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CONTINUING EDUCATION

Children's Evolved Learning Abilities and Their Implications for Education

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Abstract
In this article, I examine children's evolved learning mechanisms that make humans the most educable of animals. These include (1) skeletal perceptual and cognitive mechanisms that get fleshed out over the course of development, mainly through play; (2) a high level of plasticity that is greatest early in life but that persists into adulthood; (3) remarkable social-learning capabilities; and (4) dispositions toward exploration and play. I next examine some evolutionary mismatches—conflicts between psychological mechanisms evolved in ancient environments and their utility in modern ones—specifically with respect to modern educational systems. I then suggest some ways educators can take advantage of children's evolved learning abilities to minimize the effects of evolutionary mismatches, including (1) following developmentally appropriate practices (which are also evolutionarily appropriate practices), (2) increasing opportunities for physical activities, (3) increasing opportunities to learn through play, and (4) taking advantage of stress-adapted children's "hidden talents." I argue that evolutionary theory informs teachers and parents about how children evolved to learn and can result in more-enlightened teaching methods that will result in a more enjoyable and successful learning experiences for children.

Keywords Plasticity · Social learning · Exploration · Play · Evolutionary mismatches · Developmentally appropriate practice

Homo sapiens is an exceptional species, particularly with respect to learning novel information. Yet, with the possible exception of language, humans' cognitive abilities are not unique but can be found in varying degrees and distributions in other animals. No other species, however, has the combination of cognitive mechanisms or their flexible use that humans do. Humans also inhabit a broader range of ecologies than any other mammal, and this has resulted in substantial cultural diversity,

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necessitating flexible cognitive (and social-cognitive) abilities. Because of the range of physical and social environments that humans may be born into, they must be accomplished learners, able to acquire the specific technical and social skills of their culture. In other words, they must be highly educable. However, acquiring the many skills and customs of any human culture takes time, and humans' slow road to maturity provides that time and coevolved with the brain enhancements required for survival in any human society.

In this literature review, I first explore children's evolved learning abilities, followed by looking at mismatches between some of these learning abilities and modern environments. I then make some suggestions to minimize these mismatches to enhance children's education by taking advantage of their evolved learning abilities in educational settings.

The Evolution and Development of Children's Learning

Learning—changes in behavior or knowledge as a result of experience—is found in all animals with a nervous system but is especially important for long-lived species that inhabit varied environments. Natural selection has provided such animals with specialized perceptual and cognitive mechanisms associated with a species' ancestral ecology that maximize learning. Natural selection has further shaped learning-related mechanisms in the young of some species, providing special developmental adaptations suitable for an animal's particular ontogenetic niche (Bjorklund, 2015). This is especially true for human children, who evolved the abilities to acquire—over the course of nearly two decades before attaining adulthood—the technological and social knowledge of any of the diverse human cultures.

Children's impressive learning abilities are afforded by a big brain that provides the neural architecture for language, enhanced working-memory capacity, focused attention, self-regulation, and planning; but in addition, human children possess a suite of evolved adaptations that permit them the unparalleled capacity to adapt to seemingly any human culture: (1) skeletal perceptual and cognitive mechanisms that get fleshed out over the course of development; (2) a high level of plasticity—the ability to modify one's behavior, cognition, and brain—that is greatest early in life but that persists into adulthood; (3) remarkable social-learning capabilities; (4) dispositions toward exploration and play. These are the backdrop for children's exceptional learning abilities and provide parents and educators with insights into how best to educate the young of their species.

The Evolution and Development of Skeletal Perceptual and Cognitive Mechanisms

Mainstream evolutionary psychology has been rightly criticized for proposing that children are born with innate mechanisms that operate relatively effectively given the right degree of maturation and the appropriate triggering stimuli. This perspective has difficulty explaining humans' abilities to master evolutionarily novel skills, such as reading, or dealing with evolutionarily novel environments, such as schools; it also minimizes (or eliminates) the role of development in explaining human learning and cognition. At the other theoretical extreme is the equally untenable blank-slate position, arguing that all neurologically typical humans are born with a brain without biases or constraints and that people acquire all culturally relevant behaviors via domain-general learning mechanisms. This is the *Standard Social Science Model* that Tooby and Cosmides (1992) critiqued in their early advocacy of evolutionary psychology theory; there is simply too little time and too much for children to learn, from language to social norms, for an unconstrained and unbiased brain to master. An intermediate position, which describes better the actual process of development, is provided by evolutionary developmental psychologists, who propose that infants are born with some low-level perceptual and cognitive biases and constraints that make acquiring some content and abilities easier than others (Bjorklund, 2021; Geary, 2005). Abilities associated with evolutionarily-relevant domains (e.g., tool use or social relations) increase in sophistication as they are fleshed out over the course of development through exploration, play, and social interaction. Thus, what evolved are not fully functioning (i.e., innate) abilities, but rather low-level mechanisms that emerge in a species-typical manner when infants and children experience a species-typical environment.

Take, for example, people's fear of snakes. Research has shown that infants and toddlers are not inherently fearful of snakes, in fact they are often quite fascinated by them (LoBue & Adolph, 2019); however, young children seem to be *prepared* to acquire a fear of snakes relative to other potentially dangerous animals. This is reflected in studies in which infants were shown videos of snakes and other exotic animals, with the videos being associated with either a fearful or a pleasant voice (DeLoache & LoBue, 2009). Although the type of voice made no difference in how long the infants looked at the other potentially dangerous animals, they looked significantly longer at the videos of snakes when they were paired with a fearful voice versus a pleasant voice. Apparently, natural selection used snakes' serpentine movement, distinct from the movement of most vertebrates, as the basis for developing an adaptive response to a potentially deadly animal (see LoBue & Adolph, 2019 and Rakison, 2022 for reviews).

As another example, consider young children's development of tool use. Human artifacts are ubiquitous, and although tool use is not unique to humans, the environments of no other species are so filled with artifacts, mostly tools used to solve problems of daily living. Researchers have discovered that children as young as 12 months easily acquire the *design stance* when it comes to tools—believing that a tool was designed for a specific purpose. For example, young children believe that hammers are for hitting and spoons are for eating, and, as a result, are less apt to use a tool for a purpose other than one they had been shown (Bloom & Markson, 1998; German & Johnson, 2002). This is known as *functional fixedness* and is usually seen as a hindrance to problem solving, in that it can inhibit innovation. However, the expression of the design stance in young children may be better viewed as adaptive, in that it facilitates children's understanding of how to use important artifacts in their culture. By watching and imitating more knowledgeable adults who use a tool in a functional way, children can more easily acquire proficient tool use than would be the case with a trial-and-error procedure. According to Casler and Kelemen (2005, p. 479), "young children exhibit rapid learning for artifact function, already possessing an early foundation to some of our most remarkable capacities as tool manufacturers and users."

Such fleshed-out, evolved biases can be thought of as *adaptations*, alterations in the structure or function of an organism that provided a survival or reproductive benefit to one's ancestors. Some of the adaptations seen early in life may be immature expressions of similar adaptations useful in adults, such as those dealing with social relations or perhaps tool use. Others, called *ontogenetic adaptations* (Bjorklund, 1997, 2015; Hernández Blasi & Bjorklund, 2003), serve to adapt infants and children to their current environment (the niche of childhood) and not necessarily to future ones, and disappear or are substantially modified when they are no longer useful. Although many ontogenetic adaptations are found in infancy or even the prenatal period (e.g., neonatal reflexes; fetuses getting oxygen and nutrition through the umbilical cord), others are found in early childhood and may be especially influential in how and what children learn (e.g., young children's rapid adoption of the design stance, making acquisition of culturally appropriate tool functions highly likely). For example, children's tendencies to overestimate their cognitive and behavioral abilities may affect their perception of how well they are performing a task, their persistence on a task, and thus their eventual mastery of that task (Lockhart et al., 2017).

As another example, consider *egocentricity*, Piaget's observation that young children see the world from their own perspective and have a difficult time putting themselves in someone else's shoes. Children become less egocentric with age (although none of us completely outgrows it), and such a self-centered perspective clearly limits the performance on many cognitive and social-cognitive tasks. However, despite its limitations, an egocentric perspective may afford some benefits to young children. For example, young children's egocentricity causes them to reference objects and events to themselves, and such promiscuous self-referencing may have benefits for learning. Research has shown that children tend to remember items and experiences better when the learner is told to reference the event to themselves (How does this word relate to you?) (e.g., Ross et al., 2011), something that young children are wont to do on their own.

Geary (1995, 2005) developed a model that describes how low-level, skeletal abilities are transformed into adaptive cognitive mechanisms. Geary proposed the existence of different evolutionarily relevant *domains of mind*, with low-level abilities hierarchically related to other abilities within the same domain (see also Mithen, 1996). Geary's model is illustrated in Fig. 1. Geary proposed two overarching domains, one dealing with ecological information (folk biology and folk physics) and the other dealing with social information (folk psychology), with each domain, in turn, consisting of more specific domains (biological and physical for ecological; the self, individual, and group for social), which themselves consist of even more rudimentary domains. As mentioned previously, abilities in these lowest-level domains become fleshed out in development through exploration, play, and social interaction. Geary further distinguished between *biologically primary* and *biologically secondary abilities*, the former being selected by natural selection over the

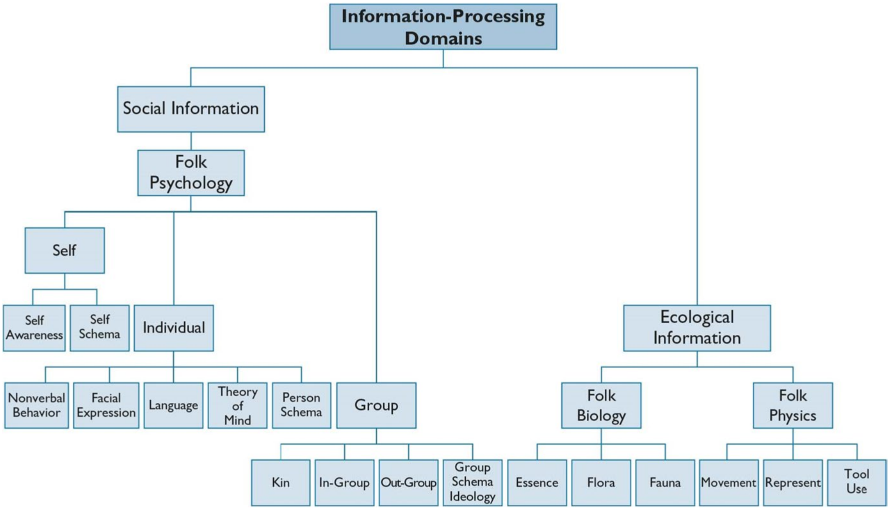

Fig. 1 Geary proposed that the mind is hierarchically organized into domains, with lower-level modules, designed to process less-complex information, serving as building blocks for higher-level more complex and flexible modules. Within the social domain of folk psychology, domains are further organized into those dealing with **a** self-knowledge, **b** individuals, and **c** groups. Within the ecological domain, Geary proposes two subdomains, one dealing with the biological world and the other the physical world. (Source: Geary, D. C. (2005). The origin of mind: evolution of brain, cognition, and general intelligence. American Psychological Association.)

course of evolution, whereas the latter are cultural inventions built upon biologically primary abilities. Biologically primary abilities are species universal, children are intrinsically motived to exercise them, and they are acquired by children in all but the most deprived environments. Language is a prototypic example of a biologically primary ability. In contrast, biologically secondary abilities are cultural inventions, and external pressure and tedious repetition are often necessary for their mastery. Reading is a prototypic example of a biologically secondary ability.

Geary's proposal of the existence of biologically secondary abilities acknowledges the obvious fact that many contemporary human cognitive skills did not themselves experience selection pressures but are evolutionary novelties and unique to specific societies. This realization means that humans evolved not only domain-specific abilities associated with recurrent problems faced by their ancestors, but also cognitive mechanisms able to adapt to novel circumstances, unanticipated by natural selection. To accomplish this, Geary proposed a domain-general mechanism that affords the neural, cognitive, and behavioral *plasticity*—the ability to change—required for the acquisition of biologically secondary abilities. Such plasticity is greatest early in life and increases the chance that children will acquire the skills necessary for success in their particular ecological niche.

Developmental Plasticity and Children's Sensitivity to Early Environments

Learning involves changes in behaviors, knowledge, and thus in brains, and can be thought of as an example of plasticity. The nervous systems of young organisms are particularly plastic, permitting them to adjust to a range of environments and often to recover from the effects of early deleterious experiences. This is especially true for *Homo sapiens*, who demonstrate a degree of neural and cognitive plasticity unmatched by any other species, which persists, in varying degrees, into adulthood. Perhaps somewhat ironically, this enhanced plasticity was afforded in large part by retention of infantile or juvenile ancestral traits into later development, a phenomenon referred to as *neoteny*. Relative to other great apes, humans retain into infancy and early childhood the rapid prenatal rate of brain growth in terms of size of neurons, formation of dendritic connections, and myelination (e.g., Liu et al., 2012; Miller et al., 2012). As a result, much brain development, that would occur in the warmth of their mothers' womb if human infants followed the typical primate pattern, now occurs postnatally in a world filled with sights, sounds, and social interactions, which, some scholars have proposed, changed the very nature of human cognition (e.g., Bjorklund, 2021; Konner, 2010).

Humans' extension of prenatal brain-growth rate provides infants with a prolonged period of developmental plasticity, before too many neurons become dedicated to specific functions. This can be seen in young children's abilities to recover from the negative effects of early deleterious environments, including damage to certain areas of brain, and growing up in deprived conditions such as those associated with stultifying institutions. With respect to recovery of function from brain damage, evidence dating back to the nineteenth century clearly demonstrates that young children with damage to language areas of the brain show far greater recovery of function than older children or adults. According to Witelson (1987, p. 676), "there is a remarkable functional plasticity for language functions following brain damage in childhood in that the eventual cognitive level reached is often far beyond that observed in cases of adult brain damage, even those having extensive remedial education. These results attest to the operation of marked neural plasticity at least in the immature brain." Similar patterns are observed for less-severe brain injuries such as concussions (see Yeats & Taylor, 2005). With respect to recovery from the deleterious effects due to lack of social and physical stimulation associated with institutional life, a number of studies clearly show that children who are removed from such institutions and placed in adoptive or foster homes by the age of about 2 years typically show reversals of their early impaired conditions; recovery is less likely when children remain institutionalized beyond their second birthdays (e.g., Bick et al., 2018; Nelson et al., 2007). Children's extended period of brain development affords them the plasticity to substantially alter their course of ontogeny in response to changes in their environment.

Although plasticity decreases with age, it does not disappear, and, in fact, human neural plasticity is extended later in life relative to that found in other primates. For example, gene expressions associated with synapse formation (*synaptogenesis*) in the cerebral cortex peaks later in humans (about 5 years) than in chimpanzees (before 1 year) (Liu et al., 2012), and, critically, is similar in adolescent and adult humans to that observed in juvenile chimpanzees (see Bufill et al., 2011; Somel et al., 2009). According to Bufill et al., (2011, p. 735), "human neurons belonging to particular association areas retain juvenile characteristic throughout adulthood, which suggests that a neuronal neoteny has occurred in *H. sapiens*, which allows the human brain to function, to a certain degree, like a juvenile brain during adult life… Neuronal neoteny contributes to increasing information storage and processing capacity throughout life, which is why it was selected during primate evolution and, to a much greater extent, during the evolution of the genus *Homo*."

There are many implications for human infants' and children's extended plasticity. One is that the nervous systems of young humans are immature and limited to how they can make sense of some forms of stimulation. For example, infants and young children process information more slowly than older children and adults, with little processing being *automatic*, such that it requires little of one's limited mental/neural capacity. This slower, inefficient processing may make some educational interventions ineffective, and perhaps even detrimental, a topic I will examine briefly in a later section. Despite the obvious disadvantages of infants' inefficient neural processing, there are some benefits. According to Bjorklund and Green (1992, pp. 49–50):

Because little in the way of cognitive processing can be automatized early, presumably because of children's incomplete myelination, they are better prepared to adapt, cognitively, to later environments. If experiences early in life yielded automatization, the child would lose the flexibility necessary for adult life. Processes automatized in response to the demands of early childhood may be useless and likely detrimental for coping with the very different cognitive demands faced by adults. Cognitive flexibility in the species is maintained by an immature nervous system that gradually permits the automatization of more mental operations, increasing the likelihood that lessons learned as a young child will not interfere with the qualitatively different tasks required of the adult.

Children's Remarkable Social-Learning Abilities

Homo sapiens are special among animals in a number of ways (although this could be said of any extant species), among them, possessing a high degree of sociability. In fact, humans can be described as a *hypersocial species*, similar in many ways to the eusocial insects, but with the addition of a large brain (Tomasello, 2019; Wilson, 2013). Humans have evolved a complex suite of social adaptations, developed over infancy, childhood, and adolescence, beginning with attachment in infancy to mating and parenting behaviors in adulthood. Among these social adaptations are those related to *social learning*—the acquisition of social information and behavior, or more generally, situations in which one individual comes to behave similarly to others—and it is via social learning that children and adults acquire much of what is important to succeed in any culture.

Before examining children's social-learning abilities, it is necessary to take a step backwards to examine the developmental root of humans' remarkable sociality, the ability to view others as *intentional agents*, people who do things for a reason, or "on purpose." Viewing others as having intentions—including knowledge, beliefs, and desires—develops over infancy and is clearly expressed as infants engage in *shared attention*, which involves the triadic interaction between two social partners (e.g., an infant and her mother) and a third object (which can sometimes be another person). For instance, a mother may point or gaze at an object while catching her infant's attention, drawing the baby into a social relationship that extends beyond the mother–infant dyad. Although parents may engage in such behavior from the earliest days of an infant's life, it is not until about 9 months that infants actively partake in shared attention, with this ability increasing in frequency and sophistication over the next year or so (see Tomasello, 2019). Treating others as intentional agents is the basis for all subsequent social adaptations, including theory of mind and advanced forms of social learning. Although chimpanzees show some glimmer of understanding that other individuals have intentions (e.g., they will follow the gaze of another animal), they do not seem to engage in shared attention equivalent to what 9- and 10-month-old human babies do (Carpenter et al., 1995; Tomonaga et al., 2004).

The ability to treat others as intentional agents is central to the more advanced forms of social learning. For example, in *emulation*, an individual identifies the goal of a model but does not copy the precise behaviors to achieve that goal (i.e., same goals but different means). For instance, a child watches someone sifting sand through her fingers to get seashells, but, instead of sifting, he tosses sand in the air to reveal the shells. Emulation can be contrasted with *imitation*, where the observer both understands the goal of the model and uses the same or similar behaviors to achieve the goal (i.e., same means and goals). The most sophisticated form of social learning is *teaching*, or *instructed learning*, in which "the teacher" modifies their behavior only in the presence of "the student," without the teacher getting any immediate benefits (Nielsen, 2012; Tomasello et al., 1993).

Although it is often difficult to distinguish among these different forms of social learning, research has shown that toddlers are aware of a model's intentions and will often engage in emulation rather than imitation, attaining the goal a model *intended* rather than one that was observed. For example, 18-month-olds who watched a model seemingly trying to remove the wooden ends of a dumbbell but failed, later, when given the dumbbells, successfully removed the ends, presumably achieving the goal the model intended rather than the one the model achieved (Meltzoff, 1995). Most chimpanzee social learning seems to involve emulation rather than true imitation (Horner & Whiten, 2005; Nagell et al., 1993).

Something interesting happens with children, however, around 3 years of age. Now children will engage in *overimitation*, copying all actions of a model, both relevant and irrelevant (Lyons et al., 2007; Nielsen et al., 2015). For example, in a pioneering study (Lyons et al., 2007), preschool children watched adults perform a series of actions on a puzzle box to retrieve a toy. Some of the actions were irrelevant to opening the box, but even when children were warned to avoid "silly," unnecessary actions, they copied them anyway. There have now been dozens of studies examining overimitation (see Hoehl et al., 2019; Whiten, 2019 for reviews); overimitation has been observed in children from both Western and traditional cultures (Nielsen et al., 2014; Stengelin et al., 2020), and although the degree to which children will copy irrelevant actions varies somewhat with context, it is not too much of an exaggeration to say that young children are almost slavish imitators. In contrast, there is no evidence that chimpanzees, humans' closest genetic relatives, engage in overimitation (Clay & Tennie, 2018; Nielsen, 2012).

Although at first glance overimitation would appear to be maladaptive, it seems to provide some benefits for social learning and continues to be observed in adults (McGuigan et al., 2011). For example, Nielsen (2012, p. 117) proposed that "directly replicating others… affords the rapid acquisition of a vast array of skills that have been developed and passed on over multiple generations, avoiding the potential pitfalls and false end-points that can come from individual learning." Moreover, children assume that what important (and usually more knowledgeable) members of their community do is culturally appropriate, or *normative*, and as being important for the "bigger overarching action sequence" (Kenward, 2012; Keupp et al., 2013). Rather than reflecting a form of inefficient cognition, overimitation may represent a human adaptation affording quick and accurate transmission of information between individuals, which Csibra and Gergely (2011) referred to as *natural pedagogy*, arguing that when learning to use objects by observing adults, children apply an *assumption of relevance*, presuming that all actions are necessary for achieving a goal.

Social learning reaches its zenith in teaching, or instructed learning, which requires a more sophisticated theory of mind, as both teacher and student must appreciate the knowledge, desires, and intentions of the other for effective pedagogy to occur. According to Tomasello and his colleagues (1993, p. 500), "To learn from an instructor culturally—to understand the instruction from something resembling the instructor's point of view—requires that children be able to understand a mental perspective that differs from their own, and then to relate that point of view to their own in an explicit fashion." Effective learning through teaching is seen at about the same time in development as overimitation, around 3 years of age, and would seemingly reflect a major evolutionary change in learning. Teaching has been observed in other animals, including some great apes, to transmit forms of grooming, greeting, and tool use (e.g., cracking nuts or "fishing" for termites, e.g., Whiten et al., 1999). However, it is rare, and no other animal engages in teaching to the extent that humans do. And unlike humans, there is no evidence of cumulative culture in great apes, with an invention or skill developed by one generation being passed on to the next, avoiding the necessity for each generation to "reinvent the wheel."

One must be cautious, however, in attributing too much of humans' ecological dominance to teaching. Although teaching is ubiquitous in Western cultures (people even speak, inappropriately, of teaching children to walk and talk), it is infrequent in traditional societies, with adults rarely directly instructing children (Lancy, 2010, 2015; Lew-Levy et al., 2017, 2020). For example, in a meta-ethnographic review of studies examining how hunter-gatherer children acquire subsistence skills, Lew-Levy and her colleagues (2017) reported that it is not until adolescence before adults begin to directly teach children complex skills such as tool manufacture and hunting. Adults in traditional and hunter-gatherer societies do, however, engage in what could be described as indirect teaching of children, as reflected by storytelling around evening fires or providing children with toy tools to use in their play, which contribute to children's acquisition of important skills and knowledge (e.g., Lew-Levy et al., 2017; Nowell, 2021; Riede et al., 2018, 2021). Regardless if we focus on teaching or imitation, children develop remarkable social-learning abilities over the preschool years, with social learning being the principal mechanism responsible for *Homo sapiens'* expansive material and intellectual culture (Legare, 2019; Tomasello, 2019).

Young Children's Dispositions Toward Exploration and Play

I mentioned earlier ontogenetic adaptations, mechanisms that may enhance children's learning at a particular time in development. Perhaps the most important of these seemingly immature tendencies with respect to learning are young children's tendencies toward exploration and play. Both exploration and play are especially characteristic of young children, foster learning, and decrease in frequency (but never totally disappear) with increasing age.

Exploration. Exploration is reflected by curiosity, neophilia, and learning about the properties of new objects and events. Gopnik (2020) makes the distinction between exploration and *exploitation*, which is reflected by focused attention and long-term, goal-directed actions and is a feature primarily of adulthood. Clearly, exploration and exploitation co-exist at all (or nearly all) stages of development, but young children's disposition toward exploration, afforded in large part by their high level of cognitive and neural plasticity, is well suited to the demands of early life and the need to learn the rudiments of many artifacts and social conventions. The youthful tendency toward exploration is beneficial to many animals, but it is especially important to long-lived animals that live in diverse environments with a broad range of behavioral possibilities. This, of course, is especially true of humans. Following Geary (2005), children would be especially motivated to explore domains associated with biologically primary abilities (discussed earlier) in the realms of folk psychology (e.g., social relations), folk biology (understanding living things), and folk physics (e.g., affordance of objects and tool use).

Given young children's relative lack of knowledge for most things in the world (they can be considered "universal novices"), it seems obvious that they would engage in exploration more so than older children and adults; their greater exploratory tendencies might simply be a by-product of their lesser world knowledge. However, recent research has shown that on causal-learning tasks (e.g., what combination of factors is responsible for a specific outcome), children are more likely than adults to explore alternative outcomes (especially potentially costly ones) and thus more likely to discover the structure of the task. For example, in a series of experiments, Liquin and Gopnik (2022) presented children and adults with a child-friendly task in which they had to decide what combination of features (blocks varying in pattern, spots vs. stripes, and color, white vs. black) made a "zaff machine" light up. The researchers reported that 4- to 7-year-old children explored the structure of the task more so than adults and learned the structure of the task better than adults, despite realizing—as the adults—that exploration would be costly.

Given humans' extended childhood, children's high degree of plasticity, and the wide range of physical and social environments in which children could possibly live, a propensity toward exploration early in life, often at the expense of exploitation, would be highly adaptive. Gopnik (2020, p. 4) captured this idea well writing, "a human mind has to explore the very wide and unpredictable range of human possibilities, both in terms of possible actions and possible hypotheses. You could think of an extended curious childhood with particularly powerful kinds of learning as a kind of turbo-powered super-sensitive period—a protected time to extract information from the environment through exploration and to imagine even far-away and unlikely hypotheses."

Play. Children play. Barring malnutrition and truly dangerous local environments, children in all cultures and throughout history play. Although play is sometimes called "the work of children," this is accurate only to the degree that it is what children spend the bulk of their time doing, much as adults spend their time working. Unlike work, play is not serious, but is fun; it is engaged in voluntarily and has no purpose other than its own activity. Playing is its own reward, not an intentional means to an end.

Despite its "purposeless" nature, no scholar of children's play believes that it has no purpose. Children in all cultures learn much about artifacts, cultural norms, and details of their local environment via play. Through play children can try out new behaviors in safe surroundings and develop their motor skills, tool-using abilities, and cognition (see Pellegrini, 2013; Yogman et al., 2018). For example, *locomotor* (or *physical*) *play* involves vigorous activity, including wrestling and play fighting, which can enhance physical fitness as well as develop social (and fighting) skills. Through *object play*, children learn about the *affordances* of objects—the quality or property of an object that defines its possible uses—as well how objects can be used. And *fantasy* (or *pretend* or *symbolic*) *play* involves an "as-if" orientation toward objects, actions, and other children, which requires *counterfactual thinking*—representing objects and people in a form other than what they really are. Fantasy play also involves thinking ahead and strategizing without engaging in trial-and-error learning. Such thinking is a central feature of human cognition, and some theorists have proposed that its development during childhood played a critical role in the evolution of human cognition. According to Nielsen (2012, p. 176), "by pretending children thus develop a capacity to generate and reason with novel suppositions and imaginary scenarios, and in so doing may get to practice the creative process that underpins innovation in adulthood." Each type of play peaks sometime in childhood and decreases into adolescence and adulthood, although never fully disappears (Pellegrini, 2013). Each type of play is observed in all cultures following a common developmental schedule, although how plays is expressed varies among cultures (e.g., children from traditional cultures are more apt to play at adult work than children in western cultures, Konner, 2010; Pellegrini, 2013).

It may be easy to see how children in nonschooled cultures learn through play, but the seemingly frivolous, playful activities of children might actually appear to be maladaptive to learning in modern schooled societies. Recent research has clearly shown that this is not the case. Perhaps the most convincing demonstration of the benefits of play on children's cognitive development comes from research showing the relation between both locomotive and fantasy play and *executive function*—processes involved in regulating one's attention and behavior that is critical in behaving flexibly and in planning. Executive function consists of three related cognitive abilities: *working memory* (or *updating*), involved in storing and manipulating information; inhibition and resisting interference; and cognitive flexibility, as reflected by how easily individuals can switch between different sets of rules or different tasks (Blair & Diamond, 2008; Zelazo, 2015).

Concerning locomotive play, studies have reported that exercise during childhood positively affects executive function and corresponding brain activity (e.g., Cook et al., 2019; Hillman & Biggan, 2017). This was illustrated in a study in which 7- to 11-year-old children were randomly assigned to either a high-dose exercise group (40 min of exercise a day for about 3 months), a low-dose exercise group (20 min of exercise a day for about 3 months), or a control group (no exercise) (Davis et al., 2011). Children in both the low- and (especially) high-dose exercise groups showed significant improvements in executive function relative to children in the control group, with corresponding changes in cortical activity during the executive-function tasks. Consistent with the findings and interpretations of other researchers (e.g., Hillman & Biggan, 2017), the authors of this study argued that "aerobic exercise increases growth factors… leading to increased capillary blood supply to the cortex and growth of new neurons and synapses, resulting in better learning and performance" (Davis et al., 2011, p. 96).

Other researchers report that children who engage in more fantasy play display elevated levels of language development, perspective taking, executive-function abilities, and self-regulation (White & Carlson, 2021; Yogman et al., 2018). This relation has been reported in correlational, experimental, and longitudinal studies. For example, in one study, 3- to 5-year-old children who took part in a pretend-play intervention showed greater increases in executive function than children in a nonimaginative play intervention (Thibodeau et al., 2016). In a 2-year longitudinal study, the amount of time preschool children engaged in free play at home (some of which was fantasy play) positively predicted a measure of self-regulation two years later (Colliver et al., 2022). According to Blair and Diamond (2008, p. 907), "During social pretend play, children must hold their own role and those of others in mind (working memory), inhibit acting out of character (employ inhibitory control), and flexibly adjust to twists and turns in the evolving plot (mental flexibility); all three of the core executive functions thus get exercise."

Not all studies looking for a relation between children's pretend play and cognitive performance have found it (see Lillard et al., 2013 for a review), suggesting that pretend play is likely not *necessary* for developing species-typical cognitive and social-cognitive abilities but may instead be one of several possible routes to developing cognitive skills, or perhaps an *epiphenomenon*, a reflection of other underlying cognitive processes (Lillard et al., 2013). More research is clearly needed to elucidate the nature of the relations between pretend play and cognitive and social-cognitive development. However, its universality, common developmental sequence, and frequent association with children's cognitive functioning, attest to pretend play as an evolved feature of *Homo sapiens'* childhood, and one that must be considered as a mechanism for developing cognitive skills and acquiring important cultural knowledge during the early years of life.

Play is what children have always done, and when children are free to choose their own playful activities they not only learn something useful about the immediate situation but also enhance their cognitive abilities and perhaps even foster their subsequent psychological adjustment. This latter point is reflected in retrospective studies by Greve and his colleagues (Greve & Thomsen, 2016; Greve et al., 2014), who reported that the amount of free play adults engaged in as children was positively associated with later self-esteem, friendship, and general psychological and physical health, and that these effects of childhood free play on adult outcomes were mediated by greater adaptivity (flexible goal adjustment).

Evolutionary Mismatches with Modern Education

The perceptual and cognitive mechanisms typifying modern children have been shaped by natural selection over tens of thousands (perhaps hundreds of thousands) of years, and almost guarantee that children will acquire the motor, social, and technological skills and knowledge of their culture. However, the ancient social environments in which children's remarkable learning abilities evolved differ in many important ways from contemporary environments, and this can result in *evolutionary mismatches*—conflicts between psychological mechanisms evolved in ancient environments and their utility in modern ones. Until the advent of agriculture and a sedentary lifestyle, dating back 10,000 to 12,000 years, most humans lived as hunter-gatherers in nomadic groups of fewer than 100 individuals (Konner, 2010; Lancy, 2015; but see Bird et al., 2019). Although there was much variability in ecological conditions among different human groups and over time, based on contemporary hunter-gatherers and on paleoanthropological evidence, the childhoods of most of our forechildren were likely spent playing in multi-age, multi-sex groups, with children having few chores, receiving little formal instruction from adults, and having no prescribed bedtime (Lancy, 2015; Nowell, 2021). Lancy (2015, p. 72) described such cultures as *neontocracies* in which "children have authority—lording it over their valet parents." Despite the lack of direct teaching and extrinsic reinforcements to master adult tasks, children in contemporary hunter-gatherer societies acquire the necessary survival skills, mostly through observation and play. Failure to do so would result in death, for, unlike children in WEIRD (Western, Educated, Industrial, Rich, Democratic) cultures, there are no alternative occupations open to hunter-gatherers.

Some of the mismatches between children's evolved learning mechanisms and contemporary culture seem obvious. Schooling itself is an evolutionary novelty and did not emerge until the existence of state-level societies (Eskelson, 2020). For children in WEIRD societies, much less learning is done "in situ," or "on the job." Rather, acquiring the three R's and other twenty-first-century knowledge is mostly done out of context, in schoolrooms with 20 or 30 same-age children, directed by a previously unknown and unrelated adult, and taught using examples with no immediate or practical relevance. The critically important skills of literacy and numeracy have no evolutionary history and only a very recent cultural one. Although writing systems can be traced back several thousand years, it was only centuries after the invention of the printing press that reading and writing became important for economic success, and it is only within the past 100 years or so that a majority of people in most societies received formal education (see Bjorklund, 2007).

It is little wonder that many children in WEIRD cultures do not like school other than for the social engagement it provides. For example, one recent study—conducted during the first 2 months of enforced home schooling due to the corona virus lockdown in 2020—asked 1500 children between the ages 8 and 13 years if they were looking forward to returning to school and what, in particular, did they miss about school (Gray, 2020). Approximately 70% of children said they were looking forward to returning to school, but fewer than 2% said they missed classes in general. Eighty-seven percent of children said they missed friends and about 6% of children said they missed recess, PE, sports, music, or art classes. Some children, of course, find school-learning enjoyable and stimulating (so much so that they make careers out of it!). But we should not be surprised that the environments in which children's (and adults') learning skills evolved and current ones are mismatched and produce problems for many of today's children and educators. Schooling may be necessary to be successful in modern society, and children obviously have the cognitive flexibility to succeed in school, but we should not be surprised that it does not come easily (or enjoyably) to many students.

The fact that children are able to master the technological skills of modern life (literacy, numeracy, scientific literacy, and more recently digital literacy) is a testament to children's cognitive and neural plasticity, discussed earlier. Recall that Geary (1995, 2005) proposed that children enter the world with a set of biologically primary skills that get fleshed out with experience. These skills are universal, and children have intrinsic motivation to acquire them. But each society, even preliterate ones, develops biologically secondary abilities suited to its particular ecology, built upon biologically primary abilities. In most nonschooled cultures, these biologically secondary skills can be acquired primarily through social learning and play. This is not the case, however, for the more abstract literary, numeracy, and scientific skills associated with modern culture, which require extrinsic motivation and often direct teaching for their acquisition. Geary proposed that the role of modern schools is to organize children's activities, enabling them to acquire the biologically secondary abilities required for occupational and social success in their society, and this usually requires direct instruction. According to Geary and Berch (2016), educators should be sensitive to the type of skills children are acquiring and modify their instruction accordingly. Geary and Berch (2016, p. 240) write: "*We have suggested that structured, explicit, teacher-directed instruction should be most effective when acquiring secondary skills that are remote from supporting primary systems and that take place in a species-atypical, classroom context where the goal is oriented toward acquiring knowledge for its own sake*" (italics in the original).

Taking Advantage of Children's Evolved Learning Abilities to Minimize the Effects of Evolutionary Mismatches

Most scholars and educators agree that the technological demands of modern society require formal instruction and formal schooling (but see Gray, 2016 for a counter argument). However, by recognizing evolutionary mismatches, educators can design learning environments that take advantage of children's evolved learning skills, enhancing children's motivation for and acquisitions of their culture's biologically secondary abilities. Fortunately, many of the ways of taking advantage of children's evolved learning abilities are not complicated to incorporate in existing curricula. For instance, as noted earlier, young children are unrealistically optimistic when it comes to their own abilities, and, rather than trying to make young children's judgments of their abilities more accurate, educators can design environments that maintain their optimism to facilitate learning. Similarly, teachers of preschoolers and early elementary school-age children can maximize children's learning by explicitly enhancing children's self-referencing of new material (i.e., taking advantage of their inherent egocentricity). Also, educators have long known that children's motivation is enhanced when they learn about meaningful and interesting material, and this is easily seen in children's reading comprehension. According to Geary (1995, p. 28), "The motivation to read… is probably driven by the content of what is being read rather than by the process itself. In fact, the content of many stories and other secondary activities (e.g., video games, television) might reflect evolutionary relevant themes that motivate engagement in these activities (e.g., social relationships, competition)." In the following sections I examine some ways in which educators can take advantage of children's evolved learning abilities and minimize the effects of evolutionary mismatches between ancestral and contemporary environments.

Developmentally Appropriate Practices are Evolutionarily Appropriate Practices

Stemming from the *sociocultural* tradition, as exemplified in the theorizing of Vygotsky (1978), cognitive development emanates from a structured interaction between children and others, as reflect in Gauvain's (2001, p. 63) statement that "cognitive development is an active constructive process that involves beings who are evolutionarily predisposed to live and learn in social context with other 'like-minded' beings. They are like-minded in terms of both the neurological system available and the social requirements that are in place." Although formal schooling does not necessarily preclude such a species-typical learning environment, especially for young children, it is easy to see how it may be difficult to achieve.

Differences in the educational consequences of early education as a function of the degree to which teachers provide children with evolutionary-relevant experiences was illustrated in a study in which college students related their enjoyment and academic success in school to the number of evolutionary-relevant experiences they recalled having in kindergarten through second grade (Gruskin & Geher, 2018; see Table 1). The researchers reported that the more evolutionary-relevant early school experiences (e.g., free play, real-world applications for learning, hands-on learning) the participants had had, the more they enjoyed elementary, middle, and high school, and the higher was their high-school grade-point average (GPA). Participants' college GPA was also indirectly affected by evolutionary-relevant experiences, mediated through higher high-school GPA. The authors concluded that "children have evolved an innate motivation to learn, but as suggested by the data, evolutionary mismatch seems to remove this desire. Children are pushed outside of their nature, and as a result suffer. By better aligning elementary-level schools with evolved education preferences, the data support the idea that students are likely better set up to retain enjoyment of learning, not just at the elementary level, but throughout their schooling" (Gruskin & Geher, 2018, pp. 344, 345). It is not possible from this study to discern the mechanism by which an evolutionary-relevant curriculum in elementary school influences subsequent academic performance. All of the participants in this retrospective study were college students, and other individual-difference factors, such as sex or socioeconomic status, were not controlled. Future research with more diverse samples and including prospective as well as retrospective studies are clearly needed.

Additional evidence for the educational benefits of evolutionary-relevant experiences comes from studies of preschool programs, particularly those that follow *developmentally appropriate practice* (National Association for the Education of Young Children, 2021) in comparison to those that rely primarily on *directed instruction*, more typical of the formal teaching used in elementary school. Originally, developmentally appropriate practice stemmed from Piaget's theory of cognitive development, recognizing that young children are qualitatively different thinkers and learners than older children. Although not based on evolutionary theory, developmentally appropriate practice involves many components that can be described

Table 1 Items included in composite evolutionary variables measured in Gruskin and Geher's study

Academic interactions with different-aged peers
Interactions with different-aged peers for play
Academic collaboration within same-age peers
Free play
Structured play
Teacher lecturing*
Learning from textbooks and workbooks*
Hands-on learning
Assessments based on testing*
Assessments based on projects
Explicit real-world applications for learning
Use of manipulatives (i.e., place-value blocks, pattern blocks, etc.)
Tools used were models made specifically for children
Tools used were similar or the same as those used by adults and professionals

*Variables were reversed scored

Source: Gruskin, K., & Geher, G. (2018). The evolved classroom: using evolutionary theory to inform elementary pedagogy. *Evolutionary Behavioral Sciences, 12*(4), 336–347 as evolutionary-relevant experiences. For example, developmentally appropriate practice involves an emphasis on learning through play as well as the importance of *discovery learning*, or child-initiated activities—that may be facilitated by teachers—with children doing their own experimenting in order to gain an understanding of some phenomenon. This is contrasted with a more didactic, or teacher-directed curriculum involving direct-instruction practices.

There have been dozens of studies contrasting the immediate and long-term educational effects of developmentally appropriate versus direct-instruction preschool programs (see Bjorklund, 2007 for review). Concerning academic performance, after 1 year in these programs the findings are mixed, with some showing benefits to the developmentally appropriate programs, others to the direct-instruction programs, and still others finding no differences. When long-term (greater than 1 year) effects are assessed, more studies find greater benefits for developmentally appropriate programs (Burts et al., 1993; Marcon, 1999, 2002). For example, one large-scale study conducted in Germany in the 1970s contrasted 50 kindergarten classes in which children were taught specific academic skills versus 50 kindergarten classes that followed a play-based curriculum (Winkelmann et al., 1977, as described in Darling-Hammond & Snyder, 1992). Although children attending the academic kindergartens fared better in terms of academic skills in first grade, by fourth grade the children who attended the play-based kindergarten programs excelled in reading and arithmetic and showed better social and emotional adjustment than children who had attended the academic kindergarten programs.

Other studies have similarly shown that differences are greatest, favoring the developmentally appropriate programs, when considering motivational and psychosocial factors (Burts et al., 1993; Stipek et al., 1995). For instance, one study reported an advantage for knowledge of letters and reading achievement for children attending direct-instructional programs (but not in knowledge of numbers); however, children attending developmentally appropriate programs were less dependent on adults for permission and approval, expressed greater pride in accomplishment, chose more challenging math problems to perform, rated themselves as having greater intellectual abilities, had higher expectations for success on school-like tasks, and said they worried less about school than children in direct-instruction programs (Stipek et al., 1995). In other words, any academic benefits gained from a direct-instruction program had its costs in terms of motivation. Overall, there are no long-term academic benefits of direct-instruction preschool programs relative to developmentally (and evolutionarily) appropriate ones, and there may actually be some negative motivational consequences of such programs, causing one group or researchers to conclude “it may be developmentally prudent to let children explore the world at their own pace rather than to impose our adult timetables and anxieties on them” (Hyson et al., 1990, p. 421).

Consistent with this position are the results of a recent longitudinal study that followed over 2,900 children from low-income homes, some of whom had been randomly assigned to participate in direct-instruction preschool programs (Durkin et al., 2022). Although children attending the academically oriented preschool programs showed an advantage in achievement in first grade relative to children in a control group, this effect was reversed by third grade, with achievement differences in favor of children who did *not* participate in the preschool program being even greater in sixth grade. In an interview discussing the unexpected results, Dale Farran, principal investigator of the longitudinal study, suggested it might be time to rethink preschool education for at-risk children. Rather than drilling children on basic skills, perhaps more play-oriented preschool programs, similar to ones that more affluent parents choose for their children, are called for (Kamenetz, 2022).

Of course, most direct-instruction preschool programs offer children some time to play, and most developmentally appropriate programs involve some explicit teaching. As Geary and Berch (2016) argued, the need for explicit direct instruction should be related to how remote a biologically secondary skill is from a child's supporting biologically primary skills. That is, whether learning is best through discovery, play, or direct instruction may depend on the skill that is learned. This is illustrated in a study in which preschool children were introduced to a novel toy and either (1) instructed how to perform a specific set of behaviors to produce a specific outcome (make a squeaking sound) (pedagogical condition), (2) simply shown the same behaviors with the same outcome but without any specific instructions, or (3) introduced to the new toy without any demonstration (Bonawitz et al., 2011). Children were then given the opportunity to play with the toy. Children in the pedagogical condition spent more time playing with the squeaker, the one function they were shown, but they played with the toy less and discovered significantly fewer other functions of the toy than children in the other conditions. Bonawitz and her colleagues concluded that direct instruction facilitates children's acquisition of information or specific skills, but in doing so, it reduces the range of hypotheses children consider. As Bonawitz et al., (2011, p. 329) state, "The decision about how to balance direct instruction and discovery learning largely depends on the lesson to be learned." It seems undeniable that direct teaching is beneficial for acquiring complicated skills, although discovery learning, with appropriate supports from adults, also plays a role in acquiring both relatively simple and more complex skills (see Alfieri et al., 2011; Geary & Beach, 2016).

Direct teaching is likely to be especially ineffective for infants and toddlers, in that successful teaching requires more advanced social-cognitive abilities than observational learning (Tomasello et al., 1993). Despite this, over the past 50 years or so there have been many books (and more recently, video platforms) that have promised to enhance the learning and intelligence of infants, toddlers, and even fetuses with little or no success (see Bjorklund, 2007; Bjorklund & Beers, 2016 for reviews). For example, Logan (1991) argued that prenatal stimulation will prevent the loss of brain cells that begins prenatally and continues through the first two years of life, permitting greater potential learning postnatally. However, this process of *selective cell death*, rather than being detrimental to brain development, is central to it, affording the necessary process of neural pruning. According to one developmental neuroscientist, "One has to consider the possibility that very ambitious early enrichment and teaching programs may lead to crowding effects and to an early decrease in the size and number of brain regions that are largely unspecified and that may be necessary for creativity in the adolescent and adult" (Huttenlocher, 2002, p. 214).

The explosion of digital media over the past several decades has produced new efforts to enhance infants' and toddlers' cognitive abilities. Although television has been an integral part of young children's lives for nearly 70 years, DVDs and other computer-based platforms are providing more opportunities to enhance young children's cognitive abilities. However, despite the obvious entertainment value such technologies afford young children, there is no convincing evidence that children much younger than 2 years of age experience cognitive benefits from exposure to these platforms in comparison to exposure to "real-life" people. It is not that infants and young children cannot learn information (such as new words) from watching videos; rather, children much before their second birthdays consistently display a *video deficit*, learning novel words or actions better when watching a live model versus a model via video (e.g., Barr, 2010; Strouse & Samson, 2021).

Some research evidence points to the possibility that frequent exposure to baby educational videos may actually be detrimental to cognitive development (e.g., Courage et al., 2010; Zimmerman et al., 2007). For instance, one study reported that each hour 8- to 16-month-old infants watched *Baby Einstein* videos was associated with learning 6 to 8 *fewer* vocabulary words (Zimmerman et al., 2007). Other research suggests that visual media exposure prior to the age of 2 impairs executive function (Lillard et al., 2015). For example, in one study, 9-month-olds exposed to higher amounts of visual media showed poorer self-regulation (e.g., failure to delay gratification, problem shifting focus from one task to another, distractibility) 3 years later, even after controlling for important parental and family factors (Radesky et al., 2014). Other research has shown that the more hours preschoolers watched television, the poorer were their executive-function abilities (Nathanson et al., 2014). The effects are especially strong for preschool children who watch fast-paced cartoon shows in contrast to educationally designed programs (Huber et al., 2018; Lillard et al., 2015). Other research has found that preschoolers who watch excess amounts of visual media not only show deficits in some cognitive measures, but also in measures of organization and myelination of brain white-matter tracts that support language and emergent literacy skills (Hutton et al., 2020). Although higher-SES families might be more likely to use educational videos with their infants and young children than lower-SES families, the reverse seems to be true for total screen-time exposure. A 2020 survey reported that children from lower-SES homes (household income < $30,000 per year) spend 1.56 times more on screens than children from higher-SES homes (> $75,000 per year) (Rideout & Robb, 2020).

Taken together, the research evidence clearly points to the educational benefits of developmentally (and evolutionarily) appropriate learning experiences, at least during the early years of life. Moreover, when young children receive stimulation in excess of the species norm (as in overexposure to two-dimensional video displays), there is the possibility of negative short-term (and possibility long-term) consequences (cf. Turkewitz & Kenny, 1982).

Increasing Opportunities for Physical Activities

Earlier I noted children's propensity to engage in often highly vigorous locomotive play and the positive relation between physical fitness and cognitive abilities, such as executive function. There is a growing literature showing that executive function is related to a host of academic abilities (e.g., Albert et al., 2020), and there is evidence dating back more than 50 years of the positive relation between physical activity/physical fitness and children's academic achievement (see Castelli et al., 2014). In the most recent meta-analysis examining this relation, Castelli and colleagues (2014) examined studies published between 1967 and 2013 and reported a significant relation between the amount of physical activity children engaged in and cognitive and academic performance with a moderate effect size (0.383). Further, 79% of the articles in their database reported positive associations between academic performance and physical activity/physical fitness, with the remainder finding no significant differences. Most studies examining the relationship between physical fitness (or cardiorespiratory fitness) and cognitive or academic performance have not examined or reported sex difference (see Hillman & Biggan, 2017). One recent study that did, found significant positive effects of cardiorespiratory fitness and working-memory abilities for preadolescent males but not for females (Drollette et al., 2016), whereas another recent study reported significant but slightly different patterns in the relations between moderate-to-vigorous physical activity and school GPA for 11- to 13-year-old boys and girls (Haapala et al., 2020). Future research needs to examine more thoroughly sex (and other individual) differences with respect to the relationship between physical fitness and cognitive/academic abilities.

There are likely several reasons for the generally positive effects of recess and physical activity on children's academic performance (see Chen et al., 2021; Pellegrini & Bjorklund, 1997). For example, recess, or simply breaks between rigorous academic tasks, serves to distribute practice on a topic, which has repeatedly been shown to enhance learning (e.g., Chen et al., 2018). Physical activity may also directly affect brain and cognitive functioning, as discussed earlier in research documenting the positive relation between exercise and executive function in children (e.g., Davis et al., 2011; Hillman & Biggan, 2017).

It would seem relatively easy to increase the amount of physical activity (and locomotive play) that children get by increasing the frequency of outdoor recess. A number of studies dating back at least to the 1990s have reported significant improvements in children's attention to in-class material and academic performance attributed to the frequency or timing of recess (e.g., Holmes et al., 2006; Murray & Ramstetter, 2013; Pellegrini et al., 1995). For example, in a series of studies with kindergarten, second-grade, and fourth-grade children, the timing of recess was varied so that some children had recess delayed by 30 min for 2 days a week relative to the other days (Pellegrini et al., 1995). Children's attention to seat work was examined both before and after recess. At each grade, children were significantly more attentive after recess than before, and the effects of delaying recess were significantly greater for the younger than for the older children. In related research, a 2-year study conducted in New Zealand modified recess for children in grades 1 through 8, providing children more opportunity for "risky play," including more rough-and-tumble play and tree climbing (Farmer et al., 2017). Teachers and administrators at these schools believed that children enjoyed school more, were better behaved, were more cooperative with one another, and increased in physical activity as a result of engaging in more risky play with few negative effects.

Despite the positive effects of recess, the frequency of recess has been steadily declining in the USA over the past 50 years (see Murray & Ramstetter, 2013). This decline is based in part on the belief that recess, and physical education in general, is more of a distraction to learning than a benefit. This position was supported by the conclusion of the influential *A Nation At Risk* report (National Commission on Excellence in Education, 1983), which argued that America's educational system was failing to properly educate students and was filled with "frills such as driver's education and physical education." The research evidence clearly refutes this, and other countries with successful and rigorous education systems have moved in the opposite direction. Finish schoolchildren (and their teachers), for example, take 15-min breaks every hour (Walker, 2014), and Japanese schoolchildren have a 10- to 15-min break every hour (Murray & Ramstetter, 2013). Recess, and especially one that involves the possibility of locomotive play, is an evolutionary-relevant experience for young children and one that has demonstrated benefits for education (Pellegrini & Dupuis, 2010).

Increasing Opportunities to Learn Through Play

In an earlier section, I cited a growing literature showing the positive effects of play on young children's cognitive abilities, particularly executive function. On the surface, it would seem to be relatively easy for educators to take advantage of children's propensity for play and incorporate more of it into a preschool or early elementary-school curriculum. Despite the benefits of free play, however, simply "letting children loose" in a classroom will not likely result in them acquiring the academic skills and knowledge expected for children growing up in WEIRD societies. Rather, school environments and curricula must be structured so that young children can discover and nurture important skills and knowledge in the process of play. Play may be particularly important during infancy, toddlerhood, and the preschool years, as children learn the affordances of objects through play and generally exercise their biologically primary abilities (discussed earlier), which Geary (2005) argues are species universal and acquired and fleshed out through social interaction and play.

Guided play is one technique that combines children's playful motivation with direct instruction to maximize young children's learning of educationally important material. Guided play is defined as "learning experiences that combine the child-directed nature of free play with the focus on learning outcomes and adult mentorship" (Weisberg et al., 2016, p. 175). For example, in a classroom setting, teachers can observe children during free play and encourage them to learn specific skills or obtain specific outcomes in the setting. This can be seen in a study in which 4- and 5-year-old children were given an array of geometric shapes (rectangles, triangles, pentagons, and hexagons) in one of three conditions: *Didactic Instruction*, in which an adult described to children each of the shapes and explored the shapes (discovering the shapes' "secret," for instance, rectangles have four sides); *Free-Play*, in which children played with the materials in any way they wished; and *Guided Play*, in which an adult described the shapes in the same way as in the Didactic Instruction condition but encouraged children to explore and discover the shapes' secret (Fisher et al., 2013). When children were later asked to sort shapes (for example, sort the rectangles together), those in the Guided-Play condition performed best and children the Free-Play condition performed worst, with performance of children in the Didactic-Instruction in-between the two.

Other forms of guided play involve situations in which adults organize the context to emphasize certain learning goals, insuring children can freely explore or play within the setting. For instance, in studies conducted in science museums, exhibits were constructed that increased the possibility that children would discover certain facts or principles while playing with the materials (that is, discovery learning). In numerous studies, young children indeed learned and remembered the intended lessons and transferred them to new learning contexts (see Haden et al., 2021 for a review).

Because of children's intrinsic motivation to explore and play, particularly in interaction with other people, guided play increases the likelihood that children will persist at tasks and use their evolved social-learning abilities to acquire important social, technical, and academic skills (Toub et al., 2016; Weisberg et al., 2013). Guided play also takes advantage of working within Vygotsky's *zone of proximal development*, defined as the difference between a child's "actual developmental level as determined by independent problem solving" and their level of "potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 8). Parents, teachers, and more knowledgeable peers can *scaffold* the performance of a less-experienced individual during play, responding contingently to the novice's actions in a learning situation (Wood et al., 1976).

Although incorporating guided play into early education curricula seems reasonable, it would appear to be less easily done for older children, who would seem to require direct instruction for acquiring more abstract concepts and skills such as mathematics (Geary & Berch, 2016). However, the results of a meta-analysis examining the effectiveness of different pedagogical methods in children, adolescents, and adults suggest otherwise: better educational outcomes were found, on average, for instruction that involved enhanced discovery learning (much like guided play) compared to other forms of instruction for people of all ages (Alfieri et al., 2011). Similarly, the theory behind a Montessori curriculum has much in common with guided play (children are free to interact in a carefully prepared environment), and research has found that the academic achievement of children attending Montessori programs is frequently greater than for children attending conventional schools (see Lillard, 2018), even after controlling for family income (Lillard & Else-Quest, 2006; Lillard et al., 2017).

Taking Advantage of Stress-Adapted Children's Hidden Talents

Earlier I emphasized that children's high degree of plasticity afforded enhanced learning abilities. The substantial degree plasticity early in life makes children highly sensitive to early experiences, with the possibility of modifying their ontogenetic course as a result of such experiences. Boyce and Ellis (2005, p. 290) used the concept of *conditional adaptations* to capture this phenomenon, which they defined as "evolved mechanisms that detect and respond to specific features of childhood environments—features that have proven reliable over evolutionary time in predicting the nature of the social and physical world into which children will mature—and entrain developmental pathways that reliably matched those features during a species' natural selective history."

Following Boyce and Ellis's logic, children who experience different types of early environments may develop different patterns of cognitive abilities, which educators can take advantage of to optimize children's learning. Most of this research has been based on *life history theory*, which, at its simplest, is concerned with how animals allocate bodily and behavioral resources as a function of their local ecology. With respect to human children, life history theory proposes that children develop strategies that maximize their ability to adapt to their local environment, and the type of strategy they develop depends on qualities of the environment. For example, research has accumulated showing that children growing up in harsh and unpredictable environments (characteristic of children from low-socioeconomic families)—while showing deficits in a host of cognitive and academic skills including executive function (e.g., Chang et al., 2019)—may possess a host of *hidden talents* (Ellis et al., 2022; Frankenhuis et al., 2020). These stress-adapted individuals often display cognitive strengths in (1) tracking changing information in the immediate environment; (2) cognitive flexibility, as reflected by the ability to shift attention between tasks; and (3) replacing older, irrelevant information from working memory with new, updated information (e.g., Fields et al., 2021; Mittal et al., 2015; Nweze et al., 2021; Young et al., 2018, 2022). For example, Mittal and his colleagues (2015) reported that young adults who had experienced harsh and unpredictable childhoods showed deficits in inhibition (a component of executive function) but displayed enhanced abilities in task shifting (also a component of executive function) compared to people who had experienced less-harsh and more stable early environments, but only when testing was done in uncertain contexts. In other research, adults who experienced high unpredictability as children showed superior working-memory performance for texts relative to adults growing up in more predictable environments, but only for material involving uncertainty; participants growing up in unpredictable environments showed significantly worse performance for control stories (Young et al., 2018).

Although educators are well aware of the cognitive limitations of children growing up in stressed environments and have developed curricula to encourage such children to think and act more like children from less-stressed backgrounds, alternative approaches that design curricula that acknowledge stress-adapted children's hidden talents may be able to take advantage of the cognitive adaptations developed by children growing up in less-than-optimal modern circumstances. Ellis and his colleagues (2022) provided a number of suggestions for how educators might promote learning in stress-adapted children, chief among them having curricular content being anchored on ecologically relevant skills and concepts. For example, because low-SES children are typically highly attentive to differences in social rank, reasoning problems could be used that are related to dominance and social status. Teachers might also develop ways of using stress-adapted children's greater cognitive flexibility and updating abilities to teach complex topics such as algebra. The number of studies examining the potential benefits (in addition to deficits) in cognitive functioning of children growing up in adverse environments is rapidly expanding, although this research is still in its infancy, and patterns of result often vary between studies. Nonetheless, I believe that additional research on the potential cognitive strengths of stress-adapted children has the potential to inform educational practice to enhance the lives of children growing up in harsh and unpredictable circumstances.

Conclusion

Homo sapiens are the most educable of animals. The education process begins early in life, with evolved cognitive mechanism affording children, and later adults, the ability to acquire the social and technological skills needed for success in any of the many possible human cultures. Humans' evolved ways of learning were shaped in ancient environments in which children received little direct teaching from adults but learned mostly through play with peers in multi-age groups and through observing others as they went about their daily lives. In a real sense, our forechildren were mostly self-educated. Contemporary children possess the same evolved learning mechanisms as their ancestors, but the novelty of what contemporary children must learn has resulted in evolutionary mismatches, sometimes resulting in reduced motivation and the hindering of learning. Evolutionary theory is not necessary to develop effective pedagogy; this can be seen in developmentally appropriate preschool programs, whose practices are also evolutionarily appropriate. However, having an underlying theory that informs teachers and parents about how children evolved to learn will result in more enlightened teaching methods that will result in more enjoyable and successful learning experiences for children.

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