# Nurturing Nature: How Brain Development Is Inherently Social and Emotional, and What This Means for Education

**Article** *in* Educational Psychologist · July 2019

DOI: 10.1080/00461520.2019.1633924



Mary Helen Immordino-Yang
University of Southern California



Linda Darling-Hammond
Stanford University



Christina R Kundrak
University of Southern California

Educational Psychologist

ISSN: 0046-1520 (Print) 1532-6985 (Online) Journal homepage: https://www.tandfonline.com/loi/hedp20

# Nurturing Nature: How Brain Development Is Inherently Social and Emotional, and What This Means for Education

Mary Helen Immordino-Yang, Linda Darling-Hammond & Christina R. Krone

EDUCATIONAL PSYCHOLOGIST, *54*(3), 185–204, 2019

ISSN: 0046-1520 print / 1532-6985 online
DOI: 10.1080/00461520.2019.1633924

Routledge
Taylor & Francis Group



# Nurturing Nature: How Brain Development Is Inherently Social and Emotional, and What This Means for Education

Mary Helen Immordino-Yang[1,2,3], Linda Darling-Hammond[4,5], and Christina R. Krone[1,2]

[1]*Brain and Creativity Institute, University of Southern California*
[2]*Rossier School of Education, University of Southern California*
[3]*Neuroscience Graduate Program, University of Southern California*
[4]*Learning Policy Institute, Palo Alto, California*
[5]*Graduate School of Education, Stanford University*

New advances in neurobiology are revealing that brain development and the learning it enables are directly dependent on social-emotional experience. Growing bodies of research reveal the importance of socially triggered epigenetic contributions to brain development and brain network configuration, with implications for social-emotional functioning, cognition, motivation, and learning. Brain development is also impacted by health-related and physical developmental factors, such as sleep, toxin exposure, and puberty, which in turn influence social-emotional functioning and cognition. An appreciation of the dynamic interdependencies of social-emotional experience, health-related factors, brain development and learning underscores the importance of a "whole child" approach to education reform and leads to important insights for research on social-emotional learning. To facilitate these interdisciplinary conversations, here we conceptualize within a developmental framework current evidence on the fundamental and ubiquitous biological constraints and affordances undergirding social-emotional learning–related constructs and learning more broadly. Learning indeed depends on how nature is nurtured.

Throughout life, and to an extraordinary degree in young people, the brain develops in relation to opportunities to engage actively and safely with rich and meaningful environments, social relationships and emotions, and socially transmitted ideas and information (Chan et al., 2018; Diamond, 2010; Farah, 2017; Immordino-Yang, 2015; Noble et al., 2015). Consistent with foundational work in education and psychology (Bruner, 1990; Montessori, 1914; Vygotsky, 1978), research is revealing that the brain's malleability, the evolutionary plasticity that allows us to adapt to the demands of our environments and to learn, is triggered and organized largely via socially enabled, emotionally driven opportunities for cognitive development. High-quality social interaction therefore presents a critical opportunity and responsibility for education.

There is a growing awareness in education research, policy, and practice that emotional and social competencies impact learning (Hamilton, Doss, & Steiner, 2019; Jones, Bouffard, & Weissbourd, 2013; Osher et al., 2016; Pekrun & Linnenbrink-Garcia, 2012). An expanding body of educational research focuses on social-emotional learning (SEL), including emotion regulation and awareness, social communication, collaboration skills, and the like (Collaborative for Academic, Social, and Emotional Learning, 2015). SEL practices and policies are gaining evidence and traction in mainstream education, and a good deal is being learned about the teachability of SEL,

Correspondence should be addressed to Mary Helen Immordino-Yang, University of Southern California, 3620A McClintock Avenue, Los Angeles, CA 90089-2921. E-mail: immordin@usc.edu

*Note.* Parts of this article are adapted with permission from *The Brain Basis for Integrated Social, Emotional, and Academic Development: How Emotions and Social Relationships Drive Learning*, by M. H. Immordino-Yang, L. Darling-Hammond, and C. Krone, © 2018 The Aspen Institute (www.aspeninstitute.org). All Rights Reserved. Adapted with permission. For a more complete list of relevant work, see https://assets.aspeninstitute.org/content/uploads/2018/08/NCSEAD-Footnotes-Research-Brief.pdf?_ga=2.41722466.1702787075.1557800053-404269238.1536851220.

as well as about links between SEL, motivation, and academic achievement (Dweck, 2017; Jones & Kahn, 2017; Roeser, Urdan, & Stephens, 2009; Taylor, Oberle, Durlak, & Weissberg, 2017; Wentzel & Miele, 2016).

However, significant questions remain (Jones, Farrington, Jagers, Brackett, & Kahn, 2018). How do social-emotional skills develop, including potential sensitive and high-leverage developmental periods, and what supports are needed at different ages and stages? In an era of unprecedented immigration, diversity, inequality, and exposure to trauma, how can we ensure that SEL practices are reliable, culturally responsive, appropriate for individuals' needs, and equitably applied? How are SEL skills, academic emotions, and learning related, and how can SEL skills be most meaningfully integrated into educational experiences? How should social-emotional skills be measured, and for which sets of skills can schools be reasonably held accountable?

To help education researchers build toward a new era of SEL research that provides practical answers to these questions, in this article we provide a developmental, biopsychosocial look at *why* and *how* academic learning may be so dependent on culturally situated social relationships and emotional experiences. In particular, we focus on connecting the science of human development with recent neuroscientific insights into the fundamentally social and context-dependent nature of human biology. We integrate a broad range of neurobiological findings into an educationally relevant narrative elucidating (a) the biological constraints and affordances that derive from the social and emotional contexts in which humans live and (b) the ways that developmental processes, including those related to health and physical development, interact with these constraints and affordances.

We take this broad psychosocial approach with the aim of informing the future of SEL, which we see as the educational research and intervention field that focuses specifically on the aspects of behavior and learning that involve interacting with other people and managing one's self, emotions and goals. As science progresses, it is becoming increasingly evident that the cultural learning and social-emotional experiences that result from everyday human interactions and cognitions play a critical role in brain development and learning across the life span. In this sense, human beings are *biologically* cultural (Rogoff, 2003; Tomasello, 2009), and education is a major acculturating force. We believe that an appreciation of the biopsychosocial nature of human development could potentially be useful as SEL researchers work to discern the hidden factors contributing to the SEL constructs they care about, including developmental, contextual, and individual variance. Our main focus is not on specific SEL constructs from the education literature but instead on how social context and emotional experience, broadly construed, shape the trajectory of human biological development and make learning, including SEL, possible.

## BRAIN DEVELOPMENT SUPPORTS LEARNING, AND VICE VERSA

Brain development after birth does not just involve the brain getting bigger or stronger or increasing its number of connections (Gogtay et al., 2004). Instead, brain development mainly involves the generation, pruning, and reorganization of neural connections to form brain networks that reflect a person's experiences and help him or her adapt to the world in which they live (Dennis et al., 2013; Zielinski, Gennatas, Zhou, Seeley, & Raichle, 2010). After all, this makes good evolutionary and developmental sense. As a person engages with situations, problems, ideas, and social relationships, these experiences influence patterns of brain structure and function that undergird that person's changing skills and inclinations over time.

The developmental sculpting of the brain's networks through learning is akin to the process of growing a botanical garden. When given adequate opportunity, plants naturally grow through various developmentally appropriate phases, such as seed germination and cycles of budding and flowering. However, the particular characteristics of a garden reflect the age and types of the plants and a combination of geography, climate, soil quality, care, cultural context (such as preferences for rock gardens vs. wildflowers) and the gardener's own choices. The garden is also affected by how it is laid out and used (e.g., for picnicking under shade trees, growing vegetables, strolling along paths, or playing active sports). In this way, the local conditions, the gardener's skills and taste, the patterns of use, and time all shape the garden and affect its future growth and health.

Just as a garden grows differently in different climates and with different plants, styles of gardening, and use, a person's brain develops differently depending on age, predispositions, priorities, experiences, and environment. When given adequate opportunity, support, and encouragement, children naturally think, feel emotions, and engage with their social and physical worlds. These patterns of thoughts, feelings, and engagement organize brain development over time and in age-specific ways, influencing growth, intelligence, and health into the future.

## SOCIAL-EMOTIONAL INTERACTIONS ARE EPIGENETIC FORCES THAT MAKE BRAIN DEVELOPMENT POSSIBLE AND CONTRIBUTE TO INDIVIDUAL VARIABILITY

In 1990, a major multinational scientific project was launched to document the full genetic makeup of humans. The Human Genome Project resulted in a startling discovery: Humans have far *fewer* genes than had been predicted

(International Human Genome Sequencing Consortium, 2004), and fewer than many simpler organisms, including many plants. How could the most intelligent and flexible creatures on the planet have so few uniquely human genes with which to specify abilities? The answer speaks squarely to the purpose of culture, childrearing, and education: Our amazing intellectual potential appears to derive partly from the evolutionary *loss* of genetic information (Deacon, 2011). Our genes appear to underspecify our development, and that information deficit makes possible (and in fact necessary) our unparalleled proclivity for socially mediated learning (Rogoff, 2003; Tomasello, 2009). For our genes to grow a fully functioning human, we must have adequate opportunity to meaningfully interact with others and to *learn*. This learning extends across the settings a person lives in: family, community, and school.

Although the components of the genetic code could be likened to a gardener's seeds and instruction manual, the epigenetic forces—the environmental forces from "above the genome"—provide the supports and triggers that open and close various pages of the manual, and even reorder, copy, and delete pages, telling the gardener whether, when, where, and how to plant various seeds given dynamic environmental conditions and how to care for, arrange, prune, and fertilize plants at different stages, in accordance with the changing weather conditions and the desired uses and appearance of the garden.

Epigenetic forces are like the climate, the weather, and the gardener's actions. They are aspects of the person's social, emotional, cognitive, physical, and physiological contexts—the engaging and rigorous intellectual opportunities, warm and rich social relationships, and healthy physical and emotional environments in which a person lives. Together, these forces trigger and organize brain development and, therefore, a person's readiness and capacities to learn. Although healthy human environments can vary greatly in their specific characteristics and cultural features, when a person's world is seriously impoverished on any of these dimensions, brain development and the learning that depends on it are compromised (Butler, Yang, Laube, Kühn, & Immordino-Yang, 2018; Farah, 2017; Harms, Shannon Bowen, Hanson, & Pollak, 2018; Nelson, 2014; Noble et al., 2015). When a person's world is enriched on these dimensions, brain development is facilitated and learning is enabled (Diamond, Krech, & Rosenzweig, 1964; Neville et al., 2013; Schore, 2001; Watamura, Donzella, Alwin, & Gunnar, 2003).

Except in the rare case of severe, life-threatening genetic disorders, all children have the genes essential for brain development and the propensity to learn. However, genes are not sufficient to build a person, and the genome itself is dynamic, changing in response to environmental cues (Zimmer, 2018). Continual, age-appropriate, and individualized contextual support provides the epigenetic forces that turn genes on and off, copy and arrange them, so that growth, development, thinking, and learning can occur (Carey, 2012; Francis, 2011; Parrington, 2015). In other words, the motivations, sense of agency, social interactions, and emotions that form the core of SEL are likely enabling, in the most basic way, the brain development that supports learning.

Overall, though differences in individuals' intelligence are somewhat heritable in optimal learning environments (Plomin & Spinath, 2004), in suboptimal environments, measures of environmental quality and learning opportunities overwhelmingly swamp the predictive power of genes (Bates, Lewis, & Weiss, 2013). Following the garden analogy, individuals may inherit "seeds" for various kinds of plants, but it is the gardening and environmental conditions that determine which seeds will grow, thrive, and thereby reveal their potential. Important to note, across the life span, targeted school designs, interventions, and supports of the sorts broadly related to SEL have been shown to improve neural and cognitive functioning and emotional health, with long-term benefits for individuals (Diamond & Lee, 2011; Nelson, 2014; Neville et al., 2013; Oh et al., 2018; Pakulak et al., 2017; Semple, Lee, Dinelia, Ae, & Miller, 2010).

Connecting back to SEL research, the fact that development relies on environmental interactions underscores the potential for significant variability in SEL growth trajectories. Although the sequence of spurts in brain development is relatively universal, variability in how and when brain regions develop reflects interactions between individuals' propensities and their social, emotional, cultural, cognitive, and physical contexts. Considering variability and its sources is, therefore, important for SEL research. Predicting and accommodating this variability would support the design and testing of interventions that leverage or compensate for dynamic person–environment interactions to support healthy development as well as behavior in the moment.

## THE BRAIN DEVELOPMENT THAT SUPPORTS LEARNING DEPENDS ON SOCIAL EXPERIENCE

Think of a hysterical baby up past bedtime, whose distraught parent lifts and hugs her, shushes, lays the child's head where she can hear the parent's heartbeat, and sings her to sleep. In the minutes that follow, both the baby's and the parent's blood pressure lower, stress hormones normalize, and hormones involved in bonding and social affiliation increase (Gunnar, 1998). Over the course of these minutes, both the parent and the baby undergo physiological changes that influence not only immune functioning and digestion but also brain structure, especially in regions associated with learning and memory, and in the adult, with executive functioning, which supports self-regulation and goal-directed behavior (Swain et al., 2017). Exposure to these socially triggered hormones opens a window of plasticity in the parent's brain development (Feldman, 2015) and signals the infant's brain to grow (Curley & Champagne, 2016; Gerhardt, 2014; Sethna et al., 2017).

As the preceding example demonstrates, individuals coregulate one another's physiology (Helm, Sbarra, & Ferrer, 2014; Lunkenheimer et al., 2015; Saxbe & Repetti, 2010), which means that the quality of a person's relationships and social interactions shapes their development and health, both of the body and of the brain (Belsky, Houts, & Fearon, 2010; Fox, Zeanah, & Nelson, 2014; Sapolsky, 2017; Swain et al., 2017). For example, infants' prenatal brain development is impacted by maternal stress, which is in turn related to toddler behavior, and child temperament and learning (Babenko, Kovalchuk, & Metz, 2015; Kim et al., 2017; Yehuda et al., 2005).

The brains of children and adolescents who experience persistent adversity respond by strengthening circuits that promote aggressive and anxious tendencies at the expense of circuits for cognition, reasoning, and memory (Briggs-Gowan et al., 2015; McLaughlin et al., 2015; Nelson, 2014). This represents a major shift in their SEL trajectory that research and interventions should address. The hormonal signaling molecules responsible for these effects on neural development are also toxic in large amounts, making individuals more likely to develop health problems, including mental health disorders such as addiction, anxiety, and depression (Bick, Fox, Zeanah, & Nelson, 2017; Norman et al., 2012; Shonkoff et al., 2012), and physical health problems, such as heart disease, obesity, and cancer (Bucci, Marques, Oh, & Harris, 2016; Dong et al., 2004; Miller & Chen, 2013). Connections between social and physical maturation are also seen in less extreme conditions: toddlers with poor attachment to caregivers undergo puberty earlier (Belsky et al., 2010), as do preteen girls whose cohabiting parents are socially aggressive to each other (e.g., refusing to talk, threatening to leave; Saxbe & Repetti, 2009). Stress shortens the window of increased neural plasticity and growth in adolescence (Tottenham & Galván, 2016) and predicts earlier sexual maturity and worse psychosocial outcomes (Negriff, Saxbe, & Trickett, 2015), with implications for risky decisions that influence educational outcomes (Baams, Dubas, Overbeek, & Van Aken, 2015; Braams, Van Duijvenvoorde, Peper, & Crone, 2015).

As these examples illustrate, the brain functioning that supports learning is related to physical development and depends on social and emotional experience. This brain functioning in turn sets up youths' SEL trajectory and biases their situational responding. The way that individuals experience relationships in the home, community, school, and workplace influences their biological development, and hence how they live and think (Harris, 2018; Levy, Heissel, Richeson, & Adam, 2016; Royle, Russell, & Wilson, 2014). Even in adults, close relationships are associated with emotions that influence hormone coregulation, with implications for cognition, sleep quality, and health (Saxbe et al., 2015; Wang & Campos, 2017). Although the brain is malleable and changed by social relationships across the life span, the most important periods of SEL are those in which the brain is most actively changing: the prenatal period through childhood, adolescence, the transition to parenthood, and old age. These are also likely to be high-leverage periods for SEL interventions.

## THE MAJOR NETWORKS OF THE BRAIN PROVIDE A VIEW INTO THE UNDERLYING PROCESSING THAT SUPPORTS SEL CAPACITIES

Although work on the brain from two to three decades ago sought to identify specific brain regions' unique contributions to mental processing, many scientists have shifted to a focus on the networks of connectivity between regions that facilitate different activity modes important for thinking and learning (Immordino-Yang, 2016; Sporns, Chialvo, Kaiser, & Hilgetag, 2004). The basic organization of these networks appears to be present at birth and to develop across the first decades of life (Fair et al., 2009; Hoff, Van den Heuvel, Benders, Kersbergen, & De Vries, 2013; Lin et al., 2008; Liu, Flax, Guise, Sukul, & Benasich, 2008; Supekar, Musen, & Menon, 2009), but it is the way the brain is *used*, especially how a person thinks, feels, and relates to others, that strengthens and tunes these dynamic networks over time (Thomason, Hamilton, & Gotlib, 2011). The growth and balance of these networks depends in part upon a person's environment, opportunities, and relationships, which together influence the "cross talk" of neurons within the same network and the delicate balance of activity among the networks (Greicius, Supekar, Menon, & Dougherty, 2009; Sporns et al., 2004). Because people are functioning within social and cultural settings, the quality of their interactions, relationships, and associated emotional experiences in these settings will both influence and depend on the functioning of these networks, with implications for SEL-related constructs and for learning more generally.

Three major brain networks together support a broad range of mental capacities, many of which, such as emotion regulation, social perspective-taking, intrinsic motivation, and others (Immordino-Yang & Sylvan, 2010), can be considered core to SEL. Through their coregulation and coordination, each of these networks contributes to integrated social, emotional, and cognitive functioning, allowing a person to operate well in the world and to leverage SEL capacities to take advantage of learning opportunities. Extensive research in adults connects the functioning of these networks to intelligence, memory, mental flexibility and creativity, mental health, capacities for emotion regulation and attention, and other essential abilities (Buckner, Andrews-Hanna, & Schacter, 2008; Menon & Uddin, 2010; Niendam et al., 2012; van den Heuvel, Stam, Kahn, & Hulshoff Pol, 2009). In children, adolescents, and across adulthood, the functioning of these networks correlates with the quality of one's environment, resources, and relationships (Chan et al., 2018; Noble et al., 2015) and improves with targeted intervention (Anguera et al., 2013; Neville et al., 2013; Pakulak et al., 2017; Rosario Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Tang & Posner, 2014). To varying degrees, these networks appear to be malleable across the life span (Tian & Ma, 2017), suggesting that SEL interventions have the potential to change the brain, and with it future behavioral tendencies (Diamond, 2010).

## The Executive Control Network

The Executive Control Network facilitates attention, allowing people to hold information in mind, shift strategies or approaches as necessary, and focus on the completion of goal-directed tasks (Beaty, Benedek, Kaufman, & Silvia, 2015; Niendam et al., 2012; Seeley et al., 2007). The Executive Control Network is important for ignoring extraneous information and distractions, as well as for regulating emotions, maintaining goals and focus, and controlling impulses. The development of the Executive Control Network is fundamental to SEL capacities, as it is involved in all sorts of SEL skills related to regulation, self-management, and self-control (Diamond, 2013).

## The Default Mode Network

The Default Mode Network is heavily recruited during all sorts of tasks that involve internally directed, interpretive, and reflective thought, for example when remembering past experiences, imagining hypothetical or future scenarios, or deliberating on inferred, abstract, or morally relevant information (Gilbert & Wilson, 2007; Immordino-Yang, Christodoulou, & Singh, 2012; Raichle et al., 2001; Smallwood, Brown, Baird, & Schooler, 2012; Spreng & Grady, 2010), or daydreaming (Kucyi & Davis, 2014). Overall, the Default Mode Network supports aspects of SEL that involve emotional meaning-making, such as learning from past social and emotional encounters, processing social and self-relevant values and beliefs, and assessing others' emotional motivations, feelings and qualities of character (Immordino-Yang, 2016). For example, the Default Mode Network is activated when reflecting on others' character virtues, but not when appreciating others' more specific physical and cognitive skills (Yang, Pavarini, Schnall, & Immordino-Yang, 2018).

Critically, the Default Mode Network is recruited when task-oriented, goal-directed behavior and externally directed attention and perception are attenuated; it does not readily coactivate with the Executive Control Network. One cannot attend to the outer world and to inner reflections simultaneously. This has important implications for SEL programing and research, in that attention-demanding tasks like listening to the teacher's instructions are relatively neurologically incompatible with mind states reliant on default-mode functioning, like reflecting on a friend's feelings or on the deeper purpose of an activity. SEL skills involving emotionally relevant reflection, future-oriented thinking, and self-relevant meaning-making are suspended when individuals are focused on concrete tasks, or when the environment feels physically or emotionally unsafe and requires vigilance (Immordino-Yang et al., 2012).

Connecting social and emotional capacities with cognitive ones, the Default Mode Network is also important for conceptual understanding, reading comprehension, creativity, nonlinear and "out-of-the-box" thinking (Beaty et al., 2015; Immordino-Yang et al., 2012; Kühn et al., 2014), feelings of inspiration and intrinsic motivation, cognitively complex social emotions like admiration and compassion (Immordino-Yang, McColl, Damasio, & Damasio, 2009), identity development (Molnar-Szakacs & Uddin, 2013), and for "looking in" or thinking about abstract ideas or things that aren't in the physical "here and now" (Immordino-Yang et al., 2012; Tamir, Bricker, Dodell-Feder, & Mitchell, 2015).

## The Salience Network

The Salience Network weighs emotional relevance and perceived importance and urgency of information to facilitate switching between mind-sets supported by the inwardly focused, meaning-oriented Default Mode Network and those supported by the outwardly focused, task-oriented Executive Control Network (Goulden et al., 2014; Menon & Uddin, 2010; Seeley et al., 2007; Uddin, 2015). This switching of mental modes reflects subjective, affective evaluation by the Salience Network of external cues from the environment and internal bodily signals, such as from hunger and anxiety. The most central hub of the Salience Network is located in a brain structure called the insula, which is visceral somatosensory cortex and heavily recruited for "gut feelings," intuitions, cravings, and subjective emotional experience (Immordino-Yang, 2015; Immordino-Yang et al., 2009). In terms of connections to SEL, the functioning of the Salience Network underscores the pivotal role of subjective emotional interpretations and motivations for recruiting neural and associated mental states important for a wide range of mental processes central to learning. The functioning of this network is probably critical, for example, for interpretations of difficulty as reflecting either the "importance" of persisting on a task, or alternately as signaling the "impossibility" of the task, in which case giving up would be adaptive (Oyserman, 2015).

In age-appropriate ways, optimal learning environments integrate SEL into scholarly activities in ways that reflect these three major brain networks. These environments recruit sustained, flexible attention, persistence, and productivity on tasks (roughly speaking, the domain of the Executive Control Network); offer support and time for reflection, memory, and meaning-making (roughly speaking, the domain of the Default Mode Network); and leverage emotional relevance (roughly speaking, the domain of the Salience Network).

## HEALTH-RELATED PHYSIOLOGICAL FACTORS IMPACT SEL

As SEL skills rely on the functioning of brain networks, it is important for SEL researchers to be aware of the physiological conditions that support or undermine brain network functioning and thus social-emotional skills and development. Environments that support the physiological preconditions for brain development support social, emotional, cognitive, and physical health and enable learning. Among those most relevant to SEL are sleep and rest, nutrition and low exposure to toxins, and physical environments that provide green space and opportunities for aerobic exercise. Educational researchers should be aware of these factors when studying SEL capacities, developing wraparound interventions, and assessing intervention outcomes. For SEL capacities to be maximally supported requires a whole child approach that considers environmental and community-level factors (Raymond, 2018), like the availability of parks and playgrounds (Roe et al., 2013). These considerations are especially critical to issues of equity, as children from underprivileged backgrounds are disproportionately exposed to harmful physiological factors, and disproportionately live in environments that do not adequately support beneficial health-related routines and behaviors (Levy et al., 2016; Tessum et al., 2019).

For example, both physical and mental health and the ability to think well and manage emotions and moods depend on getting an adequate amount of quality sleep (Ackermann et al., 2012; Van Dongen, Maislin, Mullington, & Dinges, 2003; Walker & Stickgold, 2006). Sleep is fundamental for neural plasticity and the consolidation of memories (Potkin & Bunney, 2012; Rasch & Born, 2013), as well as for removing toxic proteins that build up in the brain over waking hours (Xie et al., 2013). When people are sleep deprived, their brain networks are not as coherently organized or regulated (De Havas, Parimal, Soon, & Chee, 2012; Yeung, Lee, Cheung, & Chan, 2018; Yoo, Gujar, Hu, Jolesz, & Walker, 2007), resulting in reciprocal declines in cognitive, as well as SEL, capacities. Over time, chronic sleep deprivation leads to impairments in mood, emotion regulation, memory, cognition, creative thinking, and social and situational awareness (Durmer & Dinges, 2005). Individuals vary in the amount of sleep they need, but sufficient sleep is required for emotional wellness, well-regulated social behavior, and optimal learning and motivation.

Adequate nutrition and absence of toxins in the environment are also necessary for healthy brain development and social-emotional functioning, especially in children. Across the life span, quality of diet is related to quality of the gut microbiome, which is related to physical and emotional health and cognitive functioning (Mohajeri, La Fata, Steinert, & Weber, 2018; Sarkar et al., 2018). Deficiencies in nutrients, such as iron (Todorich, Pasquini, Garcia, Paez, & Connor, 2009), and diets rich in refined sugars and high in saturated fats (Francis & Stevenson, 2013; Molteni, Barnard, Ying, Roberts, & Gomez-Pinilla, 2002; Wu, Ying, & Gomez-Pinilla, 2004) have been found to compromise the gut microbiome and brain development and can lead to impairments in learning, memory, emotion and mood, cognition, and motivation. Exposure to environmental toxins as a result of poor water, sanitation, and hygiene conditions (Ngure et al., 2014), air pollution (Fonken et al., 2011; Younan et al., 2018), and even low levels of lead (Bellinger, Stiles, & Needleman, 1992; Koller, Brown, Spurgeon, & Levy, 2004), have negative impacts on brain development that can be permanent. These effects are felt in the SEL domain as increases in anxiety, restlessness, and aggression (Ferguson, Cassells, MacAllister, & Evans, 2013; Younan et al., 2018). Exposure to drugs and alcohol, especially among adolescents, has negative impacts on brain development (Camchong, Lim, & Kumra, 2017; Spear, 2018) and increases risk for impaired regulation and affective and social functioning (Dahl, 2004).

Physical activity also impacts the physiological regulation underlying social and emotional well-being, cognition, and memory (Erickson et al., 2011; Hillman, Erickson, & Kramer, 2008). The efficiency and organization of neural networks is supported by fitness (Krafft et al., 2014; Voss et al., 2010). Academic achievement and behavior in children, as well as physical, mental, and psychosocial well-being across all ages, have been found to improve in the short term and the long term as a result of physical exercise (Bherer, Erickson, & Liu-Ambrose, 2013; Bunketorp Käll, Malmgren, Olsson, Lindén, & Nilsson, 2015; Koutsandréou, Wegner, Niemann, & Budde, 2016; Lees & Hopkins, 2013; Voss, Nagamatsu, Liu-Ambrose, & Kramer, 2011). Although brain development and learning occur with a sedentary lifestyle, abundant research suggests that physical activity is highly beneficial and that its beneficial social-emotional and cognitive effects are strengthened with the availability of green (natural) space (Bowler, Buyung-Ali, Knight, & Pullin, 2010; Hyvönen et al., 2018). Exercise, especially in green space, improves mood and decreases anxiety and stress (Thompson Coon et al., 2011)—all of which have direct implications for SEL, for example, by making it easier to regulate negative emotion.

## SEL RESEARCH CAN BE INFORMED BY EVIDENCE FOR SENSITIVE PERIODS IN SOCIAL-EMOTIONAL BRAIN DEVELOPMENT

The development of the brain and the development of thinking run in parallel; each enables the other. Examining brain development at different stages provides insights into developmentally appropriate learning at each stage and the necessary supportive conditions. This information could be especially pertinent as SEL researchers begin focusing increasingly on developmental questions (Jones et al., 2018), because sensitive periods align with opportunities for learning. Sensitive periods could also be relevant for designing developmentally appropriate strategies for integrating SEL supports into early childhood to postsecondary education and assessments. In what follows, we highlight sensitive periods in social brain development and situate them in a broader developmental trajectory.

One major domain in which sensitive periods emerge concerns emotional well-being, most notably in the context of social relationships and individuals' associated sense of safety and belonging. In part via the release of hormones that signal the brain and trigger epigenetic effects, emotional well-being promotes health, brain development, and optimal learning, whereas chronic and excessive stress and loneliness are toxic to brain development (Cacioppo & Patrick, 2008; Lupien, McEwen, Gunnar, & Heim, 2009; Shonkoff, 2011; Zilkha & Kimchi, 2018). Stress from threats to emotional safety and feelings of belonging, such as stereotype threat, influences a person's underlying physiology and neural functioning, robbing a person of working memory resources (Beilock, Rydell, & McConnell, 2007). Such identity-related stress impacts cognitive performance in the short term (Steele, 2011), and in the longer term has been linked to premature aging of the brain and body (G. H. Brody, Yu, Chen, Beach, & Miller, 2016; Miller, Yu, Chen, & Brody, 2015). The negative effects of stress can be buffered through supportive parenting, relationships, community and school programs (Asok, Bernard, Roth, Rosen, & Dozier, 2013; G. H. Brody et al., 2016; Flannery, Beauchamp, & Fisher, 2017; Khoury, Sharma, Rush, & Fournier, 2015). Exposure to green spaces has also been found to reduce biomarkers of stress and to increase health and well-being (Roe et al., 2013; Thompson et al., 2012; Twohig-Bennett & Jones, 2018). Individuals who have experienced trauma, or toxic stress from abuse or neglect, often require extensive supports and targeted interventions strategically integrated throughout their schooling experience (Harris, 2018).

An extension of emotional well-being, cultural well-being pertains to the broader roles, group affiliations, and identities that situate a person within a group and provide a sense of shared history, values, lifestyle, and purpose (Gutiérrez & Rogoff, 2003). However, when individuals from privileged groups stereotype, marginalize, or oppress members of stigmatized groups, this imposes a lifelong emotional burden on those socially identified with the underprivileged group that impacts cognition as well as physiology (Levy et al., 2016; Steele, 2011; Yip, 2018). The experience of discrimination—which can pose physical harm; unfair treatment; economic deprivation; stereotype threat; and lack of access to housing, green space, quality food, health care, and other basic needs—is a major source of stress undermining cognition and social-emotional well-being, with implications for health, brain development, and learning (Shonkoff et al., 2012). Furthermore, if one's cultural beliefs and values feel at odds with those of the dominant cultural group, the conflict can cause misalignment between a person's goals and ways of being and the expectations of the setting (Nasir, 2011). This perceived invalidation or subordination undermines emotional and social well-being and belonging. Interventions and supports in the home, school, or community that specifically target cultural well-being improve educational, socioeconomic, and health outcomes—in large part because they support SEL (Gutiérrez, 2008; Kirmayer, Groleau, Guzder, Blake, & Jarvis, 2003; Patton, 2010; Raymond, 2018).

### Infancy

Newborns' brains are highly immature and malleable. They require extensive human interaction to develop. Infants come into the world with a set of neural reflexes that serve as primitive entry points for regulating themselves in their environment (such as breathing, eating, and maintaining a steady body temperature) and for interacting with physical objects and other people (e.g., through looking and eye contact, listening, grasping, mirroring, vocalizing, and cuddling; Brazelton, Koslowski, & Main, 1974; Johnson, Slaughter, & Carey, 1998). In engaging with their caregivers, infants notice patterns of actions, language use, and emotional expression (Snow, 1977) that tune their brain development to the features of their specific environment (Kuhl, 2010). Given their stage of brain development, infants thrive with stable routines, including living routines like feeding, bathing, and sleeping, and cultural routines like simple songs and interactive games (Gopnik, Meltzoff, & Kuhl, 2000). Infants need stable relationships with emotionally healthy, attentive caregivers (Tronick, 1989); adequate nutrition and physical care; and plentiful exposure to language (Romeo et al., 2018; Shonkoff et al., 2012).

Given the social-emotional needs of infants, healthy early-care environments feature small ratios of children to adults so that interpersonal interactions are maximized (Bornstein, Hahn, Gist, & Haynes, 2007). These interactions offer physical comfort and affectionate holding and hugging to support attachment and a sense of safety, as well as regular communication and responsive, back-and-forth interactions to support infants' development of regulated turn-taking, and language and sense-making in the relationships and settings they encounter. In addition to warm, sensitive relationships, these settings also offer regular feeding and good nutrition, sleep, and physical activities, such as sitting, rolling, crawling, and walking with adult oversight (NICHD Early Child Care Research Network, 2002; Peisner-Feinberg et al., 2001; Shonkoff et al., 2012). These activities allow babies to develop secure attachments, a sense of safety, and a capacity to explore, all of which promote their later ability to notice others' feelings and behaviors and to care for others, as well as to develop confidence in using their own resources for learning (Gopnik et al., 2000).

## Early Childhood

In late infancy and early childhood, the brain regions that control sensory, motor, language, spatial, and visual functions are maturing (B. A. Brody, Kinney, Kloman, & Gilles, 1987; Deoni, Dean, Remer, Dirks, & O'Muircheartaigh, 2015). This brain development coincides with children learning to coordinate their reflexes to form goal-directed actions, such as toddlers coordinating their gesturing and vocalizing to communicate with caregivers, or coordinating their posture, movement, and attention to learn to run, ride a wheeled toy, or read a book with an older person. Showing emotions is a key form of communication at this age (Gopnik et al., 2000; Tronick, 1989). To attain physical milestones, like walking and toileting, and social milestones, like talking and sharing joint attention, young children need predictably calm interactions with responsive and loving caregivers (Shonkoff, 2011), and emotionally and physically safe opportunities to explore and to share what they notice.

Young children are interested in learning with others about the world—real and imaginary. Young children's social learning is unparalleled in the animal kingdom and is tied to uniquely human forms of intelligence (Tomasello, 2009). With conversations and other interactions, imitation, exploration, and self-paced practice, children build simple understandings of sights, sounds, and object properties, as well as of social rituals, language, emotions, and stories (Grazzani, Ornaghi, Conte, Pepe, & Caprin, 2018; Suprawati, Anggoro, & Bukatko, 2014). Through active play and participation in daily activities, they notice patterns of cause and effect, gain agency and a sense of self, and begin to figure out how the world works (Shtulman & Carey, 2007). They learn to act alone and with others' help to satisfy their curiosities and achieve their goals (Onishi & Baillargeon, 2005; Spelke, Breinlinger, Macomber, & Jacobson, 1992). Critical to attaining these important goals are the social-emotional skills involved in making friends and figuring out how to engage with others: how to empathize, share, play cooperatively, wait patiently, and take turns; as well as to solve conflicts or problems and manage anger or frustration. Each of these skills contributes developmentally to core aspects of SEL important for schooling, such as motivation, self-determination, self-regulation, and self-awareness.

Much of this skill development happens through play (Golinkoff & Hirsh-Pasek, 2016; Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009), during which a wide range of behaviors can be modeled and practiced, including those that compose SEL. Productive early childhood education settings offer rich environments with materials to manipulate—for example, a sand table, water table, blocks, playhouse area, art supplies, musical toys—and regular opportunities to investigate, move, and play with these materials. Adults in these settings encourage children to play and work together (e.g., learning group games or setting up and cleaning up snack time), as well as to pursue their individual interests (Bodrova & Leong, 2007; Lillard, 2005).

Regular routines—such as circle time, snack time, storybook time, inside and outside play time—provide a balance of activities and learning opportunities that allow for both novelty and predictability so that children can learn to engage with others, take turns, and discuss how to handle different situations—all critical precursors to later childhood social-emotional skills. Songs, stories, and conversations in these settings model and support the development of language; music, dance, and games develop movement and a sense of timing and sequence; drawing, painting, playing, counting, and building with manipulatives develop small-motor and hand–eye coordination and cognition (Carpenter et al., 2017;

Peisner-Feinberg et al., 2001). All of these activities, in the context of affirmative and supportive interactions, build the brain's network architecture in important ways and help students become ready for more symbolic learning that they can link to these concrete experiences (Hirsh-Pasek et al., 2009; Wechsler, Melnick, Maier, & Bishop, 2016).

## Middle-Late Childhood

The physical, cognitive, and social achievements of early childhood form the foundation for concepts and skills that emerge when children begin to more formally represent their knowledge of the physical, cognitive, social, and emotional world and self. As children become able to think *about* what they and others are coming to understand, know, feel, and do, the association and planning areas of the brain involved in the integration of information gathered from different senses and sources are maturing. Children's learning involves gradually internalizing and reproducing the cognitive and social-emotional patterns, procedures, and beliefs they are exposed to at school, at home, and in the community. This exposure happens through social relationships, emotional experiences, and stories; opportunities for mathematical, spatial, and scientific reasoning; and opportunities to formalize ideas through spoken and written language and the arts.

At this developmental stage, SEL capacities and scholarly capacities are becoming increasingly integrated (Immordino-Yang, 2015). Structured opportunities to teach and learn from others; to explore, discover, and invent; and to test out the predictive power of their reasoning and calculations help children construct a sense of scholarly and personal agency and emotional well-being. Developing capacities for managing goals, strategies, peer relationships, and feelings are supported by formal social activities like participating in sports teams and music ensembles, and by informal opportunities for self-direction alone and in social settings, such as recess, free time, and helping out with household chores (Barker & Munakata, 2015; Diamond, 2014; Paradise & Rogoff, 2009; Rogoff, 2003).

Supportive learning environments in middle childhood offer opportunities to engage in inquiries and projects that allow children to set goals, seek answers, evaluate evidence, and draw conclusions; continue to engage in concrete experiences of the world on which they can begin to build more abstract thinking; and communicate ideas in multiple artistic, linguistic, and mathematical formats (Anderson, 2002). These environments also support productive collaboration with other children in undertaking these and other efforts, and teach social and emotional skills such as awareness of feelings and productive ways of articulating and managing feelings, while developing empathy and positive interpersonal relationships (Brackett, 2019; Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2019).

## Early-Middle Adolescence

Adolescence is a dramatic period of brain development. It is a fundamental period of environmentally (or epigenetically) triggered social, emotional, and cognitive growth and plasticity (Crone & Dahl, 2012; Foulkes & Blakemore, 2018; Mychasiuk & Metz, 2016; Silvers et al., 2012), as well as of vulnerability to mental illnesses such as depression and anxiety (Lichenstein, Verstynen, & Forbes, 2016). In the brain, maturation of the amygdala and reward-related structures leads to heightened sensitivity to social cues, such as eye gaze and presence of peers, as well as to social hierarchy, reputation, and physical appearance (Albert, Chein, & Steinberg, 2013). The frontal lobes, involved in planning, decision-making, executive functioning, and higher order thinking, begin a protracted period of intense development (lasting into the early 20s) that increases the strength of connections to the amygdala and other subcortical neural regions involved in emotional reactivity, social sensitivity, and reward. This brain development is associated with risk-taking and emotion swings (Albert et al., 2013; Blakemore, 2018) but also enables new and initially fragile capacities for emotional regulation, long-term planning, and abstract thinking (Dahl, 2004).

Puberty-related hormonal changes launch a period of neural plasticity that also makes the brain more vulnerable to the effects of stress and social rejection, particularly under conditions of sleep deprivation (Meyer, Lee, & Gee, 2018). These pubertal hormone surges influence brain and bodily maturation, friendships, and romantic attraction (Suleiman, Galván, Harden, & Dahl, 2017) and shift sleep patterns to later and longer (Carskadon, 2002). Each of these changes impacts SEL directly or indirectly.

Adolescents' optimal development is enabled by deeply exploring and expanding personal interests and technical skills through high-quality coursework, arts, sports, and other activities (Mehta, 2019). Effective activities are designed to help adolescents build constructive, prosocial connections through community involvement, perspective-taking, and meaning-making. Adolescents' efficacy, agency, and sense of purpose thrive with safe, supported opportunities to explore possible social identities, tastes, interests, beliefs, and values and to invest in tight relationships with family, peers, and trustworthy adults like teachers, mentors, spiritual leaders, and coaches. Adequate physical activity, social connection, nutrition, and sleep are particularly important in adolescence, as these buffer the effects of stress on the brain and improve well-being, emotion regulation, cognition, and decision-making (Blakemore, 2018).

Supportive educational settings for adolescents ensure that they continue to have strong relationships with adults who know them well, often through school advisory systems or teaching teams that can personalize instruction and supports for students in and out of school (Eccles & Roeser, 2009; Osher & Kendziora, 2010). Such settings engage students in investigations that allow them to develop critical thinking and problem-solving skills, to debate ideas and reflect on what they are learning, to attempt ambitious projects that interest them, and to receive feedback they can act on to improve their work. These opportunities help them develop a sense of agency, curiosity, habits for reflecting on their own thinking, and a growth mind-set and self-regulation to support their ongoing learning (Darling-Hammond et al., 2019; Farrington et al., 2012).

## Late Adolescence–Early Adulthood

While an individuals is in early adolescence, the number of neural connections increases, and the brain prunes the connections that are not being used during late adolescence (Giedd et al., 1999), increasing the brain's efficiency. Which connections remain is determined by a person's thought patterns and engagement with their environment, including by education-related opportunities and social relationships. Increases in neural "cross-talk" between regions further apart in the brain, especially those involved in higher level cognition and cultural values, emotions, and beliefs (Immordino-Yang & Yang, 2017), occur as short-distance connectivity decreases (Kundu et al., 2018). Tighter communication across, as opposed to within, brain regions during this developmental period (Fair et al., 2009) supports late adolescents' blossoming abilities to reason, infer, and reflect, through making connections and meaning of their skills, knowledge, and experiences (Fischer & Bidell, 2006). Opportunities to engage deeply with scholarly ideas, to apply their emerging skills to real-world problems, and to build strong and appropriate peer and adult relationships are crucial for identity development and for making decisions about committed relationships, lifestyle, and careers (Zarrett & Eccles, 2006).

Productive educational settings in late adolescence and early adulthood continue to provide opportunities for young people to be well known by adults with whom they have strong relationships—advisors, mentors, and teachers—and to examine ideas from many perspectives, using symbolic thinking, logic, and metaphor, as well as other tools to deeply explore meaning. Students should have opportunities to investigate and apply their learning in real-world contexts through projects, internships, externships, and exhibitions, with constructive feedback that allows them to develop ever more disciplined thinking and to tackle ever more advanced problems (Mehta, 2019). They should also have many opportunities to follow their interests and passions in choosing topics and approaches, reflecting on their own strategies so they can guide their own learning over time. They also should be able to engage in personally enjoyable forms of physical activity that they can undertake on their own as well as in groups, and continue throughout life, beyond the education environment (Zarrett & Eccles, 2006).

## Middle-Later Adulthood

Although the brain is considered to have reached maturity by middle adulthood, the adult brain undergoes age-related changes that reflect environmental, social, and educational factors (Chan et al., 2018; Tian & Ma, 2017). New neurons continue to form in the brain during adulthood in response to new experiences (Eriksson et al., 1998; Lledo, Alonso, & Grubb, 2006; Zhao, Deng, & Gage, 2008), but this growth can be inhibited by stress (Mirescu & Gould, 2006; Mirescu, Peters, & Gould, 2004), chronic sleep disruption (Lucassen et al., 2010; Meerlo, Mistlberger, Jacobs, Heller, & McGinty, 2009), or dietary deficiencies (Poulose, Miller, Scott, & Shukitt-Hale, 2017; Stangl & Thuret, 2009). Physical and mental activity, as well as social relationships, support adults' brain functioning and help buffer against potential age-related cognitive declines (Charles & Carstensen, 2009; Kramer & Erickson, 2007). Consistent with the biological evidence that relationships impact brain development and learning, increasing evidence points to the importance of teachers' mental health and social-emotional skills for students' success (Jennings & Greenberg, 2009; Meiklejohn et al., 2012).

Productive educational opportunities for adults build on what we know about adult learning: They connect to learners' goals and provide them with new experiences that encompass problem-solving in real-life contexts. Adults typically move through four stages in the experiential learning cycle: engaging in concrete experience; observing and reflecting, often in discussion with peers; forming insights and generalizations; and testing implications of new concepts in new situations (Kolb, 1984). In line with these insights, effective professional development for teachers—that is, learning that changes teaching practices and student learning—engages teachers in active learning related to the content and students they teach; supports collaboration with colleagues, typically in job-embedded contexts; uses models and modeling of effective practice; provides coaching and expert support; and offers opportunities for feedback and reflection (Darling-Hammond, Hyler, & Gardner, 2017).

Evidence also shows that teachers' own social-emotional skills, sleep quality, and wellness can be enhanced by training in mindfulness—which develops a calm attentiveness and awareness of experiences, often through regulation of breathing, physical stance, and stress, as well as through visualization. Studies find that such training reduces teachers' stress and emotional distress; helps them regulate emotions; and develops greater social-emotional competence, sense of self-efficacy and well-being, and emotional support for students (Benn, Akiva, Arel, & Roeser, 2012; Crain, Schonert-Reichl, & Roeser, 2017; Jennings, Frank, Snowberg, Coccia, & Greenberg, 2013; Roeser et al., 2013).

## CARVING NATURE AT ITS JOINTS: RESEARCHING DEVELOPMENTAL PROCESSES AND CONTEXTUAL AFFORDANCES IN BOTH EDUCATION AND NEUROSCIENCE

A review of the biopsychosocial context for learning makes clear the need for integrated research perspectives that consider developmental processes in relation to contextual affordances to move the field forward. In the real worlds of families, schools, and communities, social, emotional, and cognitive capacities are fully psychologically and neurobiologically intertwined. There are no brain networks, for example, that process only social, emotional, or cognitive information. In fact, all brain networks appear to contribute to social, emotional, and cognitive processing, depending on how they are engaged. And all brain networks show the effects of past social, emotional, and cognitive experience on their functioning. Accordingly, answers to the currently most pressing SEL-related questions—questions about development and sensitive/high leverage periods, about connections to academic learning and emotions, about variability, about equity, and about assessment and accountability—will not map well onto our existing theoretical trifecta without extensive qualifications and circular definitions. Instead, answering these questions will rely on understanding the dynamic *interdependence* of multiple systems and capacities *in context*. For researchers in both education and neuroscience to make headway, we need to design innovative research and pedagogical approaches capable of capturing and capitalizing on these dynamics.

In effect, although "social, emotional, and cognitive" processes lend themselves nicely to scientific analysis, in living people they are not different or dissociable things but qualitatively different dimensions of one thing: the situated, embodied, and embrained human mind (Immordino-Yang, 2015). Effective learning environments leverage multiple dimensions of the mind in service of strengthening a person's enactable skills and inclinations (see Immordino-Yang, Darling-Hammond, & Krone, 2018, for extended discussion). They do this by skillfully attending to people's thinking and meaning-making dynamically in context while taking into account their developmental stage and the adaptations, dispositions, skills, and knowledge individuals bring based on their lived experiences (Darling-Hammond et al., 2008).

Real students and teachers engage social, emotional, and cognitive processes *all at once* (Fischer & Bidell, 2006), based on their subjective interpretation of the situation and goals (Oyserman, 2015). To learn math, for example, involves processing quantities, spatial information, and logical relationships, and this processing is neuropsychologically activated and steered by emotions, attention, and motivations (Immordino-Yang & Damasio, 2007); feelings of competence, safety, and belonging (Nasir, 2011); and the quality of memories formed in previous encounters, as well as what the person sees value in accomplishing (Wentzel & Miele, 2016). There is no such thing as math cognition devoid of an emotional impetus or agnostic to its sociocultural context. In math, just as in any other kind of learning, social, emotional, and cognitive processing are each importantly contributing and become integral dimensions of one's abilities and inclinations. Even when a person is working alone, removing any of these contributions from the explanation gives an incomplete view, as individuals think in accordance with cultural orientations, beliefs, and values that have been cumulatively shaped by their lifetime of socially framed experiences (Bruner, 1990; Vygotsky, 1978). The pressing questions just listed are difficult and important exactly because they cannot be encapsulated within one of the three domains of capacities. They deal with understanding the range of ways that whole people in the real world think and feel, and the ways in which developmental opportunities can position them to benefit from resources, realize their potential, and contribute to society. Answering each will therefore require understanding the critical features of the situation in relation to the teachers' and learners' developmental histories; physiological factors and personal inclinations; and how these interact with the relevant cultural, physical, and educational affordances and aims.

Examining recent advances in education highlights promising progress toward an integrated, dynamic approach. For example, Carpenter, Franke, Johnson, Turrou, and Wager (2017) explained how effective math teaching involves strategically engaging with students around their mathematical thinking, a process that inherently engages social relationships, agency, and past experiences to build meaning and identity together with mathematical competence. Many others have argued for culturally relevant pedagogy that attends to students' personal experiences of scholarship (e.g., Gutiérrez, 2008; Hantzopoulos, 2016; Love, 2019; Nasir, 2011), and new attention is being paid to the design of engaging learning environments (e.g., Schneider, Krajcik, Lavonen, &

Salmela-Aro, expected 2020). The arguments presented in this article and elsewhere (e.g., Immordino-Yang, 2016) may give additional insight into the neurobiological mechanisms and processes undergirding the success of these approaches, and with such insight could come further understanding and innovation. We hope this interdisciplinary work will help educational researchers explicitly consider how their questions, methods, and interventions constrain, capture, and support developmental processes and affordances. In parallel, to produce work that is most useful to educators, we hope neuroscientists might consider expanding and documenting the individual variability, cultural histories, and lived experiences of their research participants to the extent possible to construct more ecologically valid tasks, data sets, and interpretations of findings (Immordino-Yang, 2013; Immordino-Yang & Yang, 2017).

Our argument here in no way negates the usefulness of existing research that focuses separately on social, emotional, and cognitive capacities, either from education or from neuroscience. Instead, we echo others' arguments that the devil for application to pedagogy across diverse settings is in appreciating the contextual and individual dynamics. Satisfying and impactful answers to our messiest real-world educational problems, answers that will help learners, educators, and policy-makers know what to do, may become more readily apparent if we carve the problem space not into sets of social, emotional, and cognitive capacities that can be advanced or deficient but into patterns of thought, behavior, and meaning-making (Ritchhart, Church, & Morrison, 2011) that honor the person's subjective experience in context (Darling-Hammond et al, 2008). Education is meant to enable the mind by guiding, expanding, constraining, and refining the developmental process. Views into the situated dynamics of the developmental process ought, then, to prove useful as units of analysis.

In sum, current educational psychology research generally carves the problem of how people learn into social, emotional, and cognitive capacities, examined as average effects described relatively independently of developmental and biological contexts. This approach launched a highly productive period of research, mainly because it called attention to the previously neglected social and emotional dimensions of learning. But it is now becoming apparent that we cannot adequately describe or predict individuals' capacities in any of these three domains without taking great pains to qualify the domains' interdependencies and the context. A new frame might better and more parsimoniously organize and synthesize what we know, furthering progress on the goal of designing contextually relevant future research that improves the quality of educational outcomes by focusing on individuals' experiences.

## TOWARD A DEVELOPMENTAL, BIOPSYCHOSOCIAL CONTEXT FOR SEL RESEARCH

A review of humans' nurturing nature makes clear the fundamental responsibility of educational research and institutions to attend to the development of the whole child (Osher et al., 2016), as well as the need to study children's SEL capacities in broader developmental and biopsychosocial context. Because SEL relies on the same brain networks involved in other aspects of mental and physical functioning, it is situated within a broader set of developing, interdependent, situation-contingent capacities. These capacities reflect, and reciprocally shape, a person's lived experience, with consequences for how people think, make decisions, and learn. Although brain science rarely translates directly into educational policy, practice, or research programs (Immordino-Yang & Gotlieb, 2017), we hope that the arguments presented here provide researchers with background knowledge that may help with the interpretation of the existing SEL evidence base, as well as lead to future theoretical models, hypotheses, and testable interventions. In particular, a neuroscientific perspective on SEL could lead to a deeper appreciation of how brain development varies across individuals and accommodates environmental demands and could provide education researchers with insights into the types of supports and interventions that might prove most helpful for different children at different times (Haft, Myers, & Hoeft, 2016; Hahn, Nierenberg, & Whitfield-Gabrieli, 2017; Raizada & Kishiyama, 2010). Given the importance of epigenetic effects of relationships both in and out of school, it also points to the need to support and study community-embedded, multigenerational resources.

Unsurprising, when children (and the adults that care for and teach them) are socially and physically well and self-regulated, they think better. Attending to SEL capacities and the contexts that support them, therefore, supports social-emotional and physical wellness, as well as scholarly achievement and cognition. Educating the whole child, and engaging families and communities in this process, is not just a luxury for those with the opportunity and the means, or a remediation strategy for the underprivileged or underperforming. An appreciation of the biopsychosocial and developmental contexts for SEL makes clear that attending to social-emotional experience in educational settings is a societal responsibility and a necessity for all children.

Based on a new evidence-based appreciation of the fundamentally social-emotional nature of human brain development—after all, it is largely socially transmitted, emotionally salient epigenetic triggers that teach the brain how to grow and think—we argue for the need to attend more systematically to the person-centered dynamics of learning in both education and neuroscience research and to focus explicitly on deciphering the influences of the layered contexts in which a person learns. This is aligned with SEL researchers' work redefining "learning" to transcend pure cognition. Even SEL, it is now clear, is situated in the broader context of multiple, interdependent dynamic systems, some of which may transcend currently available constructs.

Genuinely engaging an integrated whole-child approach to education will require substantial innovation in policies and practices infused across the processes and institutional structures of education and teacher training. SEL research and intervention, especially when strategically integrated into academic learning opportunities and embedded in community contexts, will be key to this endeavor. Doing this well will be difficult, but children's brain development, and the learning that depends on it, are at stake.

## ACKNOWLEDGMENTS

We thank D. Oyserman, D. Daniel, and A. Blodgett for discussions.

## FUNDING

MHIY was supported by a mid-career fellowship from the Spencer Foundation; LDH was supported by The Chan Zuckerberg Initiative and the California Endowment; CK was supported by the Templeton Foundation grant [010464-00001] to MHIY.

## ORCID

Mary Helen Immordino-Yang http://orcid.org/0000-0002-2875-4977
Christina R. Krone http://orcid.org/0000-0003-2497-1269

## REFERENCES

Ackermann, K., Revell, V. L., Lao, O., Rombouts, E. J., Skene, D. J., & Kayser, M. (2012). Diurnal rhythms in blood cell populations and the effect of acute sleep deprivation in healthy young men. *Sleep*, *35*(7), 933–940. doi:10.5665/sleep.1954

Albert, D., Chein, J., & Steinberg, L. (2013). The teenage brain: Peer influences on adolescent decision making. *Current Directions in Psychological Science*, *22*(2), 114–120. doi:10.1177/0963721412471347

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence*, *8*(2), 71–82. doi:10.1076/chin.8.2.71.8724

Anguera, J. A., Boccanfuso, J., Rintoul, J. L., Al-Hashimi, O., Faraji, F., Janowich, J., … Gazzaley, A. (2013). Video game training enhances cognitive control in older adults. *Nature*, *501*(7465), 97–101. doi:10.1038/nature12486

Asok, A., Bernard, K., Roth, T. L., Rosen, J., & Dozier, M. (2013). Parental responsiveness moderates the association between early-life stress and reduced telomere length. *Development and Psychopathology*, *25*(3), 577–585. doi:10.1017/S0954579413000011

Baams, L., Dubas, J. S., Overbeek, G. B., & Van Aken, M. A. G. (2015). Transitions in body and behavior: A meta-analytic study on the relationship between pubertal development and adolescent sexual behavior. *Journal of Adolescent Health*, *56*(6), 586–598. doi:10.1016/j.jadohealth.2014.11.019

Babenko, O., Kovalchuk, I., & Metz, G. A. S. (2015). Stress-induced perinatal and transgenerational epigenetic programming of brain development and mental health. *Neuroscience and Biobehavioral Reviews*, *48*, 70–91. doi:10.1016/j.neubiorev.2014.11.013

Barker, J. E., & Munakata, Y. (2015). Developing self-directed executive functioning: Recent findings and future directions. *Mind, Brain, and Education*, *9*(2), 92–99. doi:10.1111/mbe.12071

Bates, T. C., Lewis, G. J., & Weiss, A. (2013). Childhood socioeconomic status amplifies genetic effects on adult intelligence. *Psychological Science*, *24*(10), 2111–2116. doi:10.1177/0956797613488394

Beaty, R. E., Benedek, M., Kaufman, S. B., & Silvia, P. J. (2015). Default and executive network coupling supports creative idea production. *Scientific Reports*, *5*(1), 10964. doi:10.1038/srep10964

Beilock, S. L., Rydell, R. J., & McConnell, A. R. (2007). Stereotype threat and working memory: Mechanisms, alleviation, and spillover. *Journal of Experimental Psychology: General*, *136*(2), 256–276. doi:10.1037/0096-3445.136.2.256

Bellinger, D. C., Stiles, K. M., & Needleman, H. L. (1992). Low-level lead exposure, intelligence and academic achievement: A long-term follow-up study. *Pediatrics*, *90*(6), 855–861.

Belsky, J., Houts, R. M., & Fearon, R. M. P. (2010). Infant attachment security and the timing of puberty: Testing an evolutionary hypothesis. *Psychological Science*, *21*(9), 1195–1201. doi:10.1177/0956797610379867

Benn, R., Akiva, T., Arel, S., & Roeser, R. W. (2012). Mindfulness training effects for parents and educators of children with special needs. *Developmental Psychology*, *48*(5), 1476–1487. doi:10.1037/a0027537

Bherer, L., Erickson, K. I., & Liu-Ambrose, T. (2013). A review of the effects of physical activity and exercise on cognitive and brain functions in older adults. *Journal of Aging Research*, *2013*, 657508. [doi] doi:10.1155/2013/657508

Bick, J., Fox, N., Zeanah, C., & Nelson, C. A. (2017). Early deprivation, atypical brain development, and internalizing symptoms in late childhood. *Neuroscience*, *342*, 140–153. doi:10.1016/j.neuroscience.2015.09.026

Blakemore, S.-J. (2018). *Inventing ourselves: The secret life of the teenage brain*. New York, NY: PublicAffairs.

Bodrova, E., & Leong, D. J. (2007). *Tools of the mind: The Vygotskian approach to early childhood education* (2nd ed.). New York, NY: Pearson.

Bornstein, M. H., Hahn, C.-S., Gist, N. F., & Haynes, O. M. (2007). Long-term cumulative effects of childcare on children's mental development and socioemotional adjustment in a non-risk sample: The moderating effects of gender. *Early Child Development and Care*, *176*(2), 129–156. doi:10.1080/0300443042000266286

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., & Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health*, *10*(1), 1–10. doi:10.1186/1471-2458-10-456

Braams, B. R., Van Duijvenvoorde, A. C. K., Peper, J. S., & Crone, E. A. (2015). Longitudinal changes in adolescent risk-taking: A comprehensive study of neural responses to rewards, pubertal development, and risk-taking behavior. *Journal of Neuroscience*, *35*(18), 7226–7238. doi:10.1523/JNEUROSCI.4764-14.2015

Brackett, M. (2019). *Permission to feel: Unlocking the power of emotions to help our kids, ourselves, and our society thrive*. New York, NY: Celadon Books.

Brazelton, T. B., Koslowski, B., & Main, M. (1974). The origins of reciprocity: The early mother-infant interaction. In M. Lewis & L. A. Rosenblum (Eds.), *The effect of the infant on its caregiver*. Oxford, UK: Wiley-Interscience. Retrieved from https://psycnet.apa.org/record/1974-22730-007

Briggs-Gowan, M. J., Pollak, S. D., Grasso, D., Voss, J., Mian, N. D., Zobel, E., … Pine, D. S. (2015). Attention bias and anxiety in young children exposed to family violence. *Journal of Child Psychology and Psychiatry*, *56*(11), 1194–1201. doi:10.1111/jcpp.12397

Brody, B. A., Kinney, H. C., Kloman, A. S., & Gilles, F. H. (1987). Sequence of central nervous system myelination in human infancy. I. An autopsy study of myelination. *Journal of Neuropathology & Experimental Neurology*, *46*(3), 283–301. doi:10.1097/00005072-198705000-00005

Brody, G. H., Yu, T., Chen, E., Beach, S. R. H., & Miller, G. E. (2016). Family-centered prevention ameliorates the longitudinal association between risky family processes and epigenetic aging. *Journal of Child Psychology and Psychiatry*, *57*(5), 566–574. doi:10.1111/jcpp.12495

Bruner, J. (1990). *Acts of meaning: Four lectures on mind and culture.* Cambridge, MA. Harvard University Press.

Bucci, M., Marques, S. S., Oh, D., & Harris, N. B. (2016). Toxic stress in children and adolescents. *Advances in Pediatrics*, *63*(1), 403–428. doi:10.1016/j.yapd.2016.04.002

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: Anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences*, *1124*(1), 1–38. doi:10.1196/annals.1440.011

Bunketorp Käll, L., Malmgren, H., Olsson, E., Lindén, T., & Nilsson, M. (2015). Effects of a curricular physical activity intervention on children's school performance, wellness, and brain development. *Journal of School Health*, *85*(10), 704–713. doi:10.1111/josh.12303

Butler, O., Yang, X.-F., Laube, C., Kühn, S., & Immordino-Yang, M. H. (2018). Community violence exposure correlates with smaller gray matter volume and lower IQ in urban adolescents. *Human Brain Mapping*, *39*(5), 2088–2097. doi:10.1002/hbm.23988

Cacioppo, J. T., & Patrick, W. (2008). *Loneliness: Human nature and the need for social connection* (1st ed.). New York, NY. W.W. Norton & Co.

Camchong, J., Lim, K. O., & Kumra, S. (2017). Adverse effects of cannabis on adolescent brain development: A longitudinal study. *Cerebral Cortex*, *27*(3), 1922–1930. doi:10.1093/cercor/bhw015

Carey, N. (2012). *The epigenetics revolution: How modern biology is rewriting our understanding of genetics, disease and inheritance.* New York, NY: Columbia University Press.

Carpenter, T. P., Franke, M. L., Johnson, N. C., Turrou, A. C., & Wager, A. A. (2017). *Young children's mathematics: Cognitively guided instruction in early childhood education.* Portsmouth, UK: Heinemann.

Carskadon, M. A. (2002). *Adolescent sleep patterns: Biological, social, and psychological influences.* Cambridge, UK: Cambridge University Press.

Chan, M. Y., Na, J., Agres, P. F., Savalia, N. K., Park, D. C., & Wig, G. S. (2018). Socioeconomic status moderates age-related differences in the brain's functional network organization and anatomy across the adult lifespan. *Proceedings of the National Academy of Sciences*, *115*(22), E5144–E5153. doi:10.1073/pnas.1714021115

Charles, S. T., & Carstensen, L. L. (2009). Social and emotional aging. *Annual Review of Psychology*, *61*(1), 383–409. doi:10.1146/annurev.psych.093008.100448

Collaborative for Academic, Social, and Emotional Learning. (2015). *The 2015 CASEL guide: Effective social and emotional learning programs—Middle and high school edition*. Chicago, IL: Author.

Crain, T. L., Schonert-Reichl, K. A., & Roeser, R. W. (2017). Cultivating teacher mindfulness: Effects of a randomized controlled trial on work, home, and sleep outcomes. *Journal of Occupational Health Psychology*, *22*(2), 138–152. doi:10.1037/ocp0000043

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. doi:10.1038/nrn3313

Curley, J. P., & Champagne, F. A. (2016). Influence of maternal care on the developing brain: Mechanisms, temporal dynamics and sensitive periods. *Frontiers in Neuroendocrinology*, *40*, 52–66. doi:10.1016/j.yfrne.2015.11.001

Dahl, R. E. (2004). Adolescent brain development: A period of vulnerabilities and opportunities. *Annals of the New York Academy of Sciences*, *1021*(1), 1–22. doi:10.1196/annals.1308.001

Darling-Hammond, L., Barron, B., Pearson, P. D., Schoenfeld, A. H., Stage, E. K., Zimmerman, T. D., … Tilson, J. L. (2008). *Powerful learning: What we know about teaching for understanding.* San Francisco, CA: Jossey-Bass.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2019). Implications for educational practice of the science of learning and development. *Applied Developmental Science*. Advance online publication. doi:10.1080/10888691.2018.1537791

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective teacher professional development.* Palo Alto, CA: Learning Policy Institute. Retrieved from https://www.teacherscholars.org/wp-content/uploads/2017/09/Effective_Teacher_Professional_Development_REPORT.pdf

De Havas, J. A., Parimal, S., Soon, C. S., & Chee, M. W. L. (2012). Sleep deprivation reduces default mode network connectivity and anti-correlation during rest and task performance. *NeuroImage*, *59*(2), 1745–1751. doi:10.1016/j.neuroimage.2011.08.026

Deacon, T. W. (2011). *Incomplete nature: How mind emerged from matter.* New York, NY: W. W. Norton.

Dennis, E. L., Jahanshad, N., McMahon, K. L., de Zubicaray, G. I., Martin, N. G., Hickie, I. B., … Thompson, P. M. (2013). Development of brain structural connectivity between ages 12 and 30: A 4-Tesla diffusion imaging study in 439 adolescents and adults. *NeuroImage*, *64*, 671–684. doi:10.1016/j.neuroimage.2012.09.004

Deoni, S. C. L., Dean, D. C., Remer, J., Dirks, H., & O'Muircheartaigh, J. (2015). Cortical maturation and myelination in healthy toddlers and young children. *NeuroImage*, *115*, 147–161. doi:10.1016/j.neuroimage.2015.04.058

Diamond, A. (2010). The evidence base for improving school outcomes by addressing the whole child and by addressing skills and attitudes, not just content. *Early Education and Development*, *21*(5), 780–793. doi:10.1080/10409289.2010.514522

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. doi:10.1146/annurev-psych-113011-143750

Diamond, A. (2014). Want to optimize executive functions and academic outcomes? Simple, just nourish the human spirit. *Minnesota Symposia on Child Psychology*, *37*, 205–232. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4210770/pdf/nihms-605270.pdf

Diamond, M., Krech, D., & Rosenzweig, M. R. (1964). The effects of an enriched environment on the histology of the rat cerebral cortex. *The Journal of Comparative Neurology*, *123*(1), 111–120. doi:10.1002/cne.901230110

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science*, *333*(6045), 959–964. doi:10.1126/science.1204529

Dong, M., Giles, W. H., Felitti, V. J., Dube, S. R., Williams, J. E., Chapman, D. P., & Anda, R. F. (2004). Insights into causal pathways for ischemic heart disease: Adverse childhood experiences study. *Circulation*, *110*(13), 1761–1766. doi:10.1161/01.CIR.0000143074.54995.7F

Durmer, J. S., & Dinges, D. F. (2005). Neurocognitive consequences of sleep deprivation. *Seminars in Neurology*, *25*(1), 117–129.

Dweck, C. S. (2017). From needs to goals and representations: Foundations for a unified theory of motivation, personality, and development. *Psychological Review*, *124*(6), 689–719. doi:10.1037/rev0000082

Eccles, J. S., & Roeser, R. W. (2009). *Schools, academic motivation, and stage-environment fit. Handbook of adolescent psychology.* New York, NY: Wiley.

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., … Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. *Proceedings of the National Academy of Sciences*, *108*(7), 3017–3022. doi:10.1073/pnas.1015950108

Eriksson, P. S., Perfilieva, E., Björk-Eriksson, T., Alborn, A. M., Nordborg, C., Peterson, D. A., & Gage, F. H. (1998). Neurogenesis in the adult human hippocampus. *Nature Medicine*, *4*(11), 1313–1317. doi:10.1038/3305

Fair, D. A., Cohen, A. L., Power, J. D., Dosenbach, N. U. F., Church, J. A., Miezin, F. M., … Petersen, S. E. (2009). Functional brain networks develop from a "local to distributed" organization. *PLoS Computational Biology*, *5*(5), e1000381. doi:10.1371/journal.pcbi.1000381

Farah, M. J. (2017). The neuroscience of socioeconomic status: Correlates, causes, and consequences. *Neuron*, *96*(1), 56–71. doi:10.1016/j.neuron.2017.08.034

Farrington, C. A., Roderick, M., Allensworth, E., Nagaoka, J., Beechum, N. O., Keyes, T. S., & Johnson, D. W. (2012). *Teaching adolescents to become learners: The role of noncognitive factors in shaping school performance: A critical literature review.* Chicago, IL: University of Chicago Consortium On Chicago School Research.

Feldman, R. (2015). The adaptive human parental brain: Implications for children's social development. *Trends in Neurosciences*, *38*(6), 387–399. doi:10.1016/j.tins.2015.04.004

Ferguson, K. T., Cassells, R. C., MacAllister, J. W., & Evans, G. W. (2013). The physical environment and child development: An international review. *International Journal of Psychology*, *48*(4), 437–468. doi:10.1080/00207594.2013.804190

Fischer, K. W., & Bidell, T. R. (2006). Dynamic development of action, thought and emotion. In R. Lerner (Ed.), *Handbook of child psychology* (pp. 313–399). Hoboken, NJ: Wiley.

Flannery, J. E., Beauchamp, K. G., & Fisher, P. A. (2017). The role of social buffering on chronic disruptions in quality of care: Evidence from caregiver-based interventions in foster children. *Social Neuroscience*, *12*(1), 86–91. doi:10.1080/17470919.2016.1170725

Fonken, L. K., Xu, X., Weil, Z. M., Chen, G., Sun, Q., Rajagopalan, S., & Nelson, R. J. (2011). Air pollution impairs cognition, provokes depressive-like behaviors and alters hippocampal cytokine expression and morphology. *Molecular Psychiatry*, *16*(10), 987–995. doi:10.1038/mp.2011.76

Foulkes, L., & Blakemore, S.-J. (2018). Studying individual differences in human adolescent brain development. *Nature Neuroscience*, *21*(3), 315–323. doi:10.1038/s41593-018-0078-4

Fox, N. A., Zeanah, C. H., & Nelson, C. A. (2014). A matter of timing: Enhancing positive change for the developing brain. *Zero to Three*, *34*(3), 4–9.

Francis, H., & Stevenson, R. (2013). The longer-term impacts of Western diet on human cognition and the brain. *Appetite*, *63*, 119–128. doi:10.1016/j.appet.2012.12.018

Francis, R. C. (2011). *Epigenetics: How environment shapes our genes.* New York, NY: W. W. Norton & Company.

Gerhardt, S. (2014). *Why love matters: How affection shapes a baby's brain* (2nd ed.). London, UK: Routledge.

Giedd, J. N., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., … Rapoport, J. L. (1999). Brain development during childhood and adolescence: A longitudinal MRI study. *Nature Neuroscience*, *2*(10), 861–863. doi:10.1038/13158

Gilbert, D. T., & Wilson, T. D. (2007). Prospection: Experiencing the future. *Science (New York, N.Y.)*, *317*(5843), 1351–1354. doi:10.1126/science.1140734

Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greenstein, D., Vaituzis, A. C., … Thompson, P. M. (2004). Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences*, *101*(21), 8174–8179. doi:10.1073/pnas.0402680101

Golinkoff, R. M., & Hirsh-Pasek, K. (2016). *Becoming brilliant: What science tells us about raising successful children.* Washington, DC: American Psychological Association.

Gopnik, A., Meltzoff, A. N., & Kuhl, P. K. (2000). *The scientist in the crib: What early learning tells us about the mind.* New York, NY: Perennial.

Goulden, N., Khusnulina, A., Davis, N. J., Bracewell, R. M., Bokde, A. L., McNulty, J. P., & Mullins, P. G. (2014). The salience network is responsible for switching between the default mode network and the central executive network: Replication from DCM. *NeuroImage*, *99*, 180–190. doi:10.1016/j.neuroimage.2014.05.052

Grazzani, I., Ornaghi, V., Conte, E., Pepe, A., & Caprin, C. (2018). The relation between emotion understanding and theory of mind in children aged 3 to 8: The key role of language. *Frontiers in Psychology*, *9*(724), 1–10. doi:10.3389/fpsyg.2018.00724

Greicius, M. D., Supekar, K., Menon, V., & Dougherty, R. F. (2009). Resting-state functional connectivity reflects structural connectivity in the default mode network. *Cerebral Cortex*, *19*(1), 72–78. doi:10.1093/cercor/bhn059

Gunnar, M. R. (1998). Quality of early care and buffering of neuroendocrine stress reactions: Potential effects on the developing human brain. *Preventative Medicine*, *27*(2), 208–211. doi:10.1006/pmed.1998.0276

Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the third space. *Reading Research Quarterly*, *43*(2), 148–164. doi:10.1598/RRQ.43.2.3

Gutiérrez, K. D., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher*, *32*(5), 19–25. doi:10.3102/0013189X032005019

Haft, S. L., Myers, C. A., & Hoeft, F. (2016). Socio-emotional and cognitive resilience in children with reading disabilities. *Current Opinion in Behavioral Sciencs*, *10*, 133–141. doi:10.1016/j.cobeha.2016.06.005

Hahn, T., Nierenberg, A. A., & Whitfield-Gabrieli, S. (2017). Predictive analytics in mental health: Applications, guidelines, challenges and perspectives. *Molecular Psychiatry*, *22*(1), 37–43. doi:10.1038/mp.2016.201

Hamilton, L. S., Doss, C. J., & Steiner, E. D. (2019). *Support for social and emotional learning is widespread: Principals and teachers give insight into how they value, address, and measure it, and which supports they need*. Creative Commons Attribution 4.0 International License. Retrieved from www.rand.org/t/RR2991

Hantzopoulos, M. (2016). *Restoring dignity in public schools: Human rights education in action.* New York, NY: Teachers College Press.

Harms, M. B., Shannon Bowen, K. E., Hanson, J. L., & Pollak, S. D. (2018). Instrumental learning and cognitive flexibility processes are impaired in children exposed to early life stress. *Developmental Science*, *21*(4), e12596. doi:10.1111/desc.12596

Harris, N. B. (2018). *The deepest well: Healing the long-term effects of childhood adversity.* New York, NY: Houghton Mifflin Harcourt.

Helm, J. L., Sbarra, D. A., & Ferrer, E. (2014). Coregulation of respiratory sinus arrhythmia in adult romantic partners. *Emotion*, *14*(3), 522–531. doi:10.1037/a0035960

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.

Hirsh-Pasek, K., Golinkoff, R. M., Berk, L. E., & Singer, D. G. (2009). *A mandate for playful learning in preschool: Presenting the evidence.* New York, NY: Oxford University Press.

Hoff, G. E. A.-J., Van den Heuvel, M. P., Benders, M. J. N. L., Kersbergen, K. J., & De Vries, L. S. (2013). On development of functional brain connectivity in the young brain. *Frontiers in Human Neuroscience*, *7*(650), 1–7. doi:10.3389/fnhum.2013.00650

Hyvönen, K., Törnroos, K., Salonen, K., Korpela, K., Feldt, T., & Kinnunen, U. (2018). Profiles of nature exposure and outdoor activities associated with occupational well-being among employees. *Frontiers in Psychology*, *9*(754), 1–13. doi:10.3389/fpsyg.2018.00754

Immordino-Yang, M. H. (2013). Studying the effects of culture by integrating neuroscientific with ethnographic approaches. *Psychological Inquiry*, *24*(1), 42–46. doi:10.1080/1047840X.2013.770278

Immordino-Yang, M. H. (2015). *Emotions, learning, and the brain: Exploring the educational implications of affective neuroscience.* New York, NY: W. W. Norton.

Immordino-Yang, M. H. (2016). Emotion, sociality, and the brain's default mode network: Insights for educational practice and policy. *Policy Insights from the Behavioral and Brain Sciences*, *3*(2), 211–219. doi:10.1177/2372732216656869

Immordino-Yang, M. H., Christodoulou, J. A., & Singh, V. (2012). Rest is not idleness: Implications of the brain's default mode for human development and education. *Perspectives on Psychological Science*, *7*(4), 352–364. doi:10.1177/1745691612447308

Immordino-Yang, M. H., & Damasio, A. (2007). We feel, therefore we learn: The relevance of affective and social neuroscience to education. *Mind, Brain, and Education*, *1*(1), 3–10. doi:10.1111/j.1751-228X.2007.00004.x

Immordino-Yang, M. H., Darling-Hammond, L., & Krone, C. (2018). *The brain basis for integrated social, emotional, and academic development: How emotions and social relationships drive learning*. Washington, DC: National Commission on Social, Emotional, and Academic Development. Retrieved from https://www.aspeninstitute.org/publications/the-brain-basis-forintegrated-social-emotional-and-academic-development/

Immordino-Yang, M. H., & Gotlieb, R. (2017). Embodied brains, social minds, cultural meaning: Integrating neuroscientific and educational research on social-affective development. *American Educational Research Journal*, *54*(1_suppl), 344S–367S. doi:10.3102/0002831216669780

Immordino-Yang, M. H., McColl, A., Damasio, H., & Damasio, A. (2009). Neural correlates of admiration and compassion. *Proceedings of the National Academy of Sciences of the United States of America*, *106*(19), 8021–8026. doi:10.1073/pnas.0810363106

Immordino-Yang, M. H., & Sylvan, L. (2010). Admiration for virtue: Neuroscientific perspectives on a motivating emotion. *Contemporary Educational Psychology*, *35*(2), 110–115. doi:10.1016/j.cedpsych.2010.03.003

Immordino-Yang, M. H., & Yang, X.-F. (2017). Cultural differences in the neural correlates of social–emotional feelings: An interdisciplinary, developmental perspective. *Current Opinion in Psychology*, *17*, 34–40. doi:10.1016/j.copsyc.2017.06.008

International Human Genome Sequencing Consortium. (2004). Finishing the euchromatic sequence of the human genome. *Nature*, *431*(7011), 931–945.

Jennings, P. A., Frank, J. L., Snowberg, K. E., Coccia, M. A., & Greenberg, M. T. (2013). Improving classroom learning environments by Cultivating Awareness and Resilience in Education (CARE): Results of a randomized controlled trial. *School Psychology Quarterly*, *28*(4), 374–390. doi:10.1037/spq0000035

Jennings, P. A., & Greenberg, M. T. (2009). The prosocial classroom: Teacher social and emotional competence in relation to student and classroom outcomes. *Review of Educational Research*, *79*(1), 491–525. doi:10.3102/0034654308325693

Johnson, S., Slaughter, V., & Carey, S. (1998). Whose gaze will infants follow? The elicitation of gaze-following in 12-month-olds. *Developmental Science*, *1*(2), 233–238. doi:10.1111/1467-7687.00036

Jones, S., Bouffard, S. M., & Weissbourd, R. (2013). Educators' social and emotional skills vital to learning. *Phi Delta Kappan*, *94*(8), 62–65. doi:10.1177/003172171309400815

Jones, S., Farrington, C. A., Jagers, R., Brackett, M., & Kahn, J. (2018). *A research agenda for the next generation.* Washington, DC: National Commission on Social, Emotional, and Academic Development.

Jones, S., & Kahn, J. (2017). *The evidence base for how we learn: Supporting students' social, emotional, and academic development*. Washington, DC: National Commission on Social, Emotional, and Academic Development.

Khoury, B., Sharma, M., Rush, S. E., & Fournier, C. (2015). Mindfulness-based stress reduction for healthy individuals: A meta-analysis. *Journal of Psychosomatic Research*, *78*(6), 519–528. doi:10.1016/j.jpsychores.2015.03.009

Kim, D.-J., Davis, E. P., Sandman, C. A., Sporns, O., O'Donnell, B. F., Buss, C., & Hetrick, W. P. (2017). Prenatal maternal cortisol has sex-specific associations with child brain network properties. *Cerebral Cortex*, *27*(11), 5230–5241. doi:10.1093/cercor/bhw303

Kirmayer, L. J., Groleau, D., Guzder, J., Blake, C., & Jarvis, E. (2003). Cultural consultation: A model of mental health service for multicultural societies. *The Canadian Journal of Psychiatry*, *48*(3), 145–5241. doi:10.1177/070674370304800302

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Englewood Cliffs, NJ: Prentice Hall.

Koller, K., Brown, T., Spurgeon, A., & Levy, L. (2004). Recent developments in low-level lead exposure and intellectual impairment in children. *Environmental Health Perspectives*, *112*(9), 987–994. doi:10.1289/ehp.6941

Koutsandréou, F., Wegner, M., Niemann, C., & Budde, H. (2016). Effects of motor versus cardiovascular exercise training on children's working memory. *Medicine and Science in Sports and Exercise*, *48*(6), 1144–1152. doi:10.1249/MSS.0000000000000869

Krafft, C. E., Schwarz, N. F., Chi, L., Weinberger, A. L., Schaeffer, D. J., Pierce, J. E., … McDowell, J. E. (2014). An 8-month randomized controlled exercise trial alters brain activation during cognitive tasks in overweight children. *Obesity*, *22*(1), 232–242. doi:10.1002/oby.20518

Kramer, A. F., & Erickson, K. I. (2007). Capitalizing on cortical plasticity: Influence of physical activity on cognition and brain function. *Trends in Cognitive Sciences*, *11*(8), 342–348. doi:10.1016/j.tics.2007.06.009

Kucyi, A., & Davis, K. D. (2014). Dynamic functional connectivity of the default mode network tracks daydreaming. *NeuroImage*, *100*, 471–480. doi:10.1016/j.neuroimage.2014.06.044

Kuhl, P. K. (2010). Brain mechanisms in early language acquisition. *Neuron*, *67*(5), 713–727. doi:10.1016/j.neuron.2010.08.038

Kühn, S., Ritter, S. M., Müller, B. C. N., van Baaren, R. B., Brass, M., & Dijksterhuis, A. (2014). The importance of the default mode network in creativity: A structural MRI study. *The Journal of Creative Behavior*, *48*(2), 152–163. doi:10.1002/jocb.45

Kundu, P., Benson, B. E., Rosen, D., Frangou, S., Leibenluft, E., Luh, W.-M., … Ernst, M. (2018). The integration of functional brain activity from adolescence to adulthood. *The Journal of Neuroscience*, *38*(14), 3559–3570. doi:10.1523/JNEUROSCI.1864-17.2018

Lees, C., & Hopkins, J. (2013). Effect of aerobic exercise on cognition, academic achievement, and psychosocial function in children: A systematic review of randomized control trials. *Preventing Chronic Disease*, *10*, E174. doi:10.5888/pcd10.130010

Levy, D. J., Heissel, J. A., Richeson, J. A., & Adam, E. K. (2016). Psychological and biological responses to race-based social stress as pathways to disparities in educational outcomes. *American Psychologist*, *71*(6), 455–473. doi:10.1037/a0040322

Lichenstein, S. D., Verstynen, T., & Forbes, E. E. (2016). Adolescent brain development and depression: A case for the importance of connectivity of the anterior cingulate cortex. *Neuroscience and Biobehavioral Reviews*, *70*, 271–287. doi:10.1016/j.neubiorev.2016.07.024

Lillard, A. S. (2005). *Montessori: The science behind the genius.* New York, NY: Oxford University Press.

Lin, W., Zhu, Q., Gao, W., Chen, Y., Toh, C.-H., Styner, M., … Gilmore, J. H. (2008). Functional connectivity MR imaging reveals cortical functional connectivity in the developing brain. *American Journal of Neuroradiology*, *29*(10), 1883–1889. doi:10.3174/ajnr.A1256

Liu, W.-C., Flax, J. F., Guise, K. G., Sukul, V., & Benasich, A. A. (2008). Functional connectivity of the sensorimotor area in naturally sleeping infants. *Brain Research*, *1223*, 42–29. doi:10.1016/j.brainres.2008.05.054

Lledo, P. M., Alonso, M., & Grubb, M. S. (2006). Adult neurogenesis and functional plasticity in neuronal circuits. *Nature Reviews Neuroscience*, *7*(3), 179–193. doi:10.1038/nrn1867

Love, B. L. (2019). *We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom.* Boston, MA: Beacon Press.

Lucassen, P. J., Meerlo, P., Naylor, A. S., van Dam, A. M., Dayer, A. G., Fuchs, E., … Czéh, B. (2010). Regulation of adult neurogenesis by stress, sleep disruption, exercise and inflammation: Implications for depression and antidepressant action. *Neuropsychopharmacology*, *20*(1), 1–17. doi:10.1016/j.euroneuro.2009.08.003

Lunkenheimer, E., Tiberio, S. S., Buss, K. A., Lucas-Thompson, R. G., Boker, S. M., & Timpe, Z. C. (2015). Coregulation of respiratory sinus arrhythmia between parents and preschoolers: Differences by children's externalizing problems. *Developmental Psychobiology*, *57*(8), 994–1003. doi:10.1002/dev.21323

Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews Neuroscience*, *10*(6), 434–445. doi:10.1038/nrn2639

McLaughlin, K. A., Sheridan, M. A., Tibu, F., Fox, N. A., Zeanah, C. H., & Nelson, C. A. (2015). Causal effects of the early caregiving environment on development of stress response systems in children. *Proceedings of the National Academy of Sciences*, *112*(18), 5637–5642. doi:10.1073/pnas.1423363112

Meerlo, P., Mistlberger, R. E., Jacobs, B. L., Heller, H. C., & McGinty, D. (2009). New neurons in the adult brain: The role of sleep and consequences of sleep loss. *Sleep Medicine Reviews*, *13*(3), 187–194. doi:10.1016/j.smrv.2008.07.004

Mehta, J. (2019). *In search of deeper learning: The quest to remake the American high school.* Cambridge, MA: Harvard University Press.

Meiklejohn, J., Phillips, C., Freedman, M. L., Griffin, M. L., Biegel, G., Roach, A., … Saltzman, A. (2012). Integrating mindfulness training into K-12 education: Fostering the resilience of teachers and students. *Mindfulness*, *3*(4), 291–307. doi:10.1007/s12671-012-0094-5

Menon, V., & Uddin, L. Q. (2010). Saliency, switching, attention and control: A network model of insula function. *Brain Structure and Function*, *214*(5), 655–667. doi:10.1007/s00429-010-0262-0

Meyer, H. C., Lee, F. S., & Gee, D. G. (2018). The role of the endocannabinoid system and genetic variation in adolescent brain development. *Neuropsychopharmacology*, *43*(1), 21–33. doi:10.1038/npp.2017.143

Miller, G. E., & Chen, E. (2013). The biological residue of childhood poverty. *Child Development Perspectives*, *7*(2), 67–73. doi:10.1111/cdep.12021

Miller, G. E., Yu, T., Chen, E., & Brody, G. H. (2015). Self-control forecasts better psychosocial outcomes but faster epigenetic aging in low-SES youth. *Proceedings of the National Academy of Sciences*, *112*(33), 10325–10330. doi:10.1073/pnas.1505063112

Mirescu, C., & Gould, E. (2006). Stress and adult neurogenesis. *Hippocampus*, *16*(3), 233–238. doi:10.1002/hipo.20155

Mirescu, C., Peters, J. D., & Gould, E. (2004). Early life experience alters response of adult neurogenesis to stress. *Nature Neuroscience*, *7*(8), 841–846. doi:10.1038/nn1290

Mohajeri, M. H., La Fata, G., Steinert, R. E., & Weber, P. (2018). Relationship between the gut microbiome and brain function. *Nutrition Reviews*, *76*(7), 481–496. doi:10.1093/nutrit/nuy009

Molnar-Szakacs, I., & Uddin, L. Q. (2013). Self-processing and the default mode network: Interactions with the mirror neuron system. *Frontiers in Human Neuroscience*, *7*(571), 1–11. doi:10.3389/fnhum.2013.00571

Molteni, R., Barnard, R. J., Ying, Z., Roberts, C. K., & Gomez-Pinilla, F. (2002). A high-fat, refined sugar diet reduces hippocampal brain-derived neurotrophic factor, neuronal plasticity, and learning. *Neuroscience*, *112*(4), 803–814. doi:10.1016/S0306-4522(02)00123-9

Montessori, M. (1914). *Dr. Montessori's own handbook.* New York, NY: F. A. Stokes Company Publishers. Retrieved from http://www.gutenberg.org/files/29635/29635-h/29635-h.htm%0A

Mychasiuk, R., & Metz, G. A. S. (2016). Epigenetic and gene expression changes in the adolescent brain: What have we learned from animal models? Neuroscience and *Biobehavioral Reviews*, *70*, 189–197. doi:10.1016/j.neubiorev.2016.07.013

Nasir, N. (2011). *Racialized identities: Race and achievement among African American youth.* Stanford, CA: Stanford University Press.

Negriff, S., Saxbe, D. E., & Trickett, P. K. (2015). Childhood maltreatment, pubertal development, HPA axis functioning, and psychosocial outcomes: An integrative biopsychosocial model. *Developmental Psychobiology*, *57*(8), 984–993. doi:10.1002/dev.21340

Nelson, C. A. (2014). *Romania's abandoned children.* Cambridge, MA: Harvard University Press.

Neville, H. J., Stevens, C., Pakulak, E., Bell, T. A., Fanning, J., Klein, S., & Isbell, E. (2013). Family-based training program improves brain function, cognition, and behavior in lower socioeconomic status preschoolers. *Proceedings of the National Academy of Sciences*, *110*(29), 12138–12143. doi:10.1073/pnas.1304437110

Ngure, F. M., Reid, B. M., Humphrey, J. H., Mbuya, M. N., Pelto, G., & Stoltzfus, R. J. (2014). Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: Making the links. *Annals of the New York Academy of Sciences*, *1308*(1), 118–128. doi:10.1111/nyas.12330

NICHD Early Child Care Research Network. (2002). Early child care and children's development prior to school entry: Results from the NICHD Study of Early Child Care. *American Educational Research Journal*, *39*(1), 133–164. doi:10.2307/3202474

Niendam, T. A., Laird, A. R., Ray, K. L., Dean, Y. M., Glahn, D. C., & Carter, C. S. (2012). Meta-analytic evidence for a superordinate cognitive control network subserving diverse executive functions.

*Cognitive, Affective, & Behavioral Neuroscience*, *12*(2), 241–268. doi:10.3758/s13415-011-0083-5

Noble, K. G., Houston, S. M., Brito, N. H., Bartsch, H., Kan, E., Kuperman, J. M., … Sowell, E. R. (2015). Family income, parental education and brain structure in children and adolescents. *Nature Neuroscience*, *18*(5), 773–780. doi:10.1038/nn.3983

Norman, R. E., Byambaa, M., De, R., Butchart, A., Scott, J., & Vos, T. (2012). The long-term health consequences of child physical abuse, emotional abuse, and neglect: A systematic review and meta-analysis. *PLoS Medicine*, *9*(11), e1001349. doi:10.1371/journal.pmed.1001349

Oh, D. L., Jerman, P., Marques, S. S., Koita, K., Boparai, S. K. P., Harris, N. B., & Bucci, M. (2018). Systematic review of pediatric health outcomes associated with childhood adversity. *BMC Pediatrics*, *18*(1), 83–19. doi:10.1186/s12887-018-1037-7

Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science*, *308*(5719), 255–258. doi:10.1126/science.1106480

Osher, D., & Kendziora, K. (2010). Building conditions for learning and healthy adolescent development: Strategic approaches. In B. Doll, W. Pfohl, & J. Yoon (Eds.), *Handbook of youth prevention science* (pp. 121–140). New York, NY: Routledge.

Osher, D., Kidron, Y., Brackett, M., Dymnicki, A., Jones, S., & Weissberg, R. P. (2016). Advancing the science and practice of social and emotional learning: Looking back and moving forward. *Review of Research in Education*, *40*(1), 644–681. doi:10.3102/0091732X16673595

Oyserman, D. (2015). *Pathways to success through identity-based motivation.* New York, NY: Oxford University Press.

Pakulak, E., Hampton Wray, A., Longoria, Z., Garcia Isaza, A., Stevens, C., Bell, T., … Neville, H. (2017). Cultural adaptation of a neurobiologically informed intervention in local and international contexts. *New Directions for Child and Adolescent Development*, *2017*(158), 81–92. doi:10.1002/cad.20226

Paradise, R., & Rogoff, B. (2009). Side by side: Learning by observing and pitching in. *Ethos*, *37*(1), 102–138. doi:10.1111/j.1548-1352.2009.01033.x

Parrington, J. (2015). *The deeper genome: Why there is more to the human genome than meets the eye.* Oxford, UK: Oxford University Press.

Patton, L. D. (2010). *Culture centers in higher education: Perspectives on identity, theory, and practice.* Herndon, VA: Stylus Publishing.

Peisner-Feinberg, E. S., Burchinal, M. R., Clifford, R. M., Culkin, M. L., Howes, C., Kagan, S. L., & Yazejian, N. (2001). The relation of preschool child-care quality to children's cognitive and social developmental trajectories through second grade. *Child Development*, *72*(5), 1534–1553. doi:10.1111/1467-8624.00364

Pekrun, R., & Linnenbrink-Garcia, L. (2012). Academic emotions and student engagement. In S. Christenson, A. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 259–282). Boston, MA: Springer. doi:10.1007/978-1-4614-2018-7_12

Plomin, R., & Spinath, F. M. (2004). Intelligence: Genetics, genes, and genomics. *Journal of Personality and Social Psychology*, *86*(1), 112–129. doi:10.1037/0022-3514.86.1.112

Potkin, K. T., & Bunney, W. E. (2012). Sleep improves memory: The effect of sleep on long term memory in early adolescence. *PLoS ONE*, *7*(8), e42191. doi:10.1371/journal.pone.0042191

Poulose, S. M., Miller, M. G., Scott, T., & Shukitt-Hale, B. (2017). Nutritional factors affecting adult neurogenesis and cognitive function. *Advances in Nutrition: An International Review Journal*, *8*(6), 804–811. doi:10.3945/an.117.016261

Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(2), 676–682. doi:10.1073/pnas.98.2.676

Raizada, R. D. S., & Kishiyama, M. M. (2010). Effects of socioeconomic status on brain development, and how cognitive neuroscience may contribute to levelling the playing field. *Frontiers in Human Neuroscience*, *4*(3), 1–11. doi:10.3389/neuro.09.003.2010

Rasch, B., & Born, J. (2013). About sleep's role in memory. *Physiological Reviews*, *93*(2), 681–766. doi:10.1152/physrev.00032.2012

Raymond, J. P. (2018). *Wildflowers: A school superintendent's challenge to America*. Washington, DC: Wildflower Press.

Ritchhart, R., Church, M., & Morrison, K. (2011). *Making thinking visible: How to promote engagement, understanding, and independence for all learners.* San Francisco, CA: Jossey-Bass.

Roe, J., Thompson, C., Aspinall, P., Brewer, M., Duff, E., Miller, D., … Clow, A. (2013). Green space and stress: Evidence from cortisol measures in deprived urban communities. *International Journal of Environmental Research and Public Health*, *10*(9), 4086–4103. doi:10.3390/ijerph10094086

Roeser, R. W., Schonert-Reichl, K. A., Jha, A., Cullen, M., Wallace, L., Wilensky, R., … Harrison, J. (2013). Mindfulness training and reductions in teacher stress and burnout: Results from two randomized, waitlist-control field trials. *Journal of Educational Psychology*, *105*(3), 787–804. doi:10.1037/a0032093

Roeser, R. W., Urdan, T. C., & Stephens, J. M. (2009). School as a context of student motivation and achievement. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation at school* (1st ed., pp. 381–410). Mahwah, NJ: Taylor & Francis.

Rogoff, B. (2003). *The cultural nature of human development.* New York, NY: Oxford University Press.

Romeo, R. R., Leonard, J. A., Robinson, S. T., West, M. R., Mackey, A. P., Rowe, M. L., & Gabrieli, J. D. E. (2018). Beyond the 30-million-word gap: Children's conversational exposure is associated with language-related brain function. *Psychological Science*, *29*(5), 700–710. doi:10.1177/0956797617742725

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(41), 14931–14936. doi:10.1073/pnas.0506897102

Royle, N. J., Russell, A. F., & Wilson, A. J. (2014). The evolution of flexible parenting. *Science (New York, N.Y.)*, *345*(6198), 776–781. doi:10.1093/scan/nst166

Sapolsky, R. M. (2017). *Behave: The biology of humans at our best and worst.* New York, NY: Penguin Press.

Sarkar, A., Harty, S., Lehto, S. M., Moeller, A. H., Dinan, T. G., Dunbar, R. I. M., … Burnet, P. W. J. (2018). The microbiome in psychology and cognitive neuroscience. *Trends in Cognitive Sciences*, *22*(7), 611–636. doi:10.1016/j.tics.2018.04.006

Saxbe, D. E., Adam, E. K., Schetter, C. D., Guardino, C. M., Simon, C., McKinney, C. O., & Shalowitz, M. U. (2015). Cortisol covariation within parents of young children: Moderation by relationship aggression. *Psychoneuroendocrinology*, *62*, 121–128. doi:10.1016/j.psyneuen.2015.08.006

Saxbe, D. E., & Repetti, R. L. (2009). Fathers' and mothers' marital relationship predicts daughters' pubertal development two years later. *Journal of Adolescence*, *32*(2), 415–423. doi:10.1016/j.adolescence.2008.06.009

Saxbe, D. E., & Repetti, R. L. (2010). For better or worse? Coregulation of couples' cortisol levels and mood states. *Journal of Personality and Social Psychology*, *98*(1), 92–103. doi:10.1037/a0016959

Schneider, B., Krajcik, J., Lavonen, J., & Salmela-Aro, K. (Expected 2020). *Learning science: Crafting engaging science environments.* New Haven, CT: Yale University Press.

Schore, A. N. (2001). Effects of a secure attachment relationship on right brain development, affect regulation, and infant mental health. *Infant*

*Mental Health Journal*, *22*(1–2), 7–66. doi:10.1002/1097-0355(200101/04)22:1<7::AID-IMHJ2>3.0.CO;2-N

Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., … Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *Journal of Neuroscience*, *27*(9), 2349–2356. doi:10.1523/JNEUROSCI.5587-06.2007

Semple, R. J., Lee, J., Dinelia, A., Ae, R., & Miller, L. F. (2010). A randomized trial of mindfulness-based cognitive therapy for children: Promoting mindful attention to enhance social-emotional resiliency in children. *Journal of Child and Family Studies*, *19*(2), 218–229. doi:10.1007/s10826-009-9301-y

Sethna, V., Pote, I., Wang, S., Gudbrandsen, M., Blasi, A., McCusker, C., … McAlonan, G. M. (2017). Mother-infant interactions and regional brain volumes in infancy: An MRI study. *Brain Structure and Function*, *222*(5), 2379–2388. doi:10.1007/s00429-016-1347-1

Shonkoff, J. P. (2011). Protecting brains, not simply stimulating minds. *Science*, *333*(6045), 982–983. doi:10.1126/science.1206014

Shonkoff, J. P., Garner, A. S., Siegel, B. S., Dobbins, M. I., Earls, M. F., Garner, A. S., … Wood, D. L. (2012). The lifelong effects of early childhood adversity and toxic stress. *Pediatrics*, *129*(1), e232–e246. doi:10.1542/peds.2011-2663

Shtulman, A., & Carey, S. (2007). Improbable or impossible? How children reason about the possibility of extraordinary events. *Child Development*, *78*(3), 1015–1032. doi:10.1111/j.1467-8624.2007.01047.x

Silvers, J. A., McRae, K., Gabrieli, J. D., Gross, J. J., Remy, K. A., & Ochsner, K. N. (2012). Age-related differences in emotional reactivity, regulation, and rejection sensitivity in adolescence. *Emotion*, *12*(6), 1235–1247. doi:10.1037/a0028297

Smallwood, J., Brown, K., Baird, B., & Schooler, J. W. (2012). Cooperation between the default mode network and the frontal-parietal network in the production of an internal train of thought. *Brain Research*, *1428*, 60–70. doi:10.1016/j.brainres.2011.03.072

Snow, C. E. (1977). The development of conversation between mothers and babies. *Journal of Child Language*, *4*(1), 1–22. doi:10.1017/S0305000900000453

Spear, L. P. (2018). Effects of adolescent alcohol consumption on the brain and behaviour. *Nature Reviews Neuroscience*, *19*(4), 197–214. doi:10.1038/nrn.2018.10

Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review*, *99*(4), 605–632. doi:10.1037//0033-295X.99.4.605

Sporns, O., Chialvo, D. R., Kaiser, M., & Hilgetag, C. C. (2004). Organization, development and function of complex brain networks. *Trends in Cognitive Sciences*, *8*(9), 418–425. doi:10.1016/j.tics.2004.07.008

Spreng, R. N., & Grady, C. L. (2010). Patterns of brain activity supporting autobiographical memory, prospection, and theory of mind, and their relationship to the default mode network. *Journal of Cognitive Neuroscience*, *22*(6), 1112–1123. doi:10.1162/jocn.2009.21282

Stangl, D., & Thuret, S. (2009). Impact of diet on adult hippocampal neurogenesis. *Genes & Nutrition*, *4*(4), 271–282. doi:10.1007/s12263-009-0134-5

Steele, C. M. (2011). *Whistling Vivaldi: How stereotypes affect us and what we can do.* New York, NY: W. W. Norton.

Suleiman, A. B., Galván, A., Harden, K. P., & Dahl, R. E. (2017). Becoming a sexual being: The 'elephant in the room' of adolescent brain development. *Developmental Cognitive Neuroscience*, *25*, 209–220. doi:10.1016/j.dcn.2016.09.004

Supekar, K., Musen, M., & Menon, V. (2009). Development of large-scale functional brain networks in children. *PLoS Biology*, *7*(7). doi:10.1371/e1000157

Suprawati, M., Anggoro, F. K., & Bukatko, D. (2014). "I think I can": Achievement-oriented themes in storybooks from Indonesia, Japan, and the United States. *Frontiers in Psychology*, *5*(167), 1–5. doi:10.3389/fpsyg.2014.00167

Swain, J. E., Ho, S. S., Rosenblum, K. L., Morelen, D., Dayton, C. J., & Muzik, M. (2017). Parent-child intervention decreases stress and increases maternal brain activity and connectivity during own baby-cry: An exploratory study. *Development and Psychopathology*, *29*(2), 535–553. doi:10.1017/S0954579417000165

Tamir, D. I., Bricker, A. B., Dodell-Feder, D., & Mitchell, J. P. (2015). Reading fiction and reading minds: The role of simulation in the default network. *Social Cognitive and Affective Neuroscience*, *11*(2), 215–224. doi:10.1093/scan/nsv114

Tang, Y.-Y., & Posner, M. I. (2014). Training brain networks and states. *Trends in Cognitive Sciences*, *18*(7), 345–350. doi:10.1016/j.tics.2014.04.002

Taylor, R. D., Oberle, E., Durlak, J. A., & Weissberg, R. P. (2017). Promoting positive youth development through school-based social and emotional learning interventions: A meta-analysis of follow-up effects. *Child Development*, *88*(4), 1156–1171. doi:10.1111/cdev.12864

Tessum, C. W., Apte, J. S., Goodkind, A. L., Muller, N. Z., Mullins, K. A., Paolella, D. A., … Hill, J. D. (2019). Inequity in consumption of goods and services adds to racial-ethnic disparities in air pollution exposure. *Proceedings of the National Academy of Sciences*, *116*(13), 6001–6006. doi:10.1073/pnas.1818859116

Thomason, M. E., Hamilton, J. P., & Gotlib, I. H. (2011). Stress-induced activation of the HPA axis predicts connectivity between subgenual cingulate and salience network during rest in adolescents. *Journal of Child Psychology and Psychiatry*, *52*(10), 1026–1034. doi:10.1111/j.1469-7610.2011.02422.x

Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J., & Depledge, M. H. (2011). Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. *Environmental Science & Technology*, *45*(5), 1761–1772. doi:10.1021/es102947t

Thompson, C. W., Roe, J., Aspinall, P., Mitchell, R., Clow, A., & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape and Urban Planning*, *105*(3), 221–229. doi:10.1016/j.landurbplan.2011.12.015

Tian, L., & Ma, L. (2017). Microstructural changes of the human brain from early to mid-adulthood. *Frontiers in Human Neuroscience*, *11*(393), 1–12. doi:10.3389/fnhum.2017.00393

Todorich, B., Pasquini, J. M., Garcia, C. I., Paez, P. M., & Connor, J. R. (2009). Oligodendrocytes and myelination: The role of iron. *Glia*, *57*(5), 467–478. doi:10.1002/glia.20784

Tomasello, M. (2009). *The cultural origins of human cognition.* Cambridge, MA: Harvard University Press.

Tottenham, N., & Galván, A. (2016). Stress and the adolescent brain: Amygdala-prefrontal cortex circuitry and ventral striatum as developmental targets. *Neuroscience and Biobehavioral Reviews*, *70*, 217–227. doi:10.1016/j.neubiorev.2016.07.030

Tronick, E. Z. (1989). Emotions and emotional communication in infants. *American Psychologist*, *44*(2), 112–119. doi:10.1037/0003-066X.44.2.112

Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review of greenspace exposure and health outcomes. *Environmental Research*, *166*, 628–637. doi:10.15124/CRD42015025193

Uddin, L. Q. (2015). Salience processing and insular cortical function and dysfunction. *Nature Reviews Neuroscience*, *16*(1), 55–61. doi:10.1038/nrn3857

van den Heuvel, M. P., Stam, C. J., Kahn, R. S., & Hulshoff Pol, H. E. (2009). Efficiency of functional brain networks and intellectual performance. *Journal of Neuroscience*, *29*(23), 7619–7624. doi:10.1523/JNEUROSCI.1443-09.2009

Van Dongen, H. P. A., Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, *26*(2), 117–126. doi:10.1093/sleep/26.2.117

Voss, M. W., Nagamatsu, L. S., Liu-Ambrose, T., & Kramer, A. F. (2011). Exercise, brain, and cognition across the life span. *Journal of Applied Physiology*, *111*(5), 1505–1513. doi:10.1152/japplphysiol.00210.2011

Voss, M. W., Prakash, R. S., Erickson, K. I., Basak, C., Chaddock, L., Kim, J. S., … Kramer, A. F. (2010). Plasticity of brain networks in a randomized intervention trial of exercise training in older adults. *Frontiers in Aging Neuroscience*, *2*, 1–17. doi:10.3389/fnagi.2010.00032

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Walker, M. P., & Stickgold, R. (2006). Sleep, memory, and plasticity. *Annual Review of Psychology*, *57*(1), 139–166. doi:10.1146/annurev.psych.56.091103.070307

Wang, S. W., & Campos, B. (2017). Cultural experiences, social ties, and stress: Focusing on the HPA axis. In J. M. Causadias, E. H. Telzer, & N. A. Gonzales (Eds.), *The handbook of culture and biology.* Hoboken, NJ: John Wiley.

Watamura, S. E., Donzella, B., Alwin, J., & Gunnar, M. R. (2003). Morning-to-afternoon increases in cortical concentrations for infants and toddlers at child care: Age differences and behavioral correlates. *Child Development*, *74*(4), 1006–1020. doi:10.1111/1467-8624.00583

Wechsler, M., Melnick, H., Maier, A., & Bishop, J. (2016). *The building blocks of high-quality early childhood education programs.* Palo Alto, CA: Learning Policy Institute.

Wentzel, K. R., & Miele, D. (2016). *Handbook of motivation at school* (2nd ed.). New York, NY: Taylor & Francis.

Wu, A., Ying, Z., & Gomez-Pinilla, F. (2004). The interplay between oxidative stress and brain-derived neurotrophic factor modulates the outcome of a saturated fat diet on synaptic plasticity and cognition. *European Journal of Neuroscience*, *19*(7), 1699–1707. doi:10.1111/j.1460-9568.2004.03246.x

Xie, L., Kang, H., Xu, Q., Chen, M. J., Liao, Y., Thiyagarajan, M., … Nedergaard, M. (2013). Sleep drives metabolite clearance from the adult brain. *Science*, *342*(6156), 373–377. doi:10.1126/science.1241224

Yang, X.-F., Pavarini, G., Schnall, S., & Immordino-Yang, M. H. (2018). Looking up to virtue: Averting gaze facilitates moral construals via posteromedial activations. *Social Cognitive and Affective Neuroscience*, *13*(11), 1131–1139. doi:10.1093/scan/nsy081

Yehuda, R., Engel, S. M., Brand, S. R., Seckl, J., Marcus, S. M., & Berkowitz, G. S. (2005). Transgenerational effects of posttraumatic stress disorder in babies of mothers exposed to the World Trade Center attacks during pregnancy. *Endocrinology & Metabolism*, *90*(7), 4115–4118. doi:10.1210/jc.2005-0550

Yeung, M. K., Lee, T. L., Cheung, W. K., & Chan, A. S. (2018). Frontal underactivation during working memory processing in adults with acute partial sleep deprivation: A near-infrared spectroscopy study. *Frontiers in Psychology*, *9*(742), 1–15. doi:10.3389/fpsyg.2018.00742

Yip, T. (2018). Ethnic/racial identity—a double-edged sword? Associations with discrimination and psychological outcomes. *Current Directions in Psychological Science*, *27*(3), 170–175. doi:10.1177/0963721417739348

Yoo, S.-S., Gujar, N., Hu, P., Jolesz, F. A., & Walker, M. P. (2007). The human emotional brain without sleep-a prefrontal amygdala disconnect. *Current Biology*, *17*(20), R877–R878. doi:10.1016/j.cub.2007.08.007

Younan, D., Tuvblad, C., Franklin, M., Lurmann, F., Li, L., Wu, J., … Chen, J.-C. (2018). Longitudinal analysis of particulate air pollutants and adolescent delinquent behavior in Southern California. *Journal of Abnormal Child Psychology*, *46*(6), 1283–1293. doi:10.1007/s10802-017-0367-5

Zarrett, N., & Eccles, J. (2006). The passage to adulthood: Challenges of late adolescence. *New Directions in Youth Development*, *2006*(111), 13–28. doi:10.1002/yd

Zhao, C., Deng, W., & Gage, F. H. (2008). Mechanisms and functional implications of adult neurogenesis. *Cell*, *132*(4), 645–660. doi:10.1016/j.cell.2008.01.033

Zielinski, B. A., Gennatas, E. D., Zhou, J., Seeley, W. W., & Raichle, M. E. (2010). Network-level structural covariance in the developing brain. *Proceedings of the National Academy of Sciences*, *107*(42), 18191–18196. doi:10.1073/pnas.1003109107

Zilkha, N., & Kimchi, T. (2018). Social isolation's molecular signature. *Nature*, *559*(7712), 38–40. doi:10.1021/acschembio.8b00144

Zimmer, C. (2018). *She has her mother's laugh: The powers, perversions, and potential of heredity* (1st ed.). New York, NY: Dutton.