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Learning in the Early Years

OVERVIEW

Children are born to learn, and they are the most capable learners on the planet. Children's early learning opportunities build foundations for future learning and impact their capacity to reach their full potential. This chapter describes five areas of core knowledge that children gain in the first eight years of life, including learning about (1) places, (2) numbers, (3) objects, (4) people's actions and goals, and (5) social interactions, communication, and language. Understanding these five areas can help us tap into the innate ability of children to learn quickly and prodigiously well before they enter primary school. This chapter also examines the learning skills and tools that help young children learn, including executive functions, imagination, metacognition, and motivation. Finally, the chapter discusses factors that promote and hinder early learning. Taken together, this knowledge and understanding can inform policies that promote quality early childhood education and nurture children's potential to learn well.

INTRODUCTION

Children are born to learn. They learn faster, more flexibly, and more economically than any machine, and they generalize their learning to new situations far more effectively than the smartest products of contemporary computer science (Lake et al. 2017). Children's prodigious learning testifies both to their biological predisposition to learn by

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exploring the world and by engaging with others, and to their exceedingly smart and adaptable capacity for exploration and discovery. This capacity sets young children up for a lifetime of gaining and using knowledge—a critical condition for successful and productive lives in all contemporary countries and cultures.

This chapter provides an overview of children’s learning in the first eight years of life. Because children’s learning builds on what they already know, and on the ways in which they gain further knowledge, understanding what young children know and how they learn is key to designing and providing effective early childhood education (ECE). Later chapters elaborate on the content presented here and connect this content to information regarding curricula, pedagogy, teacher training, learning environments, school management, and a systems approach to ECE. As with the other chapters in this book, the content of this chapter is informed by empirical research from diverse fields. In cases in which research has yet to produce clear conclusions, limitations and suggestions for further research are noted.

In recent decades, insights into children’s learning have come primarily from studies in developmental cognitive science, a field of research that combines methods and findings from diverse disciplines including psychology, anthropology, linguistics, organismic and molecular biology, neuroscience, economics, computer science, and education. Conclusions from this field are informed by laboratory experiments probing the cognitive capacities of young children, together with experiments on model animals and machines, probing the brain systems by which children learn and the computations by which their knowledge grows. In addition, an understanding of children’s learning benefits from field research in children’s homes and schools using randomized controlled experiments and other empirical methods to evaluate interventions that aim to enhance children’s learning in the environments and at the time scales over which their learning proceeds.

This research shows that learning in the early years provides the foundations for later learning. Learning is possible at all ages, and every child can benefit from a good education, but older children will advance more easily in later grades if they achieve a firm foundation for learning during the early years. The basic science of young children’s learning sheds light on the conditions that allow all children to build that foundation, regardless of their nationality, culture, or material and social advantages or disadvantages. It does not directly translate into recipes for school curricula, but its findings are a rich source of ideas for improving education worldwide. These ideas, in turn, can be evaluated by implementing them in randomly selected schools and comparing their impacts on children’s learning and development relative to the standard curriculum implemented under otherwise comparable conditions. In this way, research on children’s learning provides information that is critical for educators and policy makers alike.

This chapter begins by reviewing research on children's prodigious learning capacities. Next, it focuses on five areas of core knowledge in which young children learn rapidly and spontaneously, developing a foundation for later learning in school: (1) places, (2) numbers, (3) objects, (4) people's actions and goals, and (5) social relationships, communication, and language. After introducing these core areas of knowledge, the chapter turns to evidence concerning the more general cognitive skills and predispositions that support children's learning across diverse content areas, including executive functions that regulate attention and action planning, imagination, their capacity for metacognition, and their motivation to learn. Finally, the chapter considers factors that promote and hinder young children's learning and highlights important questions for further research.

CHILDREN ARE BORN TO LEARN

From birth, children perceive their environment and start to learn about it, especially by looking and listening. Like animals that must move from birth and avoid predators, newborn infants perceive depth, movement, and objects. Like animals that must learn critical features of their environment from birth—for example, the location of their nest (Gallistel 1990), the approximate size of their social group (Rugani, Regolin, and Vallortigara 2010), and the appearance and behavior of their family members (Sugita 2008) and of objects (Chiandetti and Vallortigara 2011; Wood 2013)—newborn infants perceive the extended surface layout (Slater, Mattock, and Brown 1990), the approximate number of objects in an array (Izard et al. 2009), faces (Mondloch et al. 1999), patterns of biological motion (Simion Regolin, and Bulf 2008), and vocalizations (Vouloumanos and Werker 2007).

Infants not only perceive objects, places, and people from birth but also begin learning about these entities. In some cases, learning even starts before birth, as evidenced by the ability of newborn infants to detect, orient to, and identify the sounds of their native language when they first hear them outside the womb (Mehler et al. 1988), sounds that their auditory system has detected over the last months of gestation. But learning accelerates after birth as infants become immersed in the natural and social world. In the first few months of life, infants begin to distinguish human faces from those of other species (Di Giorgio et al. 2012; Heron-Delaney, Wirth, and Pascalis 2011) and to recognize their caregivers (Burnham 1993; Pascalis et al. 1995). Well before they begin to speak, infants learn to distinguish the vowels and consonants of their native language from those of foreign languages (Kuhl 2004; Werker 1989), to parse the speech stream into words (Saffran, Aslin, and Newport 1996), to discover the structure of phrases (Shi, Werker, and Cutler 2006), and to connect the most frequent

words they hear to the things and events that speakers refer to (Bergelson and Swingley 2012).

From birth, moreover, infants' learning is propelled by their inherent curiosity and sociality. Infants are naturally predisposed to explore their environment by looking, listening, and acting so they can learn about the world around them (Fantz 1964; Stahl and Feigenson 2015). Right from the start, infants are oriented to people who engage with them (Farroni et al. 2002; Meltzoff and Moore 1977; Meltzoff et al. 2018), and they learn things from others before they can do those things themselves (Liu et al. 2019; Skerry, Carey, and Spelke 2013). Infants are particularly interested in, and good at learning from and about, those who use infant-directed speech (Fernald 1985) or song (Mehr, Song, and Spelke 2016; Mehr and Spelke 2018) and those who speak and behave like the members of their families (Kinzler, Dupoux, and Spelke 2007; Liberman, Woodward, and Kinzler 2017). By the end of the first year, infants become interested in sharing what they know with others (Meltzoff 2007; Tomasello et al. 2005).

Infants' inherent interest in exploring and learning both from and about their environment continues into childhood and beyond. In addition to these early tendencies to learn from other people and to be curious about the world, young children have been found to be especially gifted learners in a number of specific areas of knowledge. Because all children's learning in school ultimately builds on the knowledge that they have gained in these core areas, the chapter turns next to this evidence.

Key Takeaways

- Children are the most capable learners on earth.
- Children's learning in the early years sets the stage for lifelong learning.

FIVE CORE KNOWLEDGE AREAS

Children possess a small number of cognitive and brain systems that help them identify and think about specific aspects of the world, such as places, things, and people. These *core knowledge areas* (also known as *core knowledge systems*) are evident in human infants, are shared by other animals, function throughout life, and are common to people living in diverse cultures. Each core knowledge area also has been tracked into the brains of animals and human adults, children, and infants, where it activates specific regions of the cerebral cortex. Thus, developmental scientists can identify common core areas across different individuals, at different ages, and living in different cultures. As scientists from diverse disciplines have studied the properties of these areas, their studies have revealed at least five distinct

core knowledge areas that are central to all children's learning. This section discusses these five areas.

Learning about Places

Beginning in infancy, children are sensitive to the structure of the places that surround them. Toddlers use that structure to learn about the environments that they explore and the paths that will take them from one place to another. Both in school and out, children also use that structure to learn the diverse spatial symbols—from pictures to maps to written texts—that introduce children to worlds beyond their immediate experience, including faraway places, long-extinct animals, myths, and microorganisms.

Infants do not begin to master walking until the end of the first year. Nevertheless, infants possess the functional brain systems that underlie navigation, spatial memory, and action planning in humans and other animals (Spelke and Lee 2012). Using these systems, infants represent locations where objects are hidden in an extended spatial layout (Newcombe and Huttenlocher 2000), the paths that agents travel (Gergely et al. 1995), and the locations that are their goals (Hamlin, Hallinan, and Woodward 2008; Liu and Spelke 2017). Once they can crawl and walk, toddlers use geometry to navigate between environmental locations (Landau, Gleitman, and Spelke 1981), as do other animals (for review, see Gallistel 1990). These and other findings provide evidence of a dedicated cognitive system by which humans and other animals represent where we are within the environment through which we travel.

The mechanisms that give rise to these representations are among the best-understood cognitive mechanisms in all of neuroscience (O'Keefe 2014). These mechanisms not only support children's learning about their immediate environment but also are fundamental to young children's learning of spatial symbols such as pictures (DeLoache et al. 1998), maps (Shusterman, Lee, and Spelke 2008; Uttal 2000), scale models (DeLoache 2000), and number lines: the simplest mathematical symbols (Dehaene 2011; Siegler and Opfer 2003). Children's early spatial representations allow them not only to learn about symbols like pictures and maps but also to learn *from* them. As early as age two, children can learn the location of a hidden object from its location in a picture (Suddendorf 2003). By age two-and-a-half, they learn from its location in a purely abstract, geometric map (Winkler-Rhoades, Carey, and Spelke 2013). Using rulers, a form of number lines, children begin to master measurement. Other spatial symbols support children's learning of the alphabet (which may begin as early as two-to-three years) and their rapid decoding of letter sequences, a skill that is essential for learning to read (Dehaene 2009). Most fundamentally, studies of the hippocampus, an ancient cortical structure that is a central locus for

spatial representation, reveal its fundamental role not only in navigation but also in conscious memory of past events (Squire et al. 2010), action planning (Pfeiffer and Foster 2013), and thought, imagination, and invention (Gupta et al. 2010; Ullman et al. 2017).

These early spatial abilities are malleable, and activities that exercise them have been shown to enhance children's learning in school. For example, children's abilities to navigate by maps and to perceive geometric structure in pictures is enhanced by practice: When five-year-old children practice these tasks for four months, their spatial abilities are improved, not only when they are tested during the first three months that follow the practice but also when they are tested a full year later, with no intervening opportunities for additional practice or rehearsal (Dillon et al. 2017). Moreover, when children exercise these abilities in contexts that encourage learning of mathematical language and symbols, children show both immediate and enduring gains in school math learning (Dean et al. 2021; Dillon et al. 2017; Lauer and Lourenco 2016; Newcombe 2010; Wai, Lubinski, and Benbow 2009). Young children's biologically based spatial abilities are resources that should be nourished over the preschool and early school years, both to enhance their intuitive understanding of the world and to enhance their readiness for learning in school.

Key Takeaways

- Early spatial abilities support children's learning about their immediate environment, as well as learning about spatial symbols such as pictures, maps, scale models, the alphabet, and number lines.
- Young children's spatial abilities can be nourished to enhance school readiness.

Learning about Numbers

Infants and children are sensitive to numbers: the relative magnitudes of different sets of objects, the relative frequencies of different events, and the transformations in number that occur as objects or events are combined. Building on this sensitivity, children learn both to choose among sets of objects, to predict the outcomes of events, and to decipher the operations at the center of primary school mathematics.

Humans and other animals have a dedicated system for representing approximate numbers of objects and events: Which bushes in the environment provide the most berries? Which open fields are most often attacked by predators (Carey 2009; Gallistel 1990)? This system is present and functional in newborn infants (Coubart et al. 2014; de Hevia et al. 2014; Izard et al. 2009), and it sharpens progressively over infancy and childhood (Halberda and Feigenson 2008; Starr and Brannon 2015). This system is

often thought to figure in children's learning of the statistical properties of the environment (O'Grady and Xu 2020), learning that is critical for predicting future events (Gershman 2017). Finally, it is known to support operations of arithmetic: infants and preschool children can compare two dot arrays based on numerosity (Xu and Spelke 2000), they can relate increases in numerosity to increases in line length (Rugani and de Hevia 2017), and they can add two arrays of dots and compare the sum to a third array (Barth et al. 2005; Barth et al. 2006; Gilmore, McCarthy, and Spelke 2010). In all these respects, children's abilities resemble those that adults use to estimate numerosity without counting (Barth, Kanwisher, and Spelke 2003; Dehaene 2011; Halberda et al. 2012; Hyde and Spelke 2009).

Like their intuitive representations of places, children's intuitive representations of number support their learning of numerical symbols, including the number words that children begin to recite at age two (Szkudlarek and Brannon 2017) but take years to master (Wynn 1990), the Arabic symbols that many children throughout the world master by age four or five (Dillon et al. 2017), and the operations of formal arithmetic that children are taught in primary school (Gilmore, McCarthy, and Spelke 2007; Halberda, Mazocco, and Feigenson 2008). The acuity of children's perception of numbers—how finely they can distinguish two sets on the basis of their numerosities—is associated with formal mathematical abilities throughout life (Chen and Li 2014; Halberda et al. 2012). Indeed, regions of the brain that are activated during tests of numerical ability (also known as numerical acuity) performed on young children also are activated when professional mathematicians reason about difficult problems in their field (Amalric and Dehaene 2016). In kindergarten children, the ability to add two arrays of dots and compare the sum to a third array, when tested near the start of the school year, predicts children's learning of school math as assessed by the teacher at the end of that year (Gilmore, McCarthy, and Spelke 2010). Once children learn both number words and Arabic notation, they can use these symbols to perform symbolic arithmetic with approximate precision before they are taught any arithmetic algorithms in school (Gilmore, McCarthy, and Spelke 2007, 2010). All these findings suggest that intuitive conceptions of numbers, arising in infancy, serve as guideposts for children's learning of school mathematics.

Further studies show that children's approximate numerical acuity improves with experience. Among Amazonian children who begin their formal education at variable ages, approximate numerical acuity is better predicted by amount of schooling than by chronological age (Piazza et al. 2013). Moreover, both lab and field studies show that activities exercising intuitive, approximate number abilities produce short-term (zero to three months) enhancement in performance of symbolic arithmetic (Dillon et al. 2017; Hyde, Khanum, and Spelke 2014; Khanum et al. 2016; Park et al. 2016). When these activities occur in contexts that foster spatial

language and introduce spatial symbols, they produce more enduring enhancements to children’s school math learning (Dean et al. 2021). Young children’s inherent numerical abilities are resources to be nourished in early childhood.

Key Takeaways

- From infancy, children’s intuitive conception of numbers provides guideposts for their learning of mathematics at school.
- The right activities to exercise that intuitive ability can produce lasting improvements in mathematical learning at school.

Learning about Objects

At birth, children detect objects and follow their motions, and they use objects to guide their developing understanding of mechanical events and their engagement with the technologies of their culture. Early knowledge of objects guides not only children’s developing understanding of the physical world but also their understanding of numbers and arithmetic.

It is often said that the world of an infant is a “buzzing, blooming confusion” of sensory-motor experience, a view first articulated by William James. Jean Piaget argued instead that infants’ sensory-motor experience is organized from the start, and he rightly noted that children’s knowledge of objects grows by leaps and bounds over the first two years of life. Piaget believed, however, that infants begin with no knowledge of objects, space, or causality. Contrary to the views of James and Piaget, research on human infants, together with research on newborn animals of other species, provides evidence that infants organize their sensory world into objects from the start. They perceive depth (Adolph, Kaplan, and Kretch 2021; Gibson and Walk 1960), and they use depth relations to perceive where one object ends and the next begins (for example, the boundary between their ball and the hand of a parent who holds it), the solid shape of an opaque object whose back is not in view (Kellman 1984), and even the continued existence and solidity of an object that moves partly or wholly out of view behind another object (Baillargeon 1986; Valenza et al. 2006) or is obscured by darkness (Clifton et al. 1991). Newborn infants are prepared to learn how objects move when they are and are not stably supported, and what happens when objects fall, collide, or disappear behind other objects. From birth, infant animals perceive objects, recognize objects that are partly or fully hidden, and reason about objects’ motions and interactions (Chiandetti and Vallortigara 2011; Regolin and Vallortigara 1995), as do young human infants (for reviews, see Baillargeon 1993; Carey 2009; Kellman and Arterberry 2006), providing evidence that abilities are present at the onset of experience of the visible world.

From these beginnings, infants rapidly learn about specific kinds of objects and their behavior through their active exploration (Schulz 2012; Stahl and Feigenson 2015; Téglás et al. 2011; Ullman et al. 2017). Infants and preschool-age children learn rapidly to recognize and categorize the objects around them by their characteristic forms and functions for human action (for review, see Rakison and Oakes 2003). Over early childhood, they learn to manipulate spoons and hammers (Keen 2011), plan multistep actions that allow them to rake in an object that is out of reach (Claxton, Keen, and McCarty 2003), stack a pile of blocks into a tower that does not fall (Chen et al. 2010), and infer the hidden properties of an object, such as its weight, from its interactions with other objects (Ullman et al. 2017).

Children use their abilities to track objects to infer how the number of objects in a set changes when a single new object is added or taken away from the set (Izard, Streri, and Spelke 2014), an important milestone for the development of the number concepts used in counting and in primary school arithmetic (Carey 2009). Preschool children also use their abilities to categorize objects by their forms and functions to extend their number concepts and develop an intuitive understanding of exact arithmetic, for example, an understanding that two dogs and two cats combine to form a set of four pets (Rosenberg and Feigenson 2013). Finally, the next section shows that young children use their knowledge of inanimate objects to enhance their understanding of people and their actions, intentions, and goals.

Key Takeaways

- Early knowledge of objects guides children’s developing understanding of the physical world, including the numbers, arithmetic, tools, and technologies of their culture.
- Fostering knowledge of objects helps children navigate the world and enhances numeracy.

Learning about People’s Actions and Goals

By three months of age, infants are sensitive to people’s actions and goals, and their emerging understanding of the actions of others serves as a foundation for the development of their own motor skills and for their understanding of people’s intentions and their mental states.

From birth, newborn infants distinguish animate from inanimate objects (Meltzoff and Moore 1977) as do other animals (Mascalzoni, Regolin, and Vallortigara 2010). Young infants perceive the bodies and actions of people from their movements (Bertenthal and Pinto 1994) and infer the goals and intentions that guide those actions (Luo and Johnson 2009). Before infants can pick up and manipulate objects, they understand that other people cause their own motions and, by moving, cause changes in the objects that

they manipulate (Liu et al. 2019). As infants become able to act intentionally on objects themselves and come to understand the actions of others, their causal knowledge grows (Muentener and Schulz 2014). Moreover, infants attribute goals and intentions to other people who engage in these actions, and they infer, by observing others' actions, what objects and events the people value (Liu et al. 2017; Woodward 1998).

Over the preschool years, children's understanding of their own and other people's actions and intentions grows extensively. They come to view other people as capable of action planning, of opening a box, for example, not out of a simple desire to see a box with an open lid, but out of a desire to access the object that the box contains (Piaget 1954; Sommerville and Woodward 2005). They also come to view other people's actions not as direct responses to the external environment but as guided by their beliefs about the environment: if a person expresses a desire for an object and a belief that it lies inside a given box, children come to expect the person to search for the object inside that box, even if they themselves know that the object lies in a different location (Wellman 2014; Wimmer and Perner 1983). Children's own action planning, and their reasoning about their own mental states, develops hand in hand with their understanding of the actions and mental states of others (Comalli et al. 2016). These developments are critical foundations for children's school readiness, because children's learning from teachers depends on their abilities to understand what the teachers intend to convey to them.

Beginning in infancy and continuing through the preschool years, young children also evaluate other people on the basis of their actions. Young infants prefer individuals who take action to help (rather than hinder) others (Hamlin et al. 2013). Further, both toddlers and preschool-age children discriminate against individuals whose actions violate social norms—including those who act in ways that are unkind, unfair, or unconventional (Hamlin et al. 2011; Hardecker et al. 2016; Yang et al. 2018). Toddlers and older children also are sensitive to others' mental states when evaluating their actions; they distinguish between intentionally versus unintentionally helpful and harmful actions (Dunfield and Kuhlmeier 2010; Vaish, Carpenter, and Tomasello 2010; Woo et al. 2017). Naturalistic studies confirm that children evaluate others on the basis of their actions: children who are more prosocial tend to be more popular among peers than children who exhibit fewer prosocial tendencies (Greener 2000; Paulus 2017).

Key Takeaways

- Children's emerging understanding of people's actions and goals serves as a foundation for the development of children's own motor skills and for their understanding of people's intentions and mental states.
- Children's deepening understanding of their own and other people's actions and intentions helps children relate to others and prepares them for school.

Learning about Social Interactions, Communication, and Language

Children are sensitive to people’s social relationships, communication, language, and mental states—the foundation for socially guided learning that is central to the development of children’s knowledge, skills, and values, both at home and in school.

From birth, infants are interested in other people: they are drawn to look at faces (Valenza et al. 1996), to attend to voices over other sounds (Vouloumanos and Werker 2007), and to gestures over other actions (Goldin-Meadow 2005; Petitto et al. 2004). Infants also are predisposed to imitate other people’s sounds and gestures (Mampe et al. 2009; Meltzoff and Moore 1977; Meltzoff et al. 2018), as are other animals (Ferrari et al. 2006; Myowa-Yamakoshi et al. 2004). Infants begin to learn the sounds and words of their language by listening to the speech of others (see the section titled “Children Are Born to Learn”). As early as three months of age, infants learn by observing the actions of the people around them (Liu, Brooks, and Spelke 2019).

Learning from others accelerates in the second year. First, children begin to exhibit a remarkable, species-specific capacity to learn language from language. Although birds and border collies can learn to associate spoken words to objects (Pepperberg 1990; Pilley and Hinzmann 2014), toddlers can learn the meanings of new words in the absence of the objects they refer to, simply by observing two people in conversation (Yuan and Fisher 2009). Moreover, toddlers use other people’s speech to learn about the world: they infer a change in the state of the world simply by hearing a person’s report of that change (Ganea et al. 2007). These changes usher in a period in which children rapidly gain competence at learning from others by evaluating their competence and social appropriateness as informers (see the section titled “Young Children’s Learning Skills and Tools”).

Rich evidence suggests that all these developments are modulated by children’s social and language experience. Advances in children’s reasoning about knowledge and ignorance are predicted by individual differences in the language that children hear at home (Devine and Hughes 2018). Even children’s learning to categorize objects—a skill that is critical for tool use—and their learning of number words and symbols—learning that is critical to their readiness for learning school mathematics—are predicted best by the number of nouns in children’s language (Negen and Sarnecka 2012; Smith 2003). Analyses of recordings of the language that is spoken directly to children at home, or spoken to others within children’s hearing, reveal that children’s vocabulary, in turn, is predicted by the number of conversational exchanges children participate in or observe (Romeo et al. 2018; Wang et al. 2020).

Research in developmental cognitive neuroscience reveals rich interactions between social cognitive development, language development, learning to use symbols, and learning to read (Dehaene 2009). Early capacities for language and action planning, propelled by predispositions to learn from social others, enable literate adults to engage in rapid learning of new writing systems (Lake et al. 2017), and they prepare children who live in homes with books and family members who read with them for learning to read and write in primary school (Castles, Rastle, and Nation 2018; Duursma, Augustyn, and Zuckerman 2008).

Alphabets are symbol systems used by people to communicate information in a manner that endures over time and distances. To master an alphabetic writing system, children must recruit and orchestrate multiple abilities that begin to emerge in infancy, including their language learning, their sensitivity to spatial patterns and symbols, and especially their capacities to make sense of the actions and discern the intentions of the people who communicate with them. As children accomplish these tasks, their minds and brains undergo qualitative changes that foster the development of this critical cognitive skill (Dehaene 2009).

The skill that children gain when they learn to read comes to enhance their learning in all areas of knowledge, for the experience of reading increases children’s vocabulary, speech, writing, and, of course, their knowledge of the world (Castles, Rastle, and Nation 2018).

Key Takeaways

- Children’s early sensitivity to social relationships, communication, language, and mental states helps them learn both about and from other people in their social worlds.
- Stimulating environments promote language and literacy development, which are key for school readiness and enhance learning across all areas of knowledge.

YOUNG CHILDREN’S LEARNING SKILLS AND TOOLS

Children’s learning in all areas of core knowledge depends on an arsenal of general learning skills and tools that support children’s engagement with and learning about the world. Children’s learning depends on a host of executive functions that regulate their attention and action planning. It depends on their powers of imagination that guide their play and their simulations of actual or possible events. It depends on their capacity for metacognition, especially their understanding of what they and others do

and do not know and how their knowledge and skills can grow. And it depends on the ways in which children's learning environments cultivate their inherent motivation to learn. These skills and tools can be enhanced by the experiences that homes and preschools can provide. This section focuses on these general cognitive skills, which are most relevant to children's ability to thrive and learn in school.

Executive Functions: Focusing Attention, Planning, and Memory

Executive functions are critical for children to learn effectively and accomplish goals. Children need to be able to focus their attention, plan, remember what has gone before, and switch flexibly from one activity to the next. The cognitive skills underlying these abilities are collectively called executive functions. Researchers have identified three fundamental executive functions that support children's learning: inhibition (for example, resisting impulses, ignoring distractions), working memory (for example, keeping information in mind, playing with ideas), and cognitive flexibility (for example, changing tasks, adjusting to change) (for reviews, see Best and Miller 2010; Carlson, Zelazo, and Faja 2013; Diamond 2013; Miyake et al. 2000).

Better executive function skills are positively related to school readiness and school performance, as well as later life outcomes such as career success (for review, see Diamond 2013). They critically underlie the ability to plan sequences of actions—both overt actions and mental ones—that are central to all school activities, from performing mental calculations to writing a paragraph. Indeed, researchers have found links between executive function skills and children's learning in the core areas of knowledge reviewed in the previous section. Children with better executive function skills perform better on measures probing their mathematical skills (Bull, Espy, and Wiebe 2008; Clark, Pritchard, and Woodward 2010; Cragg and Gilmore 2014; Prager, Sera, and Carlson 2016), social reasoning (Eisenberg et al. 2004; Perner and Lang 1999; Sabbagh et al. 2006), and language abilities (Blair and Razza 2007; Follmer 2018).

Executive functions are apparent from birth (Dehaene-Lambertz and Spelke 2015) but undergo rapid improvement during early childhood (for review, see Carlson, Zelazo, and Faja 2013). This growth is supported by brain maturation, including a part of the brain, called the prefrontal cortex, that is active even before birth. Executive function skills improve naturally as children grow, but some research also indicates that executive functions can be improved through direct skill training (for example, some working memory computer games; Aksayli, Sala, and Gobet 2019) or through curricula that emphasize executive functions skill building (for example,

training teachers in helping children improve self-regulation skills; Watts et al. 2018).

However, it is important to recognize that available evidence suggests that executive function training effects are sometimes narrow (for example, children improve on the trained task or skill but not on other skills; Aksayli, Sala, and Gobet 2019) or inconsistent across measures (for example, Watts et al. 2018; for review and discussion, see Nesbitt and Farran 2021). Further, a recent large-scale, longitudinal, field-based randomized controlled trial revealed that one of the most comprehensive curricula seeking to build young children’s executive function skills (“Tools of the Mind”) is not effective (Nesbitt and Farran 2021). At this point, it is not clear which interventions are most effective for engendering meaningful improvements in young children’s executive functions.

Key Takeaways

- Executive functions help children focus their attention, plan, and remember.
- Children with better executive function skills perform better on measures probing their mathematical skills, social reasoning, and language abilities.
- It is widely believed that executive functions are malleable, but thus far efforts to improve children’s self-control, working memory, and cognitive flexibility have proved to be less successful than efforts to enhance children’s knowledge and skills in specific cognitive domains.

Imagination: Boosting Learning and Communication Skills

Research on mental simulation underscores the importance of play and other activities that stimulate children’s imagination in ECE. Mental simulations support children’s insights, discoveries, and creativity. They play an important role in children’s learning because they allow children to manipulate and rehearse ideas that have been introduced to them, thereby enhancing learning and memory for material (Allen, Smith, and Tenenbaum 2020; Piaget 1952). They also support children’s insights, discoveries, and creativity by allowing them to represent in their minds possible objects or activities that they have never witnessed, and indeed that do not yet exist (Harris 2000; Liu et al. 2019; Piaget 1952). And they allow children to learn about activities that are too hazardous to be performed directly (for example, when a child simulates a new way to get home from school).

Imagination refers to the ability to simulate, and therefore experience, events that one is not currently perceiving, including events from the distant past, events that might happen in the future, and events that could have happened but did not. Research on children’s imagination or pretend play

underscores the value of mental simulation for children’s learning in a variety of areas of knowledge. Pretending gives children the opportunity to practice expressing themselves and communicating with others (thus facilitating social and language development) (for review, see Singer, Golinkoff, and Hirsh-Pasek 2006). Further, the intensity, quality, and complexity of children’s pretense is correlated with children’s perspective-taking abilities (Lillard and Kavanaugh 2014; Taylor and Carlson 1997)—perhaps because it allows children to practice different roles (for example, parent, teacher, student).

Research in cognitive science, neuroscience, and computational sciences has revealed that processes of mental simulation are ubiquitous in animals (for review, see Foster 2017) and human adults (for example, Liu et al. 2019). Most mental simulations occur unconsciously, at far greater speeds than the actual events that are simulated—at least 10 times faster in studies measuring simulation activity in human adults, who report no awareness of the simulations that they perform over the course of learning a new, demanding task (Liu et al. 2019).¹ Building on research with rats, recent work reveals brain processes in human adults that simulate experiences of nonspatial sequential learning tasks as well as tasks of navigation and action planning, and that these simulations aid adults’ performance (Schuck and Niv 2019). To date, no experiments in cognitive neuroscience have measured these simulation processes in human infants and young children. Because infant brains are active both during sleep and at rest, beginning before birth (for review, see Dehaene-Lambertz and Spelke 2015), and because spontaneous activity in fetal brains importantly influences the strength of synaptic connections in the visual system (Katz and Shatz 1996), the role of simulation processes in children’s learning is a fruitful area for future study.

Key Takeaways

- Imagination, or pretend play, supports insight, discovery, and creativity in children.
- Pretending provides children with an opportunity to express themselves and communicate with others.
- Pretense elicits processes of mental simulation. Although simulation processes have not been studied systematically in children, they enhance learning and memory in adults and other animals, consistent with the value of pretense and imagination in children’s learning.

Metacognition: Learning to Learn

Knowing what you know, what you do not know, and how to extend your knowledge and use it more effectively are critical tools for learning at all ages (Chatzipanteli, Grammatikopoulos, and Gregoriadis 2014; Dunlosky

and Metcalfe 2008). These metacognitive abilities can motivate learners to return to or explore material they have not mastered, and to move on from material they have already mastered and build on their knowledge in productive ways (Flavell 1979; Metcalfe 2009).

Research suggests that even infants can track and communicate about their own uncertainty in some circumstances (Goupil and Kouider 2016; Goupil, Romand-Monnier, and Kouider 2016), but preschool children are able to reflect on and articulate their own states of knowledge and ignorance more clearly (Ghetti, Hembacher, and Coughlin 2013). In one study (Cherney 2003), for example, three-year-old children's use of terms connoting uncertainty (for example, "guess," "think") versus certainty (for example, "know," "forget") was related to their performance on a spatial memory task. Children who said they "knew" where a reward was, for example, were more likely to locate the reward than those who said they "thought" it was in a particular place. Both by this assessment and on other tasks, children's metacognitive abilities improve markedly between three and five years of age (Ghetti, Hembacher, and Coughlin 2013).

Metacognition improves after the preschool years as well (Lyons and Zelazo 2011). For example, children in one study (O'Leary and Sloutsky 2017) were asked to decide which of two gray boxes contained more dots. When asked how well they thought they performed on the task, five-year-old children tended to overestimate their performance, but seven-year-old children did not. Moreover, five-year-old children continued to overestimate their performance even when they received clear feedback throughout the task about their performance (a happy face appeared when they made a correct choice and a sad face appeared when they did not). These findings suggest that children—especially at young ages—may need help tracking their knowledge and performance in classrooms.

Metacognition supports children's success in school (for example, Bryce, Whitebread, and Szücs 2015) and can be improved through direct skills training programs (Dignath, Buettner, and Langfeldt 2008). Teachers can also enhance children's learning from classroom instruction by encouraging children to engage in metacognitive thinking, for example, by asking children questions about their strategies and knowledge (such as "How did you know that would work?") (Grammer, Coffman, and Ornstein 2013).

Research with older children provides evidence that metacognition can have downsides: if children decide that they are simply not talented in some areas of core knowledge, they may decrease rather than increase their efforts to learn in those areas (Dweck 2008). Young children are less apt to exhibit this counterproductive mindset, however, and curricula emphasizing "growth mindsets" about intelligence, that is, the idea that intelligence and learning, like physical strength and athletic skill, can be increased through effort, improve older children's persistence and academic

performance under some conditions (Dweck and Yeager 2019; Yeager et al. 2019), though not others (Sisk et al. 2018). Fortunately, young children appear to use their metacognitive abilities primarily to guide their learning, and they seek to learn skills and material they have not yet mastered. There are other motivational patterns that do vary across children and bear on what and when they learn, as addressed in the next section.

Key Takeaways

- Metacognition, or knowing what you know, what you do not know, and how to extend your knowledge and use it more effectively, is critical for learning at all ages.
- Metacognitive abilities can motivate learners to return to or explore material they have not mastered, and to move on from material they have already mastered.
- Children’s metacognitive abilities improve markedly between three and five years of age.

Motivation: A Key Driver for Learning

Children are naturally curious and ready to learn both on their own and from other people (see the sections titled “Children Are Born to Learn” and “Five Core Knowledge Areas”), but individual differences in motivation to learn are also evident in childhood. Three motivational constructs of particular relevance in educational settings are *interest* (engagement with materials and activities), *persistence* (the tendency to continue working on a task even when it is difficult or results in performance mistakes), and *trust* between teachers and learners.

Research with young children reveals individual differences in levels of both interest and persistence. High levels of interest and persistence predict better academic and social achievement in school. Further, both interest and persistence are correlated with parental behaviors (Martin, Ryan, and Brooks-Gunn 2013; Neitzel, Alexander, and Johnson 2019). For example, in one longitudinal study, more supportive parenting (such as noticing and responding appropriately to children’s signals) on the part of mothers of one-year-old children predicted higher interest and persistence on novel laboratory tasks at three years of age, which in turn predicted better performance on academic skills assessments in kindergarten (Martin, Ryan, and Brooks-Gunn 2013).

Outside the parent-child context, the behaviors of other adults also affect children’s motivation. For example, laboratory studies reveal that infants and toddlers will work harder to solve a problem after observing an adult expend significant energy solving a (different) problem (Leonard, Lee, and

Schulz 2017). Further, toddlers and young children persist more on difficult tasks when adults use language that emphasizes the children's actions rather than their abilities (Cimpian et al. 2007; Lucca, Horton, and Sommerville 2019). For example, in one study (Cimpian et al. 2007), researchers asked four-year-old children to role-play scenarios in which they drew a picture of an object (for example, an apple) and then heard the teacher say either "You are a good drawer" or "You did a good job drawing." Then, children role-played drawing another picture and making a mistake (for example leaving ears off a cat). Children who had previously heard the statement that focused on their ability were less interested in drawing another picture in the future compared with children who had previously heard the statement that focused on their activity.

To be motivated to learn the material and skills presented to them in school, children must trust those who seek to teach them (Corriveau and Winters 2019). In this context, it is particularly important to recognize that much of what children are taught early in their education can seem arbitrary to them. For example, in the late preschool and early school years, children are introduced to letters that combine to form the words, phrases, and texts that they will use in reading, and to numerals that combine to form the numbers, arithmetic algorithms, and equations that they will use in solving problems in mathematics. These symbols have apparently arbitrary properties: the letter is pronounced differently in different contexts (consider the h in "hat," "the," and "night"), and the same numerals convey different numbers in different arrangements (consider the 1 and 2 in "12" and "21"). Letters and numbers therefore do not represent entities in the same manner as do pictures, which can depict the same entities in different arrangements. Children, moreover, will not appreciate why letters and numbers combine as they do until they become skilled readers and arithmetic calculators. As a consequence, many of the actions of ECE teachers, and many of the tasks they set for children, occur for reasons that children cannot yet understand. To learn what they need to know in school, children must trust that their teachers' requests and demonstrations will prove to be worthwhile.

As reviewed previously (in the "Five Core Knowledge Areas" section), young children are remarkably good at learning from others—even when the basis for a teacher's actions is opaque (Csibra and Gergely 2009; Király, Csibra, and Gergely 2013). However, laboratory research shows that young children are especially motivated to trust information provided by adults who have previously demonstrated effective actions (Birch, Akmal, and Frampton 2010) as well as those who have provided accurate information in the past (Harris 2017). For example, when given the opportunity to accept or request new information from someone who has previously displayed knowledge (versus ignorance) about what different objects are called, young children favor knowledgeable adults (Jaswal and Neely 2006; Koenig and

Harris 2005). Children are also more likely to remember information that is conveyed by competent and trusted adults (Sabbagh and Shafman 2009).

Children also tend to trust adults who are members of their own sociocultural group. For example, from infancy, children attend more to those who speak with an accent that matches the children’s home community (Kinzler, Dupoux, and Spelke 2007), and preschool-age children favor information conveyed by adults who speak their language with their community’s native accent (Kinzler, Corriveau, and Harris 2011). By four to seven years of age, children are also more trusting of information provided by those who match their own racial group membership (Chen, Corriveau, and Harris 2013).

Taken together, the results from laboratory studies suggest that children in ECE will learn best from teachers who are highly knowledgeable about the material they teach and those whose social identities align with children’s homes and local communities (Corriveau and Winters 2019). Accordingly, research on children’s educational outcomes reveals that students benefit from having teachers who are members of their own sociocultural group. For example, in the United States, having just one Black teacher before third grade significantly increases Black students’ persistence and motivation in later grades and their likelihood of graduating from high school (Gershenson et al. 2021). Having a teacher who shares children’s social identity may increase children’s trust in their teacher and the information the teacher provides—but further research is necessary to pinpoint mechanisms underlying the benefits of sociocultural convergence between teachers and students.

Key Takeaways

- Children’s motivation to learn varies depending on their level of interest and persistence, as well as the trust between teachers and learners.
- High levels of interest and persistence predict better academic and social achievement in school.
- Children learn best from competent, knowledgeable, and confident adults. They tend to trust adults whose language, culture, and interests are similar to those of the people in the child’s social world.

WHAT PROMOTES AND HINDERS CHILDREN’S LEARNING?

The capacities and motivational patterns described in previous sections guide the learning of children in all cultures, across all socioeconomic

levels. Further, gender differences in cognitive abilities are largely absent (Hyde 2005; Spelke 2005). The nurturance of these abilities and motivations therefore provides a good target for ECE programs worldwide. However, context does matter for learning. As reviewed in the previous section, features of teachers (for example, their knowledge levels, their sociocultural identities and practices) affect children's trust in the information that teachers provide. Adequate sleep and nutrition, as well as positive attention from trusted adults, are critical for learning. Freedom from prejudice and stereotyping are also important. However, many children face adversity, living and learning in conditions that can hold them back from achieving their full potential. In particular, children who experience adversity face challenges that can affect the extent to which they are apt to benefit from what others try to teach them, even though their basic aptitude for learning is as high as that of other children. When designed to meet the needs of young children, high-quality ECE programs can protect early learning trajectories (Walker et al. 2011). The following discussion describes a few factors that can hinder learning and some ways in which ECE can counter them.

Malnourishment, Insufficient Sleep, and Neglect

Inadequate nutrition and sleep, as well as neglect by caregivers, can negatively affect children's ability to learn and succeed in school (Bick and Nelson 2016; Dewald et al. 2010; Grantham-McGregor et al. 2007; Jyoti, Frongillo, and Jones 2005; McLaughlin, Sheridan, and Lambert 2014; Smith and Pollak 2020; Winicki and Jemison 2003). However, these negative influences can be at least partially addressed in schools: First, some studies reveal positive effects of school-delivered meals and snacks on children's learning and academic outcomes (for example, Aurino et al. 2018; Chakraborty and Jayaraman 2019). Second, classroom naps have been shown to boost young children's learning by enhancing their memory for information presented during the school day (Kurdziel, Duclos, and Spencer 2013). Third, when ECE educators who provide emotional warmth, sensitivity, and responsiveness are available, children can develop a secure attachment relationship with them (Fuhs, Farran, and Nesbitt 2013), which in turn can promote the growth of self-reliance, the capacity for emotional regulation, and the emergence and course of social competence, among other things (Sroufe 2005). ECE programs can also promote children's emotional security through consistency in the behavior and expectations of educators who establish clear and consistent routines for children (Williford, Carter, and Pianta 2016).

Social Biases

Young children detect and care about social categories and social group memberships—including those based on ethnicity, race, gender, and class (Rhodes and Baron 2019; Shutts 2015; Shutts et al. 2016; Skinner and Meltzoff 2019). Unfortunately, children’s sensitivity to social grouping—and to societal stereotypes—can lead them to think and behave in ways that are unfair and unkind in the classroom. Children from stigmatized groups commonly experience negative treatment on the basis of their group membership (for example, negative stereotyping, teasing, and social exclusion), and such experiences are associated with poorer academic outcomes (for example, Levy et al. 2016; Wong, Eccles, and Sameroff 2003). Research on effective strategies for identifying and addressing social biases—in particular, strategies that produce robust, long-term decreases in biases—in school is sorely needed.

Key Takeaways

- To fulfill their learning potential, children need adequate sleep and nutrition, positive social relationships with adults they trust, and freedom from prejudice and stereotyping.
- ECE can address negative factors that hinder learning.

CONCLUSION AND AREAS FOR FUTURE RESEARCH

The cognitive capacities reviewed in this chapter emerge in infancy and function throughout life. They are possessed by all children, and they can be harnessed to foster children’s learning in all countries and cultures. To realize this promise, however, ECE must be sensitive to children’s current level of understanding; take place in settings that address children’s needs for food, rest, and a safe, predictable environment; and engender children’s trust in those who teach them.

Young children explore and learn rapidly and spontaneously by building on five core areas of knowledge. Children are primed to learn by understanding places, numbers, objects, people, and relationships. We can support their predisposition to learn by enhancing the development of four key sets of skills, from executive functions and imagination to metacognition and motivation to learn. Together, this knowledge can be harnessed to establish solid foundations for quality early learning for children everywhere.

Despite how much the understanding of what and how young children learn has grown in recent decades, many open questions remain, providing a road map for future investigation. For example, because children learn by building on what they already know, how can insights from the science of learning be translated into effective early school curricula? Efforts to develop effective curricula for preschool children are hindered by the absence of systematic evaluations of specific curricular practices at this level. Nevertheless, research investigating the long-term impacts of preschools on children's school learning make it clear that curricula matter: randomized controlled experiments that test and compare the effectiveness of different curricula for enhancing preschool children's learning can reveal the strengths and weaknesses of different preschool curricula.

Field testing of educational curricula may be criticized for producing findings that may not generalize to populations and cultures beyond where the curriculum is tested, both because children in different cultures come to school with different experiences and expectations and because schools in different countries may have different educational goals for their children. The latter differences have diminished, however, given the importance of educating children to contribute to the global economy, and educational goals are easier to measure, thanks to the advent of international evaluations of students' achievement in different countries. Although children in different cultures do vary in their experiences, cultural variations are not likely to exert prominent effects on curricular interventions that are based on findings from studies of early cognitive development. The cognitive capacities reviewed in this chapter emerge in infancy and continue to function throughout life. They are possessed by all children, and they foster children's learning in all countries and cultures and at all economic levels. This research also can be harnessed to support the development of curricula, pedagogy, and learning environments, as well as to inform teacher and school management training.

Because children learn from people they trust and people from their communities, how can learning environments be created that bridge to children's homes and communities and that foster that trust? Many school systems use sports, music, and art to bridge cultural divides within the school and enlist children in activities with common goals. However, systematic studies have not measured the impacts of such activities on children's learning of the primary school curriculum: learning to read, to communicate effectively, to calculate, to measure, and to reason about the physical world, the living world, and the social and cultural environment. For example, one review of experiments evaluating effects of music training on children's school-relevant skills finds no consistent evidence that music training benefits young children's academic performance (Mehr 2015).

An alternative strategy is to introduce games with academic content into preschool and primary school classrooms as a complement to the regular academic curriculum. Recent experiments have evaluated one set of curricula for preschool, kindergarten, and first grade children consisting of games with numerical and spatial content, played socially by groups of children, led by local community members (Dillon et al. 2017) or by the regular kindergarten or first grade teacher (Dean et al. 2021; see also Clements et al. 2011; Griffin and Case 1997). The games aimed to foster children's social and communicative skills of teaching to and learning from others, as well as skills of numerical and spatial cognition. The curriculum involved no specific teaching of arithmetic, but the two best-performing curricula included both instruction in and play with spatial symbols and with numerals and their combinations. As noted in the section "Young Children's Learning Skills and Tools," these symbols and combinations follow rules that preschool children are not yet in a position to understand. When children are challenged to learn these rules in a social, game context, however, they may be motivated to master them, thereby gaining skill in an enjoyable group activity and taking the first steps in mastering these symbol systems. These curricula showed positive effects on children's numerical and geometrical reasoning, both on an immediate posttest (Dillon et al. 2017) and on tests conducted one year later (Dean et al. 2021). Because most of the children had completed the first year of primary school at the latter time point, the games may have helped both to build children's knowledge of mathematical symbols in preschool and to enhance their trust in the primary school teachers who delivered their subsequent instruction in formal mathematics.

Because productive learning happens both inside and outside school, how can adults who care for children (for example, parents, preschool teachers, primary school teachers, social workers, health care professionals) become involved in activities that promote young children's learning and healthy development and that ready them, cognitively and motivationally, for formal learning in school? Studies in developmental cognitive science suggest a wealth of activities that children might share with their siblings and family members, and that might enhance their cognitive development either at home or in preschools. In the coming years, more programs to develop, implement, and evaluate these activities in preschool and early primary school settings would be welcome. This research will be especially valuable if the curricula that it evaluates target abilities and propensities that emerge early in the preschool years, building on capacities that are shared by all children. Specific curricula that build on children's universal capacities for understanding the world, exploring, and learning may or may not prove to be effective in the field: their effectiveness must be tested in systematic field experiments. If curricula building on universal

capacities are found to be successful in one culture, however, they are likely to be effective for children in other cultures as well. Research that implements and evaluates both home-based and preschool-based activities to enhance young children’s reading readiness, math readiness, executive function, metacognitive skills, persistence, and trust in teachers promises to provide valuable information on how to better prepare all the world’s children for the transition to school (for example, Mackey et al. 2011).

See table 1.1 for a review of the key takeaways in this chapter.

Table 1.1 Chapter 1: Summary of Key Takeaways

Children are born to learn

- Children are the most capable learners on earth.
- Children’s learning in the early years sets the stage for lifelong learning.

Learning about places

- Early spatial abilities support children’s learning about their immediate environment, as well as spatial symbols such as pictures, maps, scale models, and number lines.
- Young children’s spatial abilities can be nourished to enhance school readiness.

Learning about numbers

- From infancy, children’s intuitive conception of numbers provides guideposts for their learning of mathematics at school.
- The right activities to exercise that intuitive ability can produce lasting improvements in mathematical learning at school.

Learning about objects

- Early knowledge of objects guides children’s developing understanding of the physical world, including the numbers, arithmetic, tools, and technologies of their culture.
- Fostering knowledge of objects helps children navigate the world and enhances numeracy.

Learning about people’s actions and goals

- Children’s emerging understanding of people’s actions and goals serves as a foundation for the development of children’s own motor skills and for their understanding of people’s intentions and mental states.
- Children’s deepening understanding of their own and other people’s actions and intentions helps children relate to others and prepares them for school.

Learning about social interactions, communication, and language

- Children’s early sensitivity to social relationships, communication, language, and mental states helps them learn both about and from other people in their social worlds.
- Stimulating environments promote language and literacy development, which are key for school readiness and enhance learning across all areas of knowledge.

continued next page

Table 1.1 (continued)**Executive functions: Focusing attention, planning, and memory**

- Executive functions help children focus their attention, plan, and remember.
- Children with better executive function skills perform better on measures probing their mathematical skills, social reasoning, and language abilities.
- It is widely believed that executive functions are malleable, but efforts to improve children's self-control, working memory, and cognitive flexibility have proved to be less successful than efforts to enhance children's knowledge and skills in specific cognitive domains.

Imagination: Boosting learning and communication skills

- Imagination, or pretend play, supports insight, discovery, and creativity in children.
- Pretending provides children with an opportunity to express themselves and communicate with others.
- Pretense elicits processes of mental simulation. Although simulation processes have not been studied systematically in children, they enhance learning and memory in adults and other animals, consistent with the value of pretense and imagination in children's learning.

Metacognition: Learning to learn

- Metacognition, or knowing what you know, what you do not know, and how to extend your knowledge and use it more effectively, is critical for learning at all ages.
- Metacognitive abilities can motivate learners to return to or explore material they have not mastered, and to move on from material they have already mastered.
- Children's metacognitive abilities improve markedly between three and five years of age.

Motivation: A key driver for learning

- Children's motivation to learn varies depending on their level of interest and persistence, as well as the trust between teachers and learners.
- High levels of interest and persistence predict better academic and social achievement in school.
- Children learn best from competent, knowledgeable, and confident adults. They tend to trust adults whose language, culture, and interests are similar to those of the people in the child's social world.

What promotes and hinders children's learning?

- To fulfill their learning potential, children need adequate sleep and nutrition, positive social relationships with adults they trust, and freedom from prejudice and stereotyping.
- ECE can address negative factors that hinder learning.

Source: Original table for this publication.

Note: ECE = early childhood education.

NOTE

1. Striking demonstrations of the role of mental simulation in learning, memory, and invention come from experimental research with rodents. For example, researchers have found that, when a rat completes spatial navigation tasks (that is, mazes), different cells in the hippocampus fire as the rat changes its location (O'Keefe and Nadel 1978). Interestingly, the same hippocampal neurons also fire after rats complete the maze (and do so in the same order; Gupta et al. 2010). This so-called replay at rest is critical to supporting rats' learning and memory; when neuronal replay is blocked during the rest period, rats' learning is impaired (Girardeau et al. 2009). But simulations are not simply faithful replays of a rat's past experience: rats also simulate paths through the environment that they have never taken because barriers stood in their way (Gupta et al. 2010; Ólafsdóttir et al. 2015). In this respect, rats' simulations resemble those of toddlers at play (for example, Leslie 1987).

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