during adolescence, people have a positive, adaptive nature of learning and reward sensitivity, which refers to high task engagement to earn the desired reward during a cognitive task (Capa & Bouquet, 2018). It also indicates adolescents' inherent capacity for neural and behavioral resilience.

Drawing on the synthesized scoping review of research, this article now turns to present each habit separately, with a focused discussion of the effects on health, mental health, well-being, and learning. The idea of a set of GHs aims to help students reflect upon strategies or different ways to work with their growing brain. It is important for adolescents to understand that the brain maturation process is a slow process—with notable gender and age variability—which is ongoing until they reach age 25 to 30 (Crone & Dahl, 2012; Somerville, 2016).

Food and Nutrition

The brain is the body's most energy-intensive organ. The brain functions at its very best when receiving a steady supply of energy (Magistretti & Allaman, 2015). This supply of energy is best provided by carbohydrates, protein, and fat (Jirout et al., 2019). The carbohydrates are processed into glucose, which in turn supplies the brain with energy. This allows people to think clearly and keep a sharp mind. The carbohydrates cannot be stored, meaning that they need to regularly be topped up. "Fast carbs," such as sweets, break down quickly and provide a lot of energy to the brain. Fast carbs also generate disturbing fluctuations in blood sugar. After a short while, people feel tired and want to refill. Conversely, slow carbs, such as those found in vegetables, whole grains, and legumes, take longer to digest and break down into glucose, resulting in a steady energy supply (Carneiro & Leloup, 2020).

The polyphenols, antioxidants of fruits and vegetables, boost cognitive functions. These compounds act to improve neuronal plasticity in the hippocampus, modulating pathways of signaling and transcription factors. In the same way, the brain-derived neurotrophic factor (BDNF) plays a key role in the maintenance, survival, growth, and differentiation of neurons. All these effects are produced by an increase in cerebral blood flow and an increase in the blood's nitric oxide levels and oxygenation. This provides a steady supply of energy and for a sustained period of time, which in turn makes it possible for people to engage in deep-thought activity and keep momentum when focusing (Gratton et al., 2020).

Protein may also be converted into glucose but will not provide as much energy as slow carbs. A key function of proteins is to stimulate the production of neurotransmitters such as serotonin, dopamine, and norepinephrine. All of these are central regulators of mood, concentration, learning, thinking ability, and memory. When combined, these nutritional components may have a positive impact on reducing stress-related behaviors such as anxiety. In turn, this presents possible new venues for optimal brain health (Flannery, Callaghan, Sharpton, Fisher, & Pfeifer, 2019).

A healthy diet is essential for good brain development and maintenance of optimal cognitive functions during adulthood. Furthermore, nutritional components profoundly influence the intestinal microbes, which in turn may affect gut–brain communication during adulthood and later in life. The central notion of *Food and Nutrition* as a GH is for a person to consciously set the condition for their brain to work at its optimal level by regulating its energy supply through their diet. Gut microbial research has recently opened new frontiers in neuroscience, highlighting the importance of regular and healthy meals. The gut microbiome has become increasingly relevant to adolescence, a key period of neurobiological and social–affective development. Cognitive impairments following alterations in the microbiome have led to the theory of a gut-microbiome–cognition connection (Callaghan, 2020). The use of food ingredients and their preparation are very important for the development and well-being of brain cells. Poor nutrition in the diet may impair a rapidly developing brain and its cognitive functions and may influence the academic accomplishment of children (Naveed, Lakka, & Haapala, 2020).

Exercising

Physical activity has been associated with increasing gray matter volumes in the frontal and hippocampal regions of the brain. It is also associated with increased blood flow which has effects on glucose and lipid metabolism, and on the upregulation of several growth factors, neuroplasticity, and improved vascular function (Hillman, Erickson, & Kramer, 2008). All these effects of physical activity on the brain have been linked to improved brain functions and structures, cognitive functions, and academic achievement in children and adolescents (Lubans et al., 2016). Exercise interventions, such as increasing after-school or classroom physical activity, have been found to improve cognitive functions and academic achievement in children. Physical exercise levels have been related to structural changes in the brain and subsequently with better cognition and academic achievement in comparison to sedentary individuals (Chaput et al., 2020).

Additionally, it has been demonstrated that the children involved in regular aerobic exercise performed better on verbal, perceptual, and arithmetic tests (Álvarez-Bueno et al., 2017). Some studies have found a direct association of motor skills, but not cardiorespiratory fitness, with academic performance and cognition in children. Furthermore, exercise has been shown to help the brain counteract the adverse effects of an unhealthy diet. Exercise and the gut microbiome have been independently shown to decrease psychological disorders such as depression and anxiety because they promote neurogenesis, through the BDNF, and improve the hypothalamus, pituitary, adrenal axis control (Dalton, Mermier, & Zuhl, 2019).

It seems likely that there is no single mechanism mediating all of the effects on the brain and its functions from exercise. Moreover, given the differences in biological processes at play across different age groups and populations, the impact on the brain from the influence of exercise is likely to vary with age and between individuals (Stillman, Esteban-Cornejo, Brown, Bender, & Erickson, 2020). Finally, it is worth noting that physical activity and aerobic fitness may facilitate resilience by strengthening a person's individual brain regions as well as large-scale neural circuits, which improve the emotional and behavioral regulation needed for the adolescent brain to flourish (Belcher et al., 2021).

Optimism

As Blackburn and Epel (2017) put it, your cells are listening to your thoughts. Optimism and positive thinking are related to better mental and physical health (Lai, Wang, Zhao, Qiu, & Gong, 2020). Ongoing thoughts can influence the link between brain physiology and well-being. "Positive thinking" suggests that in order to accomplish good things and pursue happiness, it is important to nurture positive thoughts and suppress the number of negative thoughts. This can be done by imagining success, self-talk to build self-esteem, and arousing pleasant thoughts which may block ideas that cause anxiety or induce stress (Ada, Comoutos, Karamitrou, & Kazak, 2019; Walter, Nikoleizig, & Alfermann, 2019). Less is known about the basis of optimism as a trait and its underlying protective mechanism against anxiety in a healthy brain (Wang et al., 2018). With knowledge of what goes on in our brain chemistry, we can better realize how optimism can affect our resilience to life stress. When exposed to criticism, rejection, fear, or pessimism, either from our own thinking or from others, we produce higher levels of the stress hormone cortisol. Prolonged elevated levels of cortisol have a wide range of negative mental and physical health outcomes on an adolescent (Adam et al., 2017). On the other hand, positive thoughts, relations, and discussions are accompanied by the release of oxytocin, the feel-good hormone. It activates the pathways in the prefrontal cortex associated with building trust and improving communication (Malhi, Das, Bell, Mattingly, & Mannie, 2019). To build resilience and psychological well-being, we need to make consistent efforts to keep an optimistic pace and coping strategies (Scheier & Carver, 2018).

Coping with Stress

Adolescent development is associated with major changes in emotional and cognitive functions, as well as a rise in stress-related psychological disorders such as anxiety and depression. It is also a time of significant maturation of the brain, marked by structural alterations in many regions. A deeper understanding of how stress affects adolescent brain development is crucial to gain a better understanding of the mechanisms that mediate the increase in stress-related psychological dysfunctions during this stage of development (Romeo, 2017). Stressful episodes or chronic stress can shape our brain, leaving behind unfavorable epigenetic and structural changes in the brain (McEwen, 2017, Sierra et al, 2014). Modifying such traces on the central nervous system would be advantageous for coping with stress. While the underlying mechanisms that facilitate this response are still a mystery, recent studies demonstrate that modulation of circulating immunity can potentially enhance the ability to deal with stressors. The ongoing stress relating to education has demonstrated a negative impact on students' learning capacity, academic performance, sleep quality and quantity, physical health, mental health, and substance use outcomes (Giota & Gustafsson, 2017; Pascoe, Hetrick, & Parker, 2020). Increasing students' stress management skills and abilities is an important target for change. Possibly, the combined GHs serve as a preventive mental vaccine against stress and depression (Ekman, personal communication). The ultimate goal is to understand how the relationship between health and well-being interrelates to develop evidence-based ways to help people thrive in our stress-filled world (Crosswell & Lockwood, 2020).

Learn New Things

New knowledge creates the immediate synaptic plasticity which is associated with learning (Cantor et al, 2019; Ghiglieri et al, 2011; Humeau & Choquet, 2019). Adolescents have an astonishing capacity to learn new skills and adapt to new environments (Fandakova & Hartley, 2020; Green & Bavelier, 2008). The dynamics of learning are challenging and contribute to personal development and growth mindsets. Fostering a positive stance to learning challenges provides a general framework to conceptualize the role of motivation in social and personality development (Dweck, 2017; Yeager et al., 2019). Curiosity is a basic element of our cognition, but its biological function, mechanisms, and neural underpinning remain poorly understood. It is nonetheless a motivator for learning, influential in decision-making, and crucial for healthy development. Curiosity is a basic component of our nature, yet we are nearly unaware of its presence in our lives. Curiosity—broadly defined as the desire to acquire new information—enhances learning strategies, metacognitive strategies, and memory in children and adolescents (Giota & Bergh, 2021; Oudeyer et al, 2016). Different learning strategies activate curiosity and interest in the classroom, which may result in distinct memory benefits across youth development (Fandakova & Gruber, 2021; McGann, 2015). When curiosity is triggered, it may prompt further development of interests that in turn make continued engagement more likely (Hidi & Renninger, 2019). Curiosity, driven by virtual experiences, may prompt new interests (Schutte, 2020). There has been very little research on curiosity, therefore, our understanding of how curiosity impacts learning is relatively poor. Recent findings suggest that curiosity elicits activity in the brain's dopaminergic circuit. Thereby, it enhances hippocampus-dependent learning, which is associated with high-curiosity states (Gruber & Ranganath, 2019; Marvin, Tedeschi, & Shohamy, 2020).

Repetition

Perhaps our most intuitive understanding of memory is that it gets better with repetition. Behavioral responses to a perceptual stimulus are typically faster with repeated exposure to the stimulus. Repeated stimulus exposure is associated with faster and more accurate behavioral responses, referred to as "behavioral priming" (Korzeniewska et al., 2020). A decrease in cortical activation upon repeated stimulus exposure, repetition suppression, has been widely observed under a variety of experimental conditions. The combination of behavioral priming and repetition suppression requires some form of improved neural processing efficiency, which is of fundamental importance for understanding cortical mechanisms of learning and implicit memory (Reber, 2013; Segaert et al, 2013). Research on the brain-health consequences of digital technology is beginning to elucidate how these novel devices and programs can both help and harm brain function (Small et al., 2020). While online tools may increase problems such as deprivation of sleep, which has several serious consequences on health and learning. However, research has found online tools for repetition-based mental exercises that activate neural circuitry, have several positive effects such as improving cognitive functioning, reducing anxiety, increasing restful sleep, and offering other brain health benefits (Small et al., 2020). Programs that use "spaced repetition" are specially designed to adapt to the learners' specific performance by using a repetition algorithm that enables new knowledge to remain in our minds (Tabibian et al., 2019).

Variety and Challenges

New experiences help develop the brain (Bessières et al., 2020). People's own experiences contribute to how their brain is shaped and its function. This constant process of change is called neuroplasticity (Laube et al., 2020). Technology, in the form of apps, can be used to enhance variety, for example, by prompting the user to move when they have been sitting for a period of time. Lifestyle apps may also build motivation and over time help promote change relevant to a positive lifestyle, better health, memory, and learning. Conversely, the combination of not learning new things and being bored due to lack of challenges is a strong and destructive process that has a negative impact on mental activities (Mathiak, Klasen, Zvyagintsev, Weber, & Mathiak, 2013). It is important to understand the combined and interactive roles of each of the GHs as a mental vaccine. At present, little is known about the neurocognitive mechanisms that underlie this adaptive phenomenon, since brain developmental studies have mainly focused on the risk side (Cousijn, Luijten, & Feldstein Ewing, 2018).

Make Autonomous Decisions

Is the adolescent brain prepared for decision-making? The adolescent brain is dynamic and plastic, ready to learn (Jansen & Kiefer, 2020), but stress has been found to alter adolescents' decision-making and development (Galván & Rahdar, 2013). A person's decisions are modulated by a variety of environmental and intrinsic contexts. For example, decision-making associated with the prospect of a high reward can motivate a person to undertake an action despite it being associated with significant risk. Predictable environments should facilitate the consideration of longer-delayed rewards (Doya, 2008). Current studies have separated decision-making processes into its various components. Evidence points to dissociation between the relatively slow, linear development of impulse control and response inhibition during adolescence versus the faster development of the reward system, which is often hyperresponsive to rewards adolescence (Blakemore, 2012). There is some basis for claiming that adolescent girls are more self-regulated in their decision-making than are adolescent boys (Altikulaç et al., 2018).

Social Interaction

Social interaction provides a smarter brain. Positive social relationships have been found to promote health and well-being (Giota & Gustafsson, 2021) and protect adolescents from mental illness and psychosomatic problems (Miller, 2011). However, extensive use of social media and screen time among adolescents has been found to be negatively related to goal-directed behavior and executive brain function in everyday life (Baumgartner, Weeda, van der Heijden, & Huizinga, 2014).

At the same time, as teens learn to navigate their social environment with increasing sophistication, the brain regions that regulate the prefrontal regions involved in the mentalizing and control systems, and subcortical regions implicated in the affective system, continue to develop through late adolescence and early adulthood (Lamblin, Murawski, Whittle, & Fornito, 2017). Adolescence is also a time of increased risk for the development of psychiatric disorders, many of which are characteristically associated with social dysfunction. The bidirectional influences between the adolescent brain and the social environment are likely to be an important determinant of an individual's risk of mental illness (Karcher & Barch, 2021). The onset of mental illness may have a drastic effect on the structure of a teenager's social networks and potentially lead to the spread of negative outcomes (Raballo & Poletti, 2020).

Human development occurs through mutual actions between the individual, their contexts, and culture, with relationships as the key driver. Relationships and contexts, along with how children appraise and interpret them, can present risks and benefits for healthy learning and development. This knowledge about the individual's responsiveness to context has both positive and negative implications across early childhood adolescence and into adulthood. Sensitive periods for brain growth and development are considered within the contextual factors that influence development including parental responsiveness and atonement, intentional skill development, mindfulness, reciprocal interactions, adversity, trauma, and enriching opportunities. The accumulated knowledge on human development and the power of context and culture needs to inform the design of systems to support positive adaptations, resilience, learning, health, and well-being (Osher, Cantor, Berg, Steyer, & Rose, 2020).

Rest and Sleep

Rest provides all-over recovery for the brain (Hedin et al., 2020). Without sleep, the cognitive and emotional regulation skills suffer, which is detrimental to learning (Fontanellaz-Castiglione, Markovic, & Tarokh, 2020). This is particularly true during adolescence (Schmidt & Van der Linden, 2015). The effects of sleep loss, restriction, and deprivation are experienced more acutely in adolescents due to the ongoing development of key regulatory and affective neural systems, compared with adults (Galván, 2020). Sleep is divided into different sleep phases and functions. The most important stages are REM sleep and deep sleep. REM sleep has significant impact on well-being and learning ability (Chow, 2020). Deep sleep facilitates synaptic plasticity since one of its main functions is to create new connections between nerve cells. In this way, new memory structures are created. Research suggests that deep sleep also consolidates a person's memory, primarily the declarative memory that allows them to recall a specific event, or remember an exact phrase (Tononi & Cirelli, 2014). Put simply, memories of the day's experiences are stored in the hippocampus before being sorted into a particular brain compartment during the deep sleep of the night, ready to recall them the following day as memories (Saletin, 2020).

Lack of sleep shuts down our executive functions and hampers logical thinking and problem-solving. However, it's possible to compensate for a bad night's sleep. Power naps, mindfulness, or meditation are ways to catch up, which have been practiced in some schools and workplaces (Cabral et al., 2018). Another problem, sleep disruption, may also have effects on the brain cells by activating microglia, synaptic plasticity, and hippocampal neurogenesis. It may alter the neurotransmitter production that in turn leads to both short-term and long-lasting imbalances of neuronal function and behavior. Similarly, depression and anxiety disorders have been associated with the disruption in brain functionality and may therefore be linked to sleep disorders. Some recent studies have shown a bidirectional link between mental health and stress from sleep reduction (Ämmälä et al., 2019; Bakour et al., 2017).

The amount of sleep, its quality, and interruptions have a significant impact on the social functioning and behavior of children and adolescents (Dewald et al, 2010). Thus, forming appropriate sleep habits, which may mean lifestyle changes, can provide better social adjustment for individuals. Inadequate sleep is also significantly associated with underachievement, decreased capacity to store and process information, less satisfaction with friendship, and low self-esteem, as well as increased loneliness in children and adolescents.

These problems may be prevented by providing adolescents with knowledge about what is required to fall asleep. For example, when the frequency of light is lowered, our brain activity changes and melatonin levels increase. Reducing the level of light in the room 2 hours prior to going to bed prepares the body for rest and provides sufficient levels of melatonin for the brain to fall asleep. The blue light of screens from television or cell phones disturbs the production of melatonin (Small et al., 2020).

SUMMARY

The aim of this overview is to provide an indication of the associations of GHs with brain structures, functions, and cognition in students and adolescents. We introduce the concept of GHs as a mental vaccine for individual optimal brain plasticity to promote health and lifelong learning.

GHs may also provide a mental framework for teachers to understand nuanced neuroscientific and psychological factors that influence learning. How puberty-related structural brain changes impact higher cognitive functioning and improvements with GHs is yet to be explored, as learning-related changes have not been tested extensively so far. However, even with the limited knowledge available to date, it is apparent that there is much room for improvement to build better support systems for youth and adults to improve their learning. It is possible that GHs could provide guidance for teachers and students, enabling them to create optimal circumstances for brain development and learning during childhood, adolescence, and adulthood. However, the evidence is mostly based on cross-sectional data and there is a need for longitudinal and intervention studies to further understand the combined effects of the GHs on cognition and optimal brain health from child to adult.

The interrelated concept of a mental vaccine also warrants additional longitudinal research in order to further understand the generative impact this can contribute with for individuals and societies.

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REFERENCES

Ada, E. N., Comoutos, N., Karamitrou, A., & Kazak, Z. (2019). Relationships between dispositional flow, motivational climate, and self-talk in physical education classes. *The Physical Educator*, *76*(2), 357–384.

Adam, E. K., Quinn, M. E., Tavernier, R., McQuillan, M. T., Dahlke, K. A., & Gilbert, K. E. (2017). Diurnal cortisol slopes and mental and physical health outcomes: A systematic review and meta-analysis. *Psychoneuroendocrinology*, *83*, 25–41. https://doi.org/10.1016/j.psyneuen.2017.05.018

Álvarez-Bueno, C., Pesce, C., Cavero-Redondo, I., Sánchez-López, M., Garrido-Miguel, M., & Martínez-Vizcaíno, V. (2017). Academic achievement and physical activity: A meta-analysis. *Pediatrics*, *140*, e20171498. https://doi.org/10.1542/peds.2017-1498

Altikulaç, S., Lee, N. C., van der Veen, C., Benneker, I., Krabbendam, L., & van Atteveldt, N. (2018). The teenage brain: Public perceptions of neurocognitive development during adolescence.

Journal of Cognitive Neuroscience, *31*(3), 339–359. https://doi.org/10.1162/jocn_a_01332

Ämmälä, A.-J., Urrila, A.-S., Lahtinen, A., Santangeli, O., Hakkarainen, A., Kantojärvi, K., … Paunio, T. (2019). Epigenetic dysregulation of genes related to synaptic long-term depression among adolescents with depressive disorder and sleep symptoms. *Sleep Medicine*, *61*, 95–103. https://doi.org/10.1016/j.sleep.2019.01.050

Andersen, S. L., & Teicher, M. H. (2008). Stress, sensitive periods and maturational events in adolescent depression. *Trends in Neurosciences*, *31*(4), 183–191. https://doi.org/10.1016/j.tins.2008.01.004

Bakour, C., Schwartz, S., O'Rourke, K., Wang, W., Sappenfield, W., Couluris, M., & Chen, H. (2017). Sleep duration trajectories and systemic inflammation in young adults: Results from the national longitudinal study of adolescent to adult health (add health). *Sleep*, *40*(11), 1–9. https://doi.org/10.1093/sleep/zsx156

Baumgartner, S. E., Weeda, W. D., van der Heijden, L. L., & Huizinga, M. (2014). The relationship between media multitasking and executive function in early adolescents. *The Journal of Early Adolescence*, *34*(8), 1120–1144. https://doi.org/10.1177/0272431614523133

Belcher, B. R., Zink, J., Azad, A., Campbell, C. E., Chakravartti, S. P., & Herting, M. M. (2021). The roles of physical activity, exercise, and fitness in promoting resilience during adolescence: Effects on mental well-being and brain development. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *6*(2), 225–237. https://doi.org/10.1016/j.bpsc.2020.08.005

Bessières, B., Travaglia, A., Mowery, T. M., Zhang, X., & Alberini, C. M. (2020). Early life experiences selectively mature learning and memory abilities. *Nature Communications*, *11*(1), 628. https://doi.org/10.1038/s41467-020-14461-3

Bilbo, S. D., & Schwarz, J. M. (2012). The immune system and developmental programming of brain and behavior. *Frontiers in Neuroendocrinology*, *33*(3), 267–286. https://doi.org/10.1016/j.yfrne.2012.08.006

Blackburn, E., & Epel, E. (2017) *The telomere effect: A revolutionary approach to living younger, healthier, longer*. New York: Grand Central Publishing.

Blakemore, S.-J. (2012). Imaging brain development: The adolescent brain. *NeuroImage*, *61*(2), 397–406. https://doi.org/10.1016/j.neuroimage.2011.11.080

Cabral, T., Mota, N. B., Fraga, L., Copelli, M., McDaniel, M. A., & Ribeiro, S. (2018). Post-class naps boost declarative learning in a naturalistic school setting. *npj Science of Learning*, *3*(1), 14. https://doi.org/10.1038/s41539-018-0031-z

Callaghan, B. (2020). Nested sensitive periods: How plasticity across the microbiota-gut-brain axis interacts to affect the development of learning and memory. *Current Opinion in Behavioral Sciences*, *36*, 55–62. https://doi.org/10.1016/j.cobeha.2020.07.011

Cantor, P., Osher, D., Berg, J., Steyer, L., & Rose, T. (2019). Malleability, plasticity, and individuality: How children learn and develop in context1. *Applied Developmental Science*, *23*(4), 307–337. https://doi.org/10.1080/10888691.2017.1398649

Capa, R. L., & Bouquet, C. A. (2018). Individual differences in reward sensitivity modulate the distinctive effects of conscious and unconscious rewards on executive performance. *Frontiers in Psychology*, *9*(148), 1–9. https://doi.org/10.3389/fpsyg.2018.00148

Carneiro, L., & Leloup, C. (2020). Mens sana in corpore sano: Does the glycemic index have a role to play? *Nutrients*, *12*(10), 2989. Retrieved from https://www.mdpi.com/2072-6643/12/10/2989

Carlsson, A. (2001). A paradigm shift in brain research. *Science*, *294*(5544), 1021–1024. https://doi.org/10.1126/science.1066969

Chaput, J.-P., Willumsen, J., Bull, F., Chou, R., Ekelund, U., Firth, J., … Katzmarzyk, P. T. (2020). 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5–17 years: Summary of the evidence. *International Journal of Behavioral Nutrition and Physical Activity*, *17*(1), 141. https://doi.org/10.1186/s12966-020-01037-z

Chow, C. M. (2020). Sleep and wellbeing, now and in the future. *International Journal of Environmental Research and Public Health*, *17*(8), 2883. Retrieved from https://www.mdpi.com/1660-4601/17/8/2883

Crone, E. A., & Dahl, R. E. (2012). Understanding adolescence as a period of social–affective engagement and goal flexibility. *Nature Reviews Neuroscience*, *13*(9), 636–650. https://doi.org/10.1038/nrn3313

Crosswell, A. D., & Lockwood, K. G. (2020). Best practices for stress measurement: How to measure psychological stress in health research. *Health Psychology Open*, *7*(2), 2055102920933072. https://doi.org/10.1177/2055102920933072

Cousijn, J., Luijten, M., & Feldstein Ewing, S. W. (2018). Adolescent resilience to addiction: A social plasticity hypothesis. *The Lancet Child & Adolescent Health*, *2*(1), 69–78. https://doi.org/10.1016/S2352-4642(17)30148-7

Dahl, R. E., Allen, N. B., Wilbrecht, L., & Suleiman, A. B. (2018). Importance of investing in adolescence from a developmental science perspective. *Nature*, *554*(7693), 441–450. https://doi.org/10.1038/nature25770

Dalton, A., Mermier, C., & Zuhl, M. (2019). Exercise influence on the microbiome–gut–brain axis. *Gut Microbes*, *10*(5), 555–568. https://doi.org/10.1080/19490976.2018.1562268

Daudt, H. M. L., van Mossel, C., & Scott, S. J. (2013). Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Medical Research Methodology*, *13*(1), 48. https://doi.org/10.1186/1471-2288-13-48

Davidow, J. Y., Foerde, K., Galván, A., & Shohamy, D. (2016). An upside to reward sensitivity: The hippocampus supports enhanced reinforcement learning in adolescence. *Neuron*, *92*(1), 93–99. https://doi.org/10.1016/j.neuron.2016.08.031

Delevich, K., Wren Thomas, A., & Wilbrecht, L. (2019). Adolescence and "late blooming" synapses of the prefrontal cortex. *Cold Spring Harbor Symposia on Quantitative Biology*, *LXXXIII*, 37–43. https://doi.org/10.1101/sqb.2018.83.037507

DePasque, S., & Galván, A. (2017). Frontostriatal development and probabilistic reinforcement learning during adolescence. *Neurobiology of Learning and Memory*, *143*, 1–7. https://doi.org/10.1016/j.nlm.2017.04.009

Dewald, J. F., Meijer, A. M., Oort, F. J., Kerkhof, G. A., & Bögels, S. M. (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep Medicine Reviews*, *14*(3), 179–189. https://doi.org/10.1016/j.smrv.2009.10.004

Doya, K. (2008). Modulators of decision making. *Nature Neuroscience*, *11*(4), 410–416. https://doi.org/10.1038/nn2077

Dubinsky, J. M., Guzey, S. S., Schwartz, M. S., Roehrig, G., MacNabb, C., Schmied, A., … Cooper, J. L. (2019). Contributions of neuroscience knowledge to teachers and their practice. *The Neuroscientist*, *25*(5), 394–407. https://doi.org/10.1177/1073858419835447

Dweck, C. S. (2017). The journey to children's mindsets—And beyond. *Child Development Perspectives*, *11*(2), 139–144. https://doi.org/10.1111/cdep.12225

Embry, D. D. (2002). The good behavior game: A best practice candidate as a universal behavioral vaccine. *Clinical Child and Family Psychology Review*, *5*(4), 273–297. https://doi.org/10.1023/A:1020977107086

Fandakova, Y., & Gruber, M. J. (2021). States of curiosity and interest enhance memory differently in adolescents and in children. *Developmental Science*, *24*(1), e13005. https://doi.org/10.1111/desc.13005

Fandakova, Y., & Hartley, C. A. (2020). Mechanisms of learning and plasticity in childhood and adolescence. *Developmental Cognitive Neuroscience*, *42*, 100764. https://doi.org/10.1016/j.dcn.2020.100764

Flannery, J., Callaghan, B., Sharpton, T., Fisher, P., & Pfeifer, J. (2019). Is adolescence the missing developmental link in microbiome–gut–brain axis communication? *Developmental Psychobiology*, *61*(5), 783–795. https://doi.org/10.1002/dev.21821

Fontanellaz-Castiglione, C. E. G., Markovic, A., & Tarokh, L. (2020). Sleep and the adolescent brain. *Current Opinion in Physiology*, *15*, 167–171. https://doi.org/10.1016/j.cophys.2020.01.008

Frith, U. (2019). Flux of life. *Developmental Cognitive Neuroscience*, *38*, 100669. https://doi.org/10.1016/j.dcn.2019.100669

Fusar-Poli, P., Salazar de Pablo, G., De Micheli, A., Nieman, D. H., Correll, C. U., Kessing, L. V., … van Amelsvoort, T. (2020). What is good mental health? A scoping review. *European Neuropsychopharmacology*, *31*, 33–46. https://doi.org/10.1016/j.euroneuro.2019.12.105

Galván, A., & Rahdar, A. (2013). The neurobiological effects of stress on adolescent decision making. *Neuroscience*, *249*, 223–231. https://doi.org/10.1016/j.neuroscience.2012.09.074

Galván, A. (2020). The need for sleep in the adolescent brain. *Trends in Cognitive Sciences*, *24*(1), 79–89. https://doi.org/10.1016/j.tics.2019.11.002

Ghiglieri, V., Sgobio, C., Costa, C., Picconi, B., & Calabresi, P. (2011). Striatum–hippocampus balance: From physiological behavior to interneuronal pathology. *Progress in Neurobiology*, *94*(2), 102–114. https://doi.org/10.1016/j.pneurobio.2011.04.005

Giota, J., & Gustafsson, J. E. (2017). Perceived demands of schooling, stress and mental health: Changes from grade 6 to grade 9 as a function of gender and cognitive ability. *Stress and Health*, *33*(3), 253–266.

Giota, J., & Gustafsson, J.-E. (2021). Perceived academic demands, peer and teacher relationships, stress, anxiety and mental health: Changes from grade 6 to 9 as a function of gender and cognitive ability. *Scandinavian Journal of Educational Research*, *65*(6), 956–971. https://doi.org/10.1080/00313831.2020.1788144

Giota, J., & Bergh, D. (2021). Adolescent academic, social and future achievement goal orientations: Implications for achievement by gender and parental education. *Scandinavian Journal of Educational Research*, *65831*(5), 1–850. https://doi.org/10.1080/00313831.2020.1755360

Gorelick, P. B., Furie, K. L., Iadecola, C., Smith, E. E., Waddy, S. P., Lloyd-Jones, D. M., … Zerna, C. (2017). Defining optimal brain health in adults: A presidential advisory from the American Heart Association/American Stroke Association. *Stroke*, *48*(10), e284–e303. https://doi.org/10.1161/STR.0000000000000148

Goswami, U. (2006). Neuroscience and education: From research to practice? *Nature Reviews Neuroscience*, *7*(5), 406–411. https://doi.org/10.1038/nrn1907

Gratton, G., Weaver, S. R., Burley, C. V., Low, K. A., Maclin, E. L., Johns, P. W., … Rendeiro, C. (2020). Dietary flavanols improve cerebral cortical oxygenation and cognition in healthy adults. *Scientific Reports*, *10*(1), 19409. https://doi.org/10.1038/s41598-020-76160-9

Green, C. S., & Bavelier, D. (2008). Exercising your brain: A review of human brain plasticity and training-induced learning. *Psychology and Aging*, *23*(4), 692–701. https://doi.org/10.1037/a0014345

Gruber, M. J., & Ranganath, C. (2019). How curiosity enhances hippocampus-dependent memory: The prediction, appraisal, curiosity, and exploration (PACE) framework. *Trends in Cognitive Sciences*, *23*(12), 1014–1025. https://doi.org/10.1016/j.tics.2019.10.003

Hedin, G., Norell-Clarke, A., Hagell, P., Tønnesen, H., Westergren, A., & Garmy, P. (2020). Facilitators and barriers for a good night's sleep among adolescents. *Frontiers in Neuroscience*, *14*(92), 1–8. https://doi.org/10.3389/fnins.2020.00092

Hidi, S. E., & Renninger, K. A. (2019). Interest development and its relation to curiosity: Needed neuroscientific research. *Educational Psychology Review*, *31*(4), 833–852. https://doi.org/10.1007/s10648-019-09491-3

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience*, *9*(1), 58–65. https://doi.org/10.1038/nrn2298

Humeau, Y., & Choquet, D. (2019). The next generation of approaches to investigate the link between synaptic plasticity and learning. *Nature Neuroscience*, *22*(10), 1536–1543. https://doi.org/10.1038/s41593-019-0480-6

Jansen, K., & Kiefer, S. M. (2020). Understanding brain development: Investing in young adolescents' cognitive and social-emotional development. *Middle School Journal*, *51*(4), 18–25. https://doi.org/10.1080/00940771.2020.1787749

Jirout, J., LoCasale-Crouch, J., Turnbull, K., Gu, Y., Cubides, M., Garzione, S., … Kranz, S. (2019). How lifestyle factors affect cognitive and executive function and the ability to learn in children. *Nutrients*, *11*(8), 1953. Retrieved from https://www.mdpi.com/2072-6643/11/8/1953

Karcher, N. R., & Barch, D. M. (2021). The ABCD study: Understanding the development of risk for mental and physical health outcomes. *Neuropsychopharmacology*, *46*(1), 131–142. https://doi.org/10.1038/s41386-020-0736-6

Korzeniewska, A., Wang, Y., Benz, H. L., Fifer, M. S., Collard, M., Milsap, G., … Crone, N. E. (2020). Changes in human brain dynamics during behavioral priming and repetition suppression. *Progress in Neurobiology*, *189*, 101788. https://doi.org/10.1016/j.pneurobio.2020.101788

Lamblin, M., Murawski, C., Whittle, S., & Fornito, A. (2017). Social connectedness, mental health and the adolescent brain. *Neuroscience & Biobehavioral Reviews*, *80*, 57–68. https://doi.org/10.1016/j.neubiorev.2017.05.010

La Rosa, C., Parolisi, R., & Bonfanti, L. (2020). Brain structural plasticity: From adult neurogenesis to immature neurons. *Frontiers in Neuroscience*, *14*(75), 1–9. https://doi.org/10.3389/fnins.2020.00075

Lai, H., Wang, S., Zhao, Y., Qiu, C., & Gong, Q. (2020). Neurostructural correlates of optimism: Gray matter density in the putamen predicts dispositional optimism in late adolescence. *Human Brain Mapping*, *41*(6), 1459–1471. https://doi.org/10.1002/hbm.24888

Laube, C., van den Bos, W., & Fandakova, Y. (2020). The relationship between pubertal hormones and brain plasticity: Implications for cognitive training in adolescence. *Developmental Cognitive Neuroscience*, *42*, 100753. https://doi.org/10.1016/j.dcn.2020.100753

Lindgren, E.-C., Haraldsson, K., & Håman, L. (2019). Voices from pupil participation in the health promotion intervention "pulse for learning and health [PuLH]" in primary and middle school. *International Journal of Environmental Research and Public Health*, *16*(22), 4543. Retrieved from https://www.mdpi.com/1660-4601/16/22/4543

Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., … Biddle, S. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics*, *138*(3), e20161642. https://doi.org/10.1542/peds.2016-1642

Magistretti, P. J., & Allaman, I. (2015). A cellular perspective on brain energy metabolism and functional imaging. *Neuron*, *86*(4), 883–901. https://doi.org/10.1016/j.neuron.2015.03.035

Malhi, G. S., Das, P., Bell, E., Mattingly, G., & Mannie, Z. (2019). Modelling resilience in adolescence and adversity: A novel framework to inform research and practice. *Translational Psychiatry*, *9*(1), 316. https://doi.org/10.1038/s41398-019-0651-y

Marvin, C. B., Tedeschi, E., & Shohamy, D. (2020). Curiosity as the impulse to know: Common behavioral and neural mechanisms underlying curiosity and impulsivity. *Current Opinion in Behavioral Sciences*, *35*, 92–98. https://doi.org/10.1016/j.cobeha.2020.08.003

Mathiak, K. A., Klasen, M., Zvyagintsev, M., Weber, R., & Mathiak, K. (2013). Neural networks underlying affective states in a multimodal virtual environment: Contributions to boredom. *Frontiers in Human Neuroscience*, *7*, 820. https://doi.org/10.3389/fnhum.2013.00820

Mattson, M. P. (2015). Lifelong brain health is a lifelong challenge: From evolutionary principles to empirical evidence. *Ageing Research Reviews*, *20*, 37–45. https://doi.org/10.1016/j.arr.2014.12.011

McEwen, B. S. (2016). In pursuit of resilience: Stress, epigenetics, and brain plasticity. *Annals of the New York Academy of Sciences*, *1373*(1), 56–64.

McEwen, B. S. (2017). Neurobiological and systemic effects of chronic stress. *Chronic Stress*, *1*, 2470547017692328. https://doi.org/10.1177/2470547017692328

McGann, J. P. (2015). Associative learning and sensory neuroplasticity: How does it happen and what is it good for? *Learning & Memory*, *22*(11), 567–576. https://doi.org/10.1101/lm.039636.115

Miller, G. (2011). Why loneliness is hazardous to your health. *Science*, *331*(6014), 138. https://doi.org/10.1126/science.331.6014.138

Monaco, A. P. (2021). An epigenetic, transgenerational model of increased mental health disorders in children, adolescents and young adults. *European Journal of Human Genetics*, *29*(3), 387–395. https://doi.org/10.1038/s41431-020-00726-4

Naveed, S., Lakka, T., & Haapala, E. A. (2020). An overview on the associations between health behaviors and brain health in children and adolescents with special reference to diet quality. *International Journal of Environmental Research and Public Health*, *17*(3), 953. Retrieved from https://www.mdpi.com/1660-4601/17/3/953

Oudeyer, P. Y., Gottlieb, J., & Lopes, M. (2016). Intrinsic motivation, curiosity, and learning: Theory and applications in educational technologies. In B. Studer, & S. Knecht (Eds.), *Progress in brain research*. (Vol. *229*, pp. 257–284). Amsterdam: Elsevier. https://doi.org/10.1016/bs.pbr.2016.05.005

Osher, D., Cantor, P., Berg, J., Steyer, L., & Rose, T. (2020). Drivers of human development: How relationships and context shape learning and development1. *Applied Developmental Science*, *24*(1), 6–36. https://doi.org/10.1080/10888691.2017.1398650

Pascoe, M. C., Hetrick, S. E., & Parker, A. G. (2020). The impact of stress on students in secondary school and higher education. *International Journal of Adolescence and Youth*, *25*(1), 104–112. https://doi.org/10.1080/02673843.2019.1596823

Peters, M. D. J., Marnie, C., Tricco, A. C., Pollock, D., Munn, Z., Alexander, L., … Khalil, H. (2021). Updated methodological guidance for the conduct of scoping reviews. *JBI Evidence Implementation*, *19*(1), 3–10. Retrieved from https://journals.lww.com/ijebh/Fulltext/2021/03000/Updated_methodological_guidance_for_the_conduct_of.2.aspx

Raballo, A., & Poletti, M. (2020). Advances in early identification of children and adolescents at risk for psychiatric illness. *Current Opinion in Psychiatry*, *33*(6), 611–617. Retrieved from https://journals.lww.com/co-psychiatry/Fulltext/2020/11000/Advances_in_early_identification_of_children_and.14.aspx

Ramus, F. (2006). Genes, brain, and cognition: A roadmap for the cognitive scientist. *Cognition*, *101*(2), 247–269. https://doi.org/10.1016/j.cognition.2006.04.003

Reber, P. J. (2013). The neural basis of implicit learning and memory: A review of neuropsychological and neuroimaging research. *Neuropsychologia*, *51*(10), 2026–2042. https://doi.org/10.1016/j.neuropsychologia.2013.06.019

Romeo, R. D. (2017). The impact of stress on the structure of the adolescent brain: Implications for adolescent mental health. *Brain Research*, *1654*, 185–191. https://doi.org/10.1016/j.brainres.2016.03.021

Saletin, J. M. (2020). Memory: Necessary for deep sleep? *Current Biology*, *30*(5), R234–R236. https://doi.org/10.1016/j.cub.2020.01.038

Scheier, M. F., & Carver, C. S. (2018). Dispositional optimism and physical health: A long look back, a quick look forward. *The American Psychologist*, *73*(9), 1082–1094. https://doi.org/10.1037/amp0000384

Schmidt, R. E., & Van der Linden, M. (2015). The relations between sleep, personality, behavioral problems, and school performance in adolescents. *Sleep Medicine Clinics*, *10*(2), 117–123.

Schriber, R. A., & Guyer, A. E. (2016). Adolescent neurobiological susceptibility to social context. *Developmental Cognitive Neuroscience*, *19*, 1–18. https://doi.org/10.1016/j.dcn.2015.12.009

Schutte, N. S. (2020). The impact of virtual reality on curiosity and other positive characteristics. *International Journal of Human–Computer Interaction*, *36*(7), 661–668. https://doi.org/10.1080/10447318.2019.1676520

Schwartz, M., & Baruch, K. (2012). Vaccine for the mind. *Human Vaccines & Immunotherapeutics*, *8*(10), 1465–1468. https://doi.org/10.4161/hv.21649

Segaert, K., Weber, K., de Lange, F. P., Petersson, K. M., & Hagoort, P. (2013). The suppression of repetition enhancement: A review of fMRI studies. *Neuropsychologia*, *51*(1), 59–66. https://doi.org/10.1016/j.neuropsychologia.2012.11.006

Shaw, G. A., Dupree, J. L., & Neigh, G. N. (2020). Adolescent maturation of the prefrontal cortex: Role of stress and sex in shaping adult risk for compromise. *Genes, Brain and Behavior*, *19*(3), e12626. https://doi.org/10.1111/gbb.12626

Sierra, A., Beccari, S., Diaz-Aparicio, I., Encinas, J. M., Comeau, S., & Tremblay, M.-È. (2014). Surveillance, phagocytosis, and inflammation: How never-resting microglia influence adult hippocampal neurogenesis. *Neural Plasticity*, *2014*, 610343. https://doi.org/10.1155/2014/610343

Slavich, G. M. (2020). Psychoneuroimmunology of stress and mental health. In K. L. Harkness, & E. P. Hayden (Eds.), *The Oxford handbook of stress and mental health*. (pp. 519–546). New York: Oxford University Press.

Small, G. W., Lee, J., Kaufman, A., Jalil, J., Siddarth, P., Gaddipati, H., … Bookheimer, S. Y. (2020). Brain health consequences of digital technology use. *Dialogues in Clinical Neuroscience*, *22*(2), 179–187. https://doi.org/10.31887/DCNS.2020.22.2/gsmall

Somerville, L. H. (2016). Searching for signatures of brain maturity: What are we searching for? *Neuron*, *92*(6), 1164–1167. https://doi.org/10.1016/j.neuron.2016.10.059

Stillman, C. M., Esteban-Cornejo, I., Brown, B., Bender, C. M., & Erickson, K. I. (2020). Effects of exercise on brain and cognition across age groups and health states. *Trends in Neurosciences*, *43*(7), 533–543. https://doi.org/10.1016/j.tins.2020.04.010

Sweatt, J. D. (2016). Neural plasticity and behavior—Sixty years of conceptual advances. *Journal of Neurochemistry*, *139*(S2), 179–199. https://doi.org/10.1111/jnc.13580

Tabibian, B., Upadhyay, U., De, A., Zarezade, A., Schölkopf, B., & Gomez-Rodriguez, M. (2019). Enhancing human learning via spaced repetition optimization. *Proceedings of the National Academy of Sciences*, *116*(10), 3988. https://doi.org/10.1073/pnas.1815156116

Tononi, G., & Cirelli, C. (2014). Sleep and the price of plasticity: From synaptic and cellular homeostasis to memory consolidation and integration. *Neuron*, *81*(1), 12–34. https://doi.org/10.1016/j.neuron.2013.12.025

Yeager, D. S., Hanselman, P., Walton, G. M., Murray, J. S., Crosnoe, R., Muller, C., … Dweck, C. S. (2019). A national experiment reveals where a growth mindset improves achievement. *Nature*, *573*(7774), 364–369. https://doi.org/10.1038/s41586-019-1466-y

VanderWeele, T. J. (2020). Activities for flourishing: An evidence-based guide. *Journal of Positive School Psychology*, *4*(1), 79–91. Retrieved from https://www.journalppw.com/index.php/JPPW/article/view/163

Walter, N., Nikoleizig, L., & Alfermann, D. (2019). Effects of self-talk training on competitive anxiety, self-efficacy, volitional skills, and performance: An intervention study with junior sub-elite athletes. *Sports*, *7*(6), 148. https://doi.org/10.3390/sports7060148

Wang, Y., Pan, Y., & Li, H. (2020). What is brain health and why is it important? *BMJ*, *371*, m3683. https://doi.org/10.1136/bmj.m3683

Wang, S., Zhao, Y., Cheng, B., Wang, X., Yang, X., Chen, T., … Gong, Q. (2018). The optimistic brain: Trait optimism mediates the influence of resting-state brain activity and connectivity on anxiety in late adolescence. *Human Brain Mapping*, *39*(10), 3943–3955. https://doi.org/10.1002/hbm.24222