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The evolved child
Applying evolutionary developmental psychology to modern schooling

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Abstract

Evolutionary developmental psychology, an emerging subdiscipline of evolutionary approaches to human behavior and cognition, focuses on the adaptive nature of psychological mechanisms built into the brains of juveniles, some of which may serve immediate demands at different stages of development, and some of which serve preparatory roles for maturity. The current article reviews some of the central ideas of evolutionary developmental psychology and investigates how human educability, which is qualitatively different from the learning capacity of other species, is governed by specific adaptations of *Homo sapiens*' childhood that serve to orient the young child to his or her cultural environment. Evolutionary developmental psychology, we argue, can be especially informative to educational policy makers who wish to take children's natural limitations, as well as their intellectual pliability, into account when planning curricula. © 2002 Elsevier Science Inc. All rights reserved.

Keywords: Evolutionary developmental psychology; Educability developmental systems approach; Miseducation

1. Introduction

Every extant organism, plant and animal alike, has evolved special features to foster its adaptation to its environment. In this sense, humans are no different from elephants, Monarch butterflies, or bottle-nosed dolphins. But, unlike other organisms, the adaptations of *Homo*

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sapiens have led, for better or worse, to our species' domination of the globe. What humans have evolved are cognitive and communicative skills that permit the transmission of knowledge from one generation to the next, resulting in the creation of culture. Cultural transmission may not actually be unique to humans; primatologists have documented 39 different behaviors, including styles of grooming, nut cracking, and termite and ant fishing, in wild populations of chimpanzees that are presumably passed along from one generation to the next via mechanisms of social learning (Whiten et al., 1999). Similar claims have been made for whales and dolphins (e.g., Rendell & Whitehead, 2001). But despite this impressive feat, chimpanzees and cetaceans are lightweights in the transmission of culture compared to humans. It is humans' educability that truly makes *H. sapiens* special. Humans possess a suite of social, cognitive, and language skills, which, although they may not originally have been selected for the transmission of culture, have, over generations, produced the grandest accomplishments of any animal that has ever lived on Earth, transformed how we make a living as a species, and truly distinguish us from the rest of the biological world.

Cultural transmission has always progressed from adults to children, often from parents to their offspring. In traditional cultures (and surely in the environments of our ancestors), culture is acquired through "on-the-job" training. Education is informal, accomplished via demonstrations and observations, "through participation with more skilled partners in culturally organized activities" (Rogoff, 1990, p. 39). Children in information-age nations similarly learn at their parents' knees, using the same evolved cognitive abilities that their aboriginal cousins use. But the phenomenon of human cultural transmission brings with it a ratchet (Tomasello, 1999), such that each new generation starts with the knowledge of the previous one, permitting the rapid expansion of information over time. This ratchet effect accelerated with the advent of agriculture and sedentary lifestyles, beginning 10,000–12,000 years ago. The specialization and instruction that civilization demanded were accomplished, for the most part, in the same way as they had been for the preceding eons: Apprentices learned from masters, on the job, often requiring years of training. But as the ratchet continued to progress, increased cultural complexity soon required instruction "out of context." It has only been in the last several hundred years (at most) that formal education has been a requirement for economic success for a majority of people in any culture, and it is still not universal. Formal education presents a serious challenge for human educability. Modern children possess the same brains and minds as did their hunter/gatherer peers dating back at least 60,000 years, and perhaps as far back as 300,000 years; yet, modern culture necessitates that children learn things unimaginable by their ancient predecessors.

It is primarily for these reasons that we believe that an evolutionary perspective can shed light on how best to educate children in the modern world. In recent years, evolutionary thinking has been applied to psychology, examining how the mind has been adapted over geological time for life in human groups (e.g., Buss, 1995; Daly & Wilson, 1988; Pinker, 1997; Tooby & Cosmides, 1992). Because it is the adults of a species who do the reproducing, the *sine qua non* of Darwinian explication, evolutionary psychologists have emphasized *adults*' adaptations to their physical, and especially their social, environments, investigating such topics as the ability to detect social cheaters (e.g., Cosmides, 1989), the features that men and women find attractive in the opposite sex (e.g., Buss, 1989), the differential mating strategies of men and women (e.g., Buss & Schmidt, 1993), and factors than influence homicide (e.g., Daly & Wilson, 1988), among many others. But children have not been ignored, and recently psychologists have begun to systematically apply evolutionary theory to understand psychological development, creating the subfield of *evolutionary developmental psychology* (e.g., Bjorklund & Pellegrini, 2000, 2002; Geary & Bjorklund, 2000). Because issues of educability are of greatest significance when dealing with children, we believe that an evolutionary *developmental* perspective will provide substantial insight to the education process. To this end, we summarize some of the major ideas of evolutionary developmental psychology, particularly as they may be applied to issues central to educational psychology.

2. Evolutionary psychology

The central claim made by evolutionary psychologists is that the human mind and behavior have been shaped by natural selection for life in the hunter/gatherer groups of our ancestors. Ancient humans faced recurrent problems dealing with finding food, avoiding predators, finding and maintaining mates, rearing children, and dealing with conspecifics. Our ancestors evolved information-processing programs to deal with these problems, making psychological mechanisms the unit of selection in evolution. According to Cosmides and Tooby (1987), adaptive behavior is predicated on adaptive thought, evolved to solve real-world problems in our *environment of evolutionary adaptedness*, usually conceived as the Pleistocene period, dating from about 1.8 million to 10,000 years before present. Moreover, these information-processing programs were designed by natural selection for specific cognitive operations, such as language, face recognition, or the processing of certain types of social interactions. This is reflected succinctly by Pinker (1997, p. 21): "The mind is organized into modules or mental organs, each with a specialized design that makes it an expert in one area of interaction with the world. The modules' basic logic is specified by our genetic program. Their operation was shaped by natural selection to solve problems of the hunting and gathering life led by our ancestors in most of our evolutionary history."

Evolutionary psychologists take an *adaptationist*, or *functional* perspective, by looking for the function that a behavior (or style of thinking) may serve (or have served in the past) in adapting individuals to their environments. This does not mean, however, that all current forms of cognition or behavior are adaptations, shaped by evolution to foster survival in us or in our ancestors. Some may be by-products of adaptations, necessary side effects that in themselves have no adaptive function, much as the belly bottom is a by-product of the umbilical cord (Buss, Haselton, Shackelford, Bleske, & Wakefield, 1998). Moreover, some by-products may actually have negative effects, just not so negative to result in extinction of the species. For example, the large skull of a human newborn is a necessary by-product of a large brain, which presumably is responsible for our intelligence and educability. However, large fetal skulls make birth difficult for women, whose pelvises are limited in size because of the constraints of bipedality, and many women and infants have died in childbirth as a result. The cost/benefit tradeoff was such, however, that the benefits of an enlarged brain outweighed the costs of neonatal and maternal death.

Evolutionary psychology has gained in influence over the past decade, enough so that subdisciplines have emerged, emphasizing evolutionary applications to more specific fields. For example, Darwinian medicine (e.g., Nesse & Williams, 1994) and psychiatry (e.g., Mealey, 1995) have emerged, applying evolutionary concepts to deal with problems of physical and mental well being. Similarly, developmental psychologists have recently taken many of the ideas of evolutionary psychology and applied them to development (e.g., Bjorklund & Pellegrini, 2000, 2002; Geary, 1999; Geary & Bjorklund, 2000), and it is to these ideas that we now turn.

3. Evolutionary developmental psychology

In many ways, an evolutionary developmental perspective should come easy to developmentalists. Developmental psychology emerged out of late-19th-century biology, and was much influenced by the evolutionary theory of the day (Cairns, 1998). Pioneers of developmental psychology — from James Mark Baldwin, G. Stanley Hall, and Sigmund Freud to Jean Piaget and Heinz Werner — incorporated, explicitly or implicitly, aspects of evolutionary thinking into their theories, as did several giants of the following generation of developmental psychology (e.g., Bowlby, 1969; Bruner, 1972). Yet, according to Charlesworth (1992), despite Darwin's considerable influence on psychology (including the recognition of the continuity of mental functioning among species, an emphasis on individual differences, a focus on adaptive behavioral functioning, and an expansion of methodologies beyond those of psychophysics and introspection popular in early psychology), his influences on child development were mostly indirect and weak. Moreover, according to Morss (1990), many evolutionary ideas applied to psychological development were actually pre-Darwinian and reflected a misunderstanding of the tenets of evolutionary biology. Along similar lines, Lickliter and Berry (1990) argued that evolutionarily oriented developmental psychologists had misapplied evolutionary theory, creating the *phylogeny fallacy*, believing "that phenotypic features of the individual are shaped by either historical events which designed its 'genetic program' *or* by environmental forces which act upon it during development" (p. 349). According to Lickliter and Berry, a more proper perspective, one that we have adopted, is to view development as the construction of traits based on the continuous and complex interaction between all levels of organization, from the genetic (i.e., evolved) through the cultural, over the course of ontogeny.

To the extent that evolutionary psychology is viewed as the study of inherited, adaptive psychological mechanisms evolved to solve social and behavioral problems faced by our ancestors, most contemporary developmental and educational psychologists will rightly be uninterested. As noted by Lickliter and Berry (1990) and others (e.g., Bjorklund & Pellegrini, 2000; Geary & Bjorklund, 2000), these mechanisms must emerge over the course of ontogeny if they are to be of interest to developmental psychologists. It is within this framework that Bjorklund and Pellegrini (2002, p. 4) defined *evolutionary developmental psychology* as "the application of the basic principles of Darwinian evolution, particularly natural selection, to explain contemporary human development. It involves the study of the genetic and environmental mechanisms that underlie the universal development of social and cognitive competencies and the evolved epigenetic (gene–environment interactions) processes that adapt these competencies to local conditions." As such, developmental patterns are *not* conceived as genetically predetermined, but differences in the social and physical (including prenatal) environment are viewed as playing a critical role in development.

Evolutionary developmental psychology, however, is not simply evolutionary psychology applied to children. Although evolutionary developmental psychologists accept many of the assumptions of contemporary evolutionary psychology, such as an adaptationist viewpoint and the importance of natural selection, taking an evolutionary *developmental* perspective causes one to view aspects of psychological functioning differently than an evolutionary perspective that treats development only superficially. For example, we emphasize the complex interaction between genes and environment throughout development, believe that domain-general, as well as domain-specific mechanisms have been greatly affected by natural selection, stress the significance of individual differences, as well as believe that higher-order cognitions should be examined from an evolutionary perspective (Bjorklund & Bering, 2001; Bjorklund & Pellegrini, 2002). In the sections to follow, we outline what we see as some of the basic tenets of evolutionary developmental psychology, particularly as they relate to educational psychology.

3.1. Evolutionary developmental psychology involves the expression of evolved, epigenetic programs, as described by the developmental systems approach

Evolutionary psychologists have often been interpreted as arguing for a form of genetic determinism, with evolved, inherited genetic programs becoming activated at the proper time in development (usually adulthood) given the proper environmental context. This is an incorrect reading, we believe, but we understand the confusion, particularly the perception that there is no need for development in such models. Generally, evolutionary psychologists concerned with adult functioning have seen no need to specify the nature of the organism–environment interaction and how it functions across ontogeny. Evolutionary developmental psychology addresses this shortcoming by providing a well-defined model of the way in which nature and nurture are proposed to interact following the precepts of the *developmental systems approach* (e.g., Gottlieb, 2000; Oyama, 2000). From this perspective, new forms and functions do not arise from the simple reading of a genetic blueprint, but emerge via the bidirectional transaction between all levels of biological and experiential factors, from the genetic through the cultural. Nothing appears fully formed. There are thus no pure genetic or environmental effects, but rather everything develops as a function of the bidirectional relationship between structure and function, occurring continuously across development.

Despite the diversity of environments children experience, development typically progresses similarly for most individuals. The reason for this is that children inherit not only a species-typical genome but also a species-typical environment. To the extent that individuals grow up in environments similar to those of their ancestors, development should follow a species-typical pattern. Animals (including humans) have evolved to "expect" a certain type of environment. For humans, this would include 9 months in a sheltered womb, a lactating, warm, and affectionate mother, kin to provide additional support, and, later in childhood, peers.

Many behaviors that have traditionally been described as "instinctive" can be better described as developing from the early interaction of the organism and its environment, broadly defined. For example, it is well established that ducklings and other precocial birds will follow the first moving, quacking thing they encounter shortly after hatching (imprinting). This phenomenon was touted by Lorenz (1965) as an example of a complex behavior that requires no experience for its expression (i.e., an instinct). But that interpretation has since been challenged. For example, when ducklings are raised in isolation and cannot hear the vocalizations of their mother, their brood mates, and are even prevented from vocalizing themselves, this "instinctive" behavior disappears. When given the choice after hatching of approaching the maternal call of their own species or that of another (e.g., a chicken), the ducklings lacking auditory experience choose randomly (see Gottlieb, 1997). What was once thought to be instinctive and encoded directly into the genes (i.e., "genes for behavior") is now known to require the subtle interaction of an animals' auditory experience (even if just its own vocalizations) with its "normal" maturation for its expression.

Although experimental manipulations that can be performed on ducklings cannot be performed ethically with human infants, there is every reason to believe that the same complex interaction of genetic disposition and environment is responsible for species-typical behaviors in humans. For example, research has shown that human infants are able to discriminate between faces and nonfaces within the first days of life (e.g., Bushnell, Sai, & Mullin, 1989; Johnson, Dziurawiec, Ellis, & Morton, 1991; Mondloch et al., 1999), and have a preference for their mothers' faces over those of other women (Walton & Bower, 1993). One may infer from this that infants possess some innate scheme for the human face. Although this may be true to a certain extent, infants' reactions to human faces may require some form of general experience to develop properly, just as ducklings require general auditory experience to display species-typical attachment behavior. Johnson and his colleagues (see research described in Johnson, 2000; Johnson & de Haan, 2001) provided evidence for this latter interpretation, looking at patterns of event-related brain potentials between adults and infants in response to different types of faces. Both adults and 6-month-old infants respond differently to upright and inverted faces, consistent with the presence of some innate or early developing cortical module for processing faces. But whereas adults process monkey faces differently than human faces, infants' reactions are the same, regardless of whether they are viewing human or monkey faces. Johnson interprets these findings as indicating that cortical processes of human faces do not reflect an "innate" schema, but rather a more general mechanism that becomes increasingly specialized with age, requiring general visual experience (presumably with human faces) in order for the species-typical pattern to emerge.

Such a perspective has important implications for education. First, individual differences in educability should not be viewed as "genetic" or "environmental" in nature, but rather as the result of the transaction between multiple levels of organization, both endogenous and exogenous to the individual, over time. This does not imply that there are no congenital differences in learning ability among children, nor that impoverished environments do not contribute substantially to poor school performance. Rather, such a perspective points out the dynamic interactions that are involved in any complex behavior, the active role of the child in influencing his or her own development, and the knowledge that changes in the environment can bring about changes in the overall developmental system. This is likely a perspective that most educational psychologists with a developmental background already ascribe to.

The mutability of genetically influenced (and thus possibly evolved) psychological characteristics is reflected in the following quote by Dawkins (1982), a vocal advocate of the position that evolutionary forces have left a strong imprint on the human mind:

> People seem to have little difficulty in appreciating the modifiability of "environmental" effects on human development. If a child has had bad teaching in mathematics, it is accepted that the resulting deficiency can be remedied by extra good teaching the following year. But any suggestion that the child's mathematical deficiency might have a genetic origin is likely to be greeted with something approaching despair: If it is in the genes, "it is written," it is "determined" and nothing can be done about it. This is pernicious rubbish on an almost astrological scale. Genetic causes and environmental causes are in principle no different from each other. Some influences of both types may be hard to reverse; others may be easy to reverse. Some may be usually hard to reverse but easy if the right agent is applied. The important point is that there is no general reason for expecting genetic influences to be any more irreversible than environmental ones. (p. 13)

More novel may be the idea that children inherit a species-typical environment as well as a species-typical genome, and that substantial variations of that environment can result in atypical behavior. Take, for example, premature infants, who experience sensory stimulation in neonatal intensive care units far in excess of what they would receive at the same gestational age (i.e., while still in the womb). Research with birds and rats has shown that infant or "prehatched" animals that receive stimulation in excess of the species norm often later display atypical sensory and cognitive abilities (e.g., Kenny & Turkewitz, 1986; Lickliter, 1990; Lickliter & Hellewell, 1992; McBride & Lickliter, 1994; Spear, 1984). For instance, when bobwhite quails receive patterned light several days before hatching (by removing part of the eggshell), they subsequently show enhanced visual discrimination abilities, but, simultaneously, deficient auditory abilities (specifically, discriminating and approaching the call of their own species) (e.g., Lickliter, 1990). Presumably, the earlier-than-usual visual stimulation resulted in neurons that would normally be dedicated to processing auditory information being instead used for processing visual information. In some ways, premature infants have experiences similar to those of these bobwhite quails, receiving stimulation beyond the typical species range (Als, 1995; Lickliter 2000). Such stimulation may disrupt early brain development (particularly of the frontal cortex), and often results in lowered IQ, impulsivity, and deficits in eye–hand coordination and attention, among others. Yet, it is not uncommon to also find areas of accelerated development in these same children, such as mathematics. Consistent with the findings for bobwhite quails, species-atypical experiences can have unforeseen consequences on brain and behavioral development.

With respect to education, children did not evolve social and cognitive mechanisms adapted to the school house. *H. sapiens* young evolved cognitive mechanisms suited for learning the ways of their clan, including technological skills such as constructing tools or making fires. From all we know about what the life of our hunter/gatherer forebears might have been like (Eibl-Eibesfeldt, 1989), children interacted with other children in small, multiage groups and acquired social and technological expertise via "on-the-job training." Learning was done "in context," and the skills one mastered were directly related to the environments in which they were acquired. Although modern societies have not eliminated on-the-job training, much cultural knowledge and important technological skills (such as reading) are acquired "out of context," while seated in school rooms filled with several dozen same-age children under the tutelage of an unrelated adult. Such a system has been necessary to pass along the expertise of one generation of information-age people to the next, and has served modern humans well. But, we argue, it is a species-atypical environment for children, and thus we should not be surprised if many youngsters do not thrive under such circumstances but experience great difficulty.

3.2. There is need for an extended childhood to learn the complexities of human social communities

Particularly important to humans' unique educability is the extended period of time spent in youth. Primates in general have prolonged juvenile periods (and associated extended lifespans), but humans have taken this trend to an extreme. What is the function of this extended juvenile period? Postponing adulthood carries with it substantial risks, most notably the chance of dying before reproducing. There must have been a potent counteracting benefit associated with delayed maturity that made the tradeoff worthwhile. That benefit was the increased learning that could be accomplished during a time when the brain retained its plasticity. One popular hypothesis holds that an extended childhood was necessary for human children to master the complexities of their social world (e.g., Alexander, 1989; Bjorklund & Kipp, 2001; Byrne & Whiten, 1988; Dunbar, 1995; Humphrey, 1976). As hominid groups became more socially complex, individuals who could more skillfully deal with other group members, both through cooperation and competition, gained more benefits in terms of quality of mates and resources, and the cognitive skills associated with social success were passed along to their offspring. But the diversity of human living conditions made it impossible for people to inherit a set of relatively fixed cognitive operations to apply in well-defined situations. Rather, human social complexity and diversity necessitated a flexible intelligence and a prolonged period of time to learn. This is supported by analysis of primate groups by Joffe (1997), who observed that brain size, length of the juvenile period, and the social complexity of a group were all positively related, consistent with the idea that a big brain may be necessary to master the complexities of a social group, but its benefits can only be realized if there is also sufficient time to learn (see also Dunbar, 1995).

Time to master the social complexities of human groups is not the only cognitive-based hypothesis for the evolution of an extended juvenile period. Kaplan, Hill, Lancaster, and Hurtado (2000) have proposed that a change in diet necessitated the prolongation of youth in our ancestors. Humans around the globe live on high-quality diets of meat and vegetables that are often quite difficult to obtain. Chimpanzees, in contrast, get very little of their nutrition from meat and most of their diet consist of easy-to-acquire ripe fruit. Whereas young hunter/

gatherer children can often successfully forage for low-density and easily accessible food such as ripe fruit, it is only older individuals who are able to extract foods of higher nutrition density such as roots and tubers or vertebrate meat through hunting. Learning to acquire high-quality food takes time, and an extended period of youth may have been needed to make the transition from a lower- to a higher-quality diet.

The prolonged period of immaturity characteristic of humans was surely the result of a multitude of factors acting synergistically over thousands of years. But the endproduct is a child whose brain is receptive to a variety of experiences and has the flexibility to master the social and technological skills of any human culture.

3.3. Many aspects of childhood serve as preparations for adulthood and were selected over the course of evolution

Developmental psychologists have implicitly, and often explicitly, assumed that experiences early in life prepare the child for life as an adult. We concur and further propose that some features of infancy and childhood were selected to enhance learning that would later benefit children in adulthood. Aspects of play, for example, may serve a preparatory role, in that through play children learn important lessons about both their physical and social environments.

One area in which evolved differences in children's behavior and experience may serve as preparation for adulthood concerns sex differences. Evolutionary psychologists have emphasized that men and women have faced different selective pressures over the millennium and have thus evolved different psychologies (see Buss & Schmidt, 1993). Such sex differences do not arise fully formed in adulthood, however, but rudiments can be found in childhood, with boys and girls being biased toward different experiences that will influence their subsequent development and behavior (see Geary, 1998, 1999). These differences are likely most apparent in the social or physical realm. For instance, boys' play is more vigorous and aggressive than that of girls' (see Pellegrini & Smith, 1998) and may serve as preparation for adult hunting and fighting. In comparison, girls in all cultures engage in more play parenting (such as doll play) than boys, which has been interpreted as an evolved tendency relating to females' eventual role as primary caregivers for their offspring (see Pellegrini & Bjorklund, in press).

But sex differences are found in the cognitive realm as well, which may have greater consequences for educational psychology. For example, the performance of some forms of spatial cognition, such as navigating through novel environments (e.g., Moffat, Hampson, & Hatzipantelis, 1998; Silverman, Choi, Mackewn, Fisher, Moro, & Olshansky, 2000) and manipulating spatial relations (e.g., Baenninger & Newcombe, 1995; Casey, 1996), favors males, often from a very early age (e.g., Levine, Huttenlocher, Taylor, & Langrock, 1999). Females, in contrast, tend to perform better than males on tasks involving object and location memory (e.g., Eals & Silverman, 1994; Silverman & Eals, 1992). One hypothesis for this difference holds that males' spatial cognition was selected for navigating over large areas, as would be involved when hunting, whereas females' spatial cognition was selected for tasks of selecting and remembering the location of fruits, berries, and tubers. That is, the presumed difference in the division of labor between ancient males and females is reflected today in gender differences in spatial cognition.

The proximal cause of such sex differences, however, is still unknown. One hypothesis holds that differences in the activity levels and preferred play styles of boys and girls — and the resulting experiences they engender—contribute to the subsequent gender differences in spatial cognition. For example, hormonal differences between the sexes direct boys to more rough-and-tumble play and activities involving spatial cognition, such as carpentry, block building, and throwing and catching objects; as a result of these experiences, boys develop better spatial skills than girls (see Bjorklund & Brown, 1998; Casey, 1996; Casey, Nuttall, & Peraris, 1999; Geary, 1998). This does not mean that males and females are equal in their ability for spatial cognition at birth and that it is only subsequent experience that promotes later differences. Hormones have an effect on brain organization, which in turn can influence how spatial information is processed. But sex differences, even those proposed to reflected evolved adaptations, do not have simple causes, and they are not immutable to environmental intervention. When gender differences in some type of educational skill (higher mathematics, for example) are an issue, attempts at remediation need to consider the possible origins of the sex difference and other factors that may make the acquisition of the skill by boys and girls different. For example, Geary (1996) has proposed that gender differences in preferences for cooperative versus competitive learning styles can be used to foster mathematics achievement by using a competitive classroom structure for boys and classrooms that emphasizes cooperation for girls. Such respective styles of learning would purportedly capitalize on foundational social biases differentiating the sexes.

For example, boys are envisioned to be intrinsically competitive and aggressive as a result of selective pressures favoring these behavioral traits, whereas girls appear to favor coalition, fusion-based strategies of problem solving as a consequence of evolutionary pressures on increased sociality (Geary, 1998). Teaching approaches that trigger these sex-appropriate dispositions may serve to foster increased competencies in selective mathematical domains by harnessing attentive and motivational resources that might otherwise go untapped by pedagogical approaches that do not take these evolved differences between boys and girls into account.

3.4. There have been different selection pressures on organisms at different times in ontogeny, and some characteristics of infants and children were selected to serve an adaptive function at that time in development and not as preparations for adulthood

Not all characteristics of youth serve as preparation for adulthood. Rather, according to evolutionary developmental psychological theory, many features of infancy and childhood have been selected in evolution to serve an adaptive function at that time in development only and not to prepare the child for later life (Bjorklund, 1997; Bjorklund & Green, 1992). That is, some features of childhood, including cognitive competencies, may provide immediate benefits to the child, either exclusively or in addition to deferred benefits. We suggested earlier that play, for instance, has deferred benefits. But it also has immediate benefits, providing exercise, knowledge of one's current environment, and a safe venue for establishing a social hierarchy and learning "one's place" in the peer group.

Some immature aspects of young children's thinking may actually have some associated benefits, their egocentric bias being a case in point (e.g., Foley & Ratner, 1998; Foley, Ratner, & Passalacqua, 1993; Mood, 1979). For instance, when involved in a cooperative task with another person, 4-year-old children are apt to attribute an action made by their partner (such as putting an object on a collage) to themselves, but they rarely falsely attribute an action they had made to the other person. Foley and Ratner (1998) argued that such an egocentric bias may result in better learning of the actions of others, in part because misattributing the actions of another to oneself may result in children linking the actions to a common source (themselves), producing a more integrated and easily retrievable event memory. Support for this contention came from a study in which children who engaged in a collaborative classification task (putting doll furniture in specific rooms in a doll house) later made both egocentric attribution errors (i.e., saying "I placed it there" when, in fact, the collaborator had) and more correct classification responses than a group who had no collaborator (Ratner, Foley, & Gimpert, 2002).

Relatedly, young children's poor self-knowledge (i.e., their metacognition) may be adaptive in some contexts. For example, children who overestimate their own abilities may attempt a wider range of activities and not perceive their less-than-perfect performance as failure (Bjorklund, 1997). Young children typically believe they are stronger, smarter, and generally more skilled than they really are (e.g., Bjorklund, Gaultney, & Green, 1993; Stipek, 1984). (Many of us may also suffer from such an overly optimistic impression of our own worth, but rarely to the same extent as that of a 4-year-old.) Following Bandura (1989), children who believe they are skilled in a domain are likely to attempt more challenging tasks and persist at them longer than less optimistic children, and this, in turn, will influence how much they learn.

The potential adaptive value of overestimating one's abilities is reflected in research on young children's knowledge of their own imitation skills (Bjorklund et al., 1993). In a series of three studies, one based on observations by parents, a second on naturalistic observations during preschool, and a third on a laboratory task, preschool children consistently overestimated their imitative abilities, with underestimation being rare. In the laboratory study, 3- and 4-year-old children who overestimated more their imitative talents had higher verbal abilities than more accurate children. The relation was reversed and nonsignificant for 5-year-olds. Bjorklund et al. suggested that young children's immature metacognition allows them to imitate a wide range of behaviors without appreciating that their attempts fall far short of perfection. Thus, bright young children continue to try a variety of different behaviors, unperturbed by the negative feedback that a more accurate perception of their abilities would provide. Stipek (1984) has similarly suggested that children's overly optimistic opinion of their own competence increases their self-confidence and has suggested that educators construct environments that serve to maintain their eagerness and optimism.

Our primary message here is that many aspects of youth are adaptive for their own sake, providing immediate rather than deferred advantages. Rather than viewing children's immature thinking as something that must be overcome, and the sooner the better, it should be viewed as potentially having some adaptive value for the child specific to that time in development. This perspective also implies that children's cognition is best suited for certain types of experiences at certain times in ontogeny and that instructing children in more "mature" forms of thinking too early in development may have inconsequential, or even deleterious, effects. We will return to this possibility later in this article.

3.5. Many, but not all, evolved psychological mechanisms are domain-specific in nature

One of the dogmas of evolutionary psychology is that humans evolved domain-specific, modular-type cognitive mechanisms, designed to solve specific, recurring problems that our ancestors faced in the environment of evolutionary adaptedness. This implies that infants enter the world with certain perceptual and cognitive abilities that will make learning some things (such as language) easier than others (such a reading), and that these abilities serve as the foundation upon which the more advanced cognition of the juvenile, adolescent, and adult is built. We concur, but believe that domain-general abilities, as reflected by working memory, speed of processing, and perhaps a general component to psychometrically measured intelligence, also experienced selection pressure and are fair topics for investigation from an evolutionary perspective. We believe that intelligence is multifaceted, including both domain-specific and domain-general mechanisms that interact to produce adaptive patterns of behavior (see Bjorklund, 2000; Bjorklund & Pellegrini, 2002), and that this fact must be considered in any fully articulated evolutionary psychological theory, particularly one that hopes to be applicable to modern educational settings.

Perhaps the best-known domain general theory of children's thinking is that of Piaget. Although few developmental psychologists today believe that Piaget's account of cognitive development reflects accurately the changes in thinking that occur over ontogeny, his theory describes what may very well be one form of intelligence influenced by a domain-general mechanism. Comparative psychologists have taken advantage of the well-established developmental milestones found in Piaget's theory of sensorimotor intelligence and examined its development in nonhuman primates and interpreted these findings with respect to a developmental evolutionary theory (see, e.g., Gibson, 1990; Jolly, 1966; Langer, 2000; Parker, 1996; Parker & McKinney, 1999). For example, Parker and McKinney (1999) propose that cognitive abilities have been added over the course of primate evolution, with humans attaining a higher level of cognitive ability than apes, and apes attaining a higher level than monkeys, all expressed in terms of Piaget's account of sensorimotor accomplishments. Moreover, whereas these abilities tend to be well integrated in humans (thus reflecting the influence of a domain-general mechanism), they are less well integrated in monkeys and apes. In other words, Parker and McKinney argue that over the course of primate evolution leading to *H. sapiens*, a single, domain-general cognitive function emerged, and that this is one of the major differences in the cognitive development of humans and apes.

3.6. Emphasis on higher-order cognition

Evolutionary psychology emphasizes the implicit nature of psychological adaptations. Men, for instance, are not explicitly calculating the waist-to-hip ratios of the reproductively viable females they come in contact with, or people are not aware of the reasons they find *filet* *mignon* appetizing but feces disgusting, but nonetheless humans have evolved distinct modules designed to solve problems in the domains of sex and eating. The fact that we do not have to learn or "think" about why we have the universal sexual and food preferences we do is a testament to the efficiency of natural selection in solving adaptive problems in the past. (From the above example, one can easily imagine what would have become of the Pleistocene denizen who inherited the wrong taste in food!).

For the most part, we agree with this approach, which permits psychologists to explain the actions of humans in the same way that the actions of nonhuman animals are explained. No special pleading for the uniqueness of humans is required to explain their actions. Human behaviors, such as those involving sex, food acquisition, conflict, reconciliation (to name just a few), and perceptions, such as aesthetic preferences, are governed by evolved psychological mechanisms that arose over time because they were successful at solving adaptive problems; they need not have first consulted with human consciousness to have found their niche in human brains. Evolutionary psychologists escape, then, the logical pitfalls involved with endowing humans with some sort of mystical, mindful chimera — usually referred to as "rationality" — and the view prominent among the social sciences that human behavior is entirely learned (see Tooby & Cosmides, 1992).

But if all human behavior is run, as it were, by the mindless machinery of the evolved brain, then how *do* we account for the differences between humans and other animals in the area of social learning — and, in particular, the type of learning that is done in educational settings? We do not believe that humans are simply "better learners" than other species. Rather, we believe, as others do (e.g., Tomasello, 1999), that humans are different *kinds* of learners, and that this has nearly everything to do with our ability to consciously think about what's happening in our own and others' heads.

Sometime around the age of 4 or 5, children come to explicitly reason that behavior is caused by unobservable mental states (Wellman, 1990; Wimmer & Perner, 1983). This is entirely dependent upon the ability to view others as intentional agents who do things for reasons that can only be discerned through actively thinking about intentions, beliefs, desires, wishes, and so on. (Why is mommy moving her hands about with those long strings in that way? Because she is trying to show me how to tie my shoelaces.) There are many forms of social learning in the animal kingdom (see Tomasello & Call, 1997), but it appears that true imitation, in which an observer understands the intentions of the demonstrator when engaging in a behavior, may be limited to humans and (perhaps) the great apes (see Whiten, 1998). This is because having a theory of mind is required for this form of learning and may be an evolutionary novelty that did not appear until very recently in primate evolution. Likewise, intentional teaching, or pedagogy, necessitates understanding that the pupil does not know what is being taught, and it is a deliberate attempt to manipulate the knowledge base of the learner by the teacher. If we could not represent mental states, parents would never have been motivated to pass on information to their offspring, culture would therefore not have evolved, and schooling could simply never have come about (see Tomasello, Kruger, & Ratner, 1993).

This is not to say that theory of mind cannot be confined to a module of some sort (e.g., Baron-Cohen, 1995), and thus is not amenable to evolutionary psychology interpretations (although there is some reason to question domain-specific accounts of theory of mind; see

Bering, 2002). We do not consciously "activate" our theories of mind in these contexts, and children do not have to learn how to represent mental states. Nonetheless, despite the generally unconscious nature of the psychological mechanisms proposed by evolutionary psychology, humans, including children, become consciously aware of some of the operations of their mind; and the behaviors occurring in the classroom, at both the chalkboard and the desk, involve thinking about thinking.

3.7. Evolved mechanisms are not always adaptive for contemporary people

As we mentioned earlier, evolutionary psychologists contend that adaptive cognitive mechanisms evolved to solve specific problems in the environment of evolutionary adaptedness. However, that environment no longer exists, and only a relative handful of "traditional" people live in conditions that even remotely resemble the conditions under which our minds evolved. Although contemporary humans face many of the same problems that our ancestors faced, life in sedentary communities with 9-to-5 jobs, mass communication, police departments, grocery stores, and internet chat rooms makes the demands of modern life very different from those experienced by our predecessors. Civilization is barely 10,000 years old, and the domestication of wild plants and animals is only slightly older. This is too little time for evolution to have shaped the human mind to cope with the novel pressures that complex culture brings. This means that the brain in a child's head born in the dawning years of the 21st century is identical to that of a child born 1000 generations earlier. The result is that many of the mechanisms that served well the Pleistocene child may be irrelevant or even deleterious to the contemporary youngster.

We think that perhaps that the best example of the modern child being hindered by the ancient brain that resides in his or her head is illustrated by the demands of formal schooling. The specialization of contemporary culture has made it necessary for children to be mass-educated "out of context," acquiring technological skills, such as reading and mathematics, that are necessary for success in modern societies. But from an evolutionary developmental psychological perspective, much of what we teach children in school is "unnatural" in that teaching involves tasks never encountered by our ancestors, and some "normal" individual differences in behaviors may be especially maladaptive in contemporary environments. In Section 4, we will examine briefly some of these aspects of formal schooling and some evolutionary developmental theory and research related to the topic.

4. Schooling as an "unnatural" experience

Although there are many reasons for variability in children's school performance ("innate" intelligence, home environment, etc.), part of the problem is related to the very nature of school and the contrasting nature of children's developing brains. As we mentioned previously, much of what modern children learn in school involves technological skills foreign to our ancestors. This does not imply that children growing up in the Pleistocene inherited, fully formed, all the information-processing mechanisms they would need to handle the problems of their world. As we have stressed throughout this article, the hallmark of human cognition is its flexibility, and the technological skills of human cultures 100,000 years ago were not mastered simply by activating innate modules. Rather, throughout *H. sapiens*' existence, children had to acquire the specific skills of their culture, skills so varied that they could not be the product of the activation of highly constrained evolved mechanisms. In this sense, contemporary and ancient children are no different, in that attaining adult proficiency in any culture requires a cognitively flexible mind and much time. What differs between modern and ancient children is not so much the complexities of the skills they must learn, but the nature of those skills and the contexts in which they are best acquired.

4.1. Biologically primary and biologically secondary abilities

Geary (1995) suggested a simple dichotomy of cognitive abilities from an evolutionary developmental perspective. Consistent with the canonical position of evolutionary psychology, Geary believes that natural selection provided children with sets of cognitive skills that would be useful in all species-typical human environments and expressed similarly for children across the globe and across time. These he referred to as *biologically primary abilities*. These skills are universal, show similar developmental trends in their acquisition, and children have intrinsic motivation to practice them, often doing so spontaneously. Language is perhaps the most obvious example of a biologically primary ability, although Geary (1995, 1996) used examples from simple mathematics to demonstrate his idea. For example, Geary cited evidence that young children readily acquire concepts of numerosity (the ability to determine accurately the quantity of small sets of items), ordinality (basic "more than" and "less than" relations), counting small sets of items (no greater than five), and simple arithmetic involving sets of no greater than three or four items, apparent even in 5-month-old infants (e.g., Wynn, 1992). Biologically primary abilities have presumably been selected over the course of evolution, and some of these skills may be found in species such as chimpanzees in addition to humans (see Bjorklund & Pellegrini, 2002).

Biologically primary abilities are contrasted with *biologically secondary abilities*, which reflect more complicated cognitive operations designed to solve problems particular to a specific culture. Biologically secondary abilities are thus cultural inventions. They are built upon the more basic biologically primary abilities, and, by definition, are not universal, must be "educated," and may require extrinsic motivation for their practice. Reading may be the most obvious example of a biologically secondary ability for contemporary children. Unlike its biologically primary mate, language, reading is not acquired universally, is rarely learned without instruction, and many children are not motivated to read spontaneously. (In fact, many literate adults read only when it is absolutely necessary.) Pinker (1997) summed up the distinction between language and reading succinctly: "Children are wired for sound, but print is an optional accessory that must be painstakingly bolted on" (p. ix). Within the domain of simple mathematics, Geary (1995) proposed that learning number names and counting much beyond five is a biologically secondary skill, as is arithmetic. Children must learn by rote their addition and multiplication facts, and it is the rare child who engages in such memorization without the benefit of some external reinforcement.

Although Geary (1996) has characterized biologically primary and biologically secondary cognitive abilities as occupying relatively distinct systems, he nevertheless leaves ample room for conceptual wedding of the two. Indeed, the entire theoretical framework he advances is dependent upon the supposition that biologically secondary abilities will be most thoroughly fleshed out wherever a given milieu effectively exploits not only the implicit neurobiological organization of the child's mind, but also the implicit knowledge he or she has obtained as a function of self-initiated engagement with his or her social, physical, and cultural environment. That is, implicit knowledge, the acquisition of which is expressly governed by innate dispositions toward discovery of basic, intuitive principles underlying, for example, the mathematical and language domains, becomes increasingly explicit in response to environmental features highlighting and then painstakingly reorganizing these principles. Language skills first appear, therefore, in the form of effortless representation of sounds, meaning-mapping, and recognition of the phonemic parsing of spoken words. These skills are then "captured" by cultural forces intent on pinning language down to paper for purposes of visual symbolic encoding. The secondary exploitation of language in this sense is highly advantageous for individuals embedded in a cultural system in which mastery of reading determines their greater adaptive success (e.g., resource acquisition, mate retention, child-rearing competency, etc.).

But the enormously rigorous and effortful acquisition of mature reading skills in children, not to mention children's (and adults') usual aversion to reading, belies, according to Geary, its relatively recent emergence in the human species, and therefore its probable uselessness in ancestral populations. What *was* useful, he reasons, were cognitive proclivities guiding successful resolution of initial conflicts within those ancient dimensions of the ontogenetic environment that had significant bearing on the ultimate survivability of the child's genetic endowment, such as competition over resources, gender identification, parental attachment, and spatial representation. One important educational implication of this reasoning is that biologically secondary cognitive abilities can perhaps be facilitated by placing learning within evolutionarily relevant thematic contexts. This is a point, in fact, emphasized by Geary (1995) himself, who states that, "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 ...)" (p. 28). An obvious application to reading instruction involves a careful, deliberate tailoring of the written material to reflect evolutionarily salient features of particular developmental stages *and* gender-based differences, such that content promotes discovery of—and eventual excellence in—reading.

But does mastering the three R's differ in any meaningful way from learning how to make stone tools, how to identify and process edible vegetation, or how to navigate between islands in a canoe? One can certainly argue that the latter tasks are of comparable or greater intellectual difficulty as the former, and all require biologically secondary abilities. What distinguishes the tasks of children from information-age societies from those of children in traditional and ancient cultures is the context in which the tasks are learned. Learning in traditional cultures is typically performed "in context," with the tasks a child performs being immediately relevant to solving a real-world problem. Skills are acquired in interaction with more expert adults or peers (see Rogoff, 1990; Rogoff, Mistry, Göncü, & Mosier, 1993). In contrast, modern technological skills are usually learned "for their own sake," not to solve any real-world problem. The motivation to learn these out-of-context skills can be seriously lacking, particularly for children who have not experienced some of the positive consequences that possessing skills such as reading and arithmetic can bring. For example, children who are read to by their parents learn that reading can be a source not only of information but also of entertainment. Young children without such positive experiences may see little reason to practice such an unnatural task.

Most educators can provide at least one anecdote about a child who was a failure in mastering some skill in the classroom but a success when that same skill was presented in a real-world context. Let us provide one of our own. High-school mathematics was not Donald's cup of tea. He failed geometry his sophomore year and squeaked by with a "D" his junior year. Upon graduation, he applied for a job on a survey crew. When asked if he had taken geometry in high school, he responded with the literal truth that, yes, he had taken 2 years of geometry. Although some might have predicted that Donald's mathematics' skill would limit him to life as a rod man, holding a stick while others did the real measuring, he developed a fascination with what his elders were doing, volunteered to work weekends when he received extra instruction on how to do the more complicated jobs, and eventually became the youngest person in his county ever to pass the licensure exam as a Registered Land Surveyor. Donald found an occupation that matched his intellectual abilities. But given his experience in high school mathematics, it seems a marvel that he ever put himself in a situation in which those skills could blossom.

We are not arguing that school systems should adopt a "back-to-nature" approach, abandoning the basic logic of classroom instruction that has permitted all children in a culture exposure to environments in which the most critical technological skills are taught. In fact, we have sometimes been disconcerted by claims of some cross-cultural psychologists who argue that Western societies should adopt the more "natural" style of education found in more traditional societies. But given the nature of what children must learn and the contexts in which mass education requires that they learn it, professionals concerned with children's formal education should not be surprised when some youngsters experience great difficulty mastering tasks that other children acquire with relative ease; and they should investigate alternative ways of getting the important cultural messages across, grounded in relevant cognitive developmental theory that takes into consideration not only how children's brains process information, but also why the brains evolved to function as they do.

4.2. Physical activity

It is not just children's intellectual skills that are sometimes at odds with the demands of formal schools, but also aspects of their physical and social development. For example, in most contemporary schools, children must spend most of their days in relatively small classrooms with same-age peers, seated in chairs or at tables, while performing "seat work" or attending to instruction from a teacher. Although young children sometimes spend their free time engaged in similarly sedentary tasks (often in the context of social play), it is more common for them to engage in physical play, especially for boys (Pellegrini & Smith, 1998). School discourages this type of activity, and much of the disruptive behavior seen in elementary schools can be attributed, we believe, to young children's need for more physical activity. Moreover, for young children in particular, prolonged focused intellectual activity may bring diminishing returns, as their ability to concentrate reduces rapidly as the length of time between breaks increases.

Support for these contentions comes from research examining the role of recess on children's school activity. Several studies have reported that elementary school children display more on-task behavior (Jarrett et al., 1998; Pellegrini & Davis, 1993; Pellegrini, Huberty, & Jones, 1995) and less "fidgeting" (Jarrett et al., 1998) following a recess break than when recess is denied to them. For example, in a series of three studies, Pellegrini et al. (1995) experimentally manipulated the timing of school recess for kindergarten, Grade 2, and Grade 4 children. Recess was delayed by 30 min, 2 days a week relative to the remaining days, and attention to seat work, assessed both before and after recess, was assessed. At each grade, children were significantly more attentive after recess than before, and the effects of recess deprivation were significantly greater for the younger than for the older children.

Age differences in the beneficial effects of recess should not be surprising, for developmental differences in selective attention and the ability to resist interference and inhibit unwanted behaviors are well documented (e.g., Bjorklund & Harnishfeger, 1990; Dempster, 1992; Schiff & Knopf, 1985). Yet, recess has been steadily disappearing from the classroom curriculum, at least in the US, based on the belief that it distracts from the schools' primary mission of instruction (see Pellegrini & Bjorklund, 1997). This seems not to be the case in many Asian schools. For example, Stevenson and Lee (1990) reported that although first- and fifth-grade children in Taipei, Taiwan, and Sendai, Japan, spent more days in school than children in Minneapolis, they had more recesses [four versus two for first graders; four or five versus two (or fewer) for the fifth graders], and that the number of hours spent in school was actually less for the two Asian school systems than for the American for first-grade children. That is, despite having what is perceived as a more rigorous curriculum, the Asian schools seemingly better recognized the cognitive and behavioral limitations of young children than the Minneapolis school and structured the day to take these limitations into consideration.

There has even been the contention that children's (particularly boys) high rates of "natural" exploration and activity have resulted in many misdiagnosed cases of attentional deficit hyperactivity disorder (ADHD; e.g., Panksepp, 1998; Pellegrini & Horvat, 1995). Such behavior does not fit well with modern schools, and it is understandable that teachers should be concerned by the disruption and difficulty in learning that such unconstrained activity often brings. We concur that children with ADHD are at a significant disadvantage in schools, and likely would be in any environment (Goldstein & Barkley, 1998); but less extreme individual differences in activity levels and attention shifting may have had some advantages in ancient environments, and may still afford some benefits in many contexts

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5. The ecology of early childhood and the educational curriculum

As we mentioned earlier, we believe that children possess not only adaptations that serve preparatory functions for adulthood (e.g., play), but also ontogenetic adaptations (e.g., suckling) that were selected to be functional at a particular time in development. With respect to the latter case, we wish to emphasize that there is an *ecology of early childhood*, and that the presumably "immature" patterns of behavior and intellectual functioning of young children have been fitted by evolution to meet specific challenges recurrent in ontogeny. This ecology is not the adult world of sex and aggression that has been the focus of traditional evolutionary psychology, but rather a world with qualitatively different problems to be solved.

While it is true, of course, that evolution depends ultimately upon the successful reproduction of mature forms, there is no legitimate reason to claim that young children are less representative of the species than are adults. Their brains, though different from ours, were subjected to selection pressures just as adults' were, and were it not for their evolved specializations to solve recurrent problems in the ecology of early childhood, the history of our species would have been written much differently than it was. But although the minds of very young children may possess adaptive mechanisms that are in some sense discontinuous from adult forms, evolutionary psychologists have, until very recently, given short shrift to the adaptive functioning of early childhood. Of even more concern for purposes of the current article, however, is the fact that some parents, educators, and physicians have not appreciated that such an ecology of early childhood exists, and have instead chosen to view this developmental period, and the cognitive and emotional immaturity that is inherently bound to it, as an ungainly phase from which young children should be hurried through on their way to maturity.

We argue that these attempts are not always in due haste (see Bjorklund, 1997; Bjorklund & Green, 1992; Bjorklund & Schwartz, 1996). Inappropriately structured preschool environments are a case in point. While general learning is preeminent among the problems associated with early childhood, the formal pedagogical instruction required in modern educational settings is a foreign element in the natural ecology of the 3- to 4-year-old child. We discuss this in more detail below, and also why we believe that early schooling programs that place a strong emphasis on academic achievement will be, at best, largely unsuccessful, and, at worst, disadvantageous to the child. First, however, we review some of the literature on the effects of early learning in other species and in human infants, paying particular attention to the potential consequences of exposing young organisms to experiences that they would not have encountered in the *ontogenetic* environment of evolutionary adaptedness.

5.1. Is earlier always better?

Although there have only been a handful of studies that have been concerned with the effects of premature learning on later functioning, the findings that have been reported may have broad implications if considered within the frame of evolution and education. For example, Rudy, Vogt, and Hyson (1984) reported that, in rats, early learning experiences could be a detriment. Pups trained on a classical conditioning task beginning when they were just 10 days old performed significantly worse on the task at Days 14 and 15 than rat pups that started training at 12 days of age. Moreover, these pups performed worse on the task than pups that started training on Day 14. That is, not only was there no savings associated with early learning, but the effect was actually in the opposite direction. Other research on conditioning and early learning in rats provides similar findings (e.g., Spear & Hyatt, 1993) and led Spear and Hyatt (1993, p. 183) to conclude that, "apparently, if experience with an episode to be learned later is given too early in life, learning that episode in later ontogeny is impaired."

These seemingly counterintuitive curves of learning are not isolated to rats. While investigating object discrimination learning in rhesus monkeys, Harlow (1959) reported similar findings of detrimental effects of early learning on later learning in rhesus monkeys. The animals began training when they were either 60, 90, 120, 150, or 366 days old and were initially given 25 trials per day, 5 days a week over a 2-month period. Afterward, the same subjects were given new sets of more complicated object discrimination problems that used the same stimuli from the earlier training, and this phase continued until each training cohort was about 1 year old. When matched for age, performance of the two youngest groups (those animals that began training at 60 and 90 days) was consistently worse than the later-trained monkeys' performance, even though the earlier-trained monkeys had, in some cases, 10 months of additional experience! In light of these findings, Harlow (1959, p. 472) concluded that "there is a tendency to think of learning or training as intrinsically good and necessarily valuable to the organism. It is entirely possible, however, that training can either be harmful or helpful, depending upon the nature of the training and the organism's stage of development." Limited research with human infants supports this contention as well, with some data showing that early learning can significantly hamper later performance (Papousek, 1977), and other data reporting only an absence of savings (Little, Lipsitt, & Rovee-Collier, 1984). Young organisms, it seems, must be "ready" for specific classes of input before they can benefit from them.

6. Miseducation

This has particularly important implications for educators who are inclined to view 3- and 4-year-olds in the same light as older children and therefore advocate formal schooling at early ages. A number of developmental researchers and policy makers have argued against academic instruction for preschoolers proposing that such programs amount to *miseducation* (e.g., Elkind, 1987; Sigel, 1987). Young children's cognitive abilities are not well matched for adult-directed academic curriculum, and the overall result is unnecessary stress and no long-term benefits.

Although surprisingly little research has been done to address these important issues, several studies have compared the effects of early high-academic preschool programs versus programs that stress child-centered, "developmentally appropriate" (Bredekamp & Copple, 1997) approaches to learning. In one of the few well-designed studies investigating this issue that we are aware of, Hyson, Hirsh-Pasek, and Rescorla (1990) (see also Rescorla, Hyson, & Hirsh-Pasek, 1991) gave 4-year-old, middle-class children tests of academic skills, social competence, emotional well being, and creativity at the end of their preschool program and again toward the end of kindergarten. While there were no significant differences reported for academic competency at either time point, children from the high-academic program demonstrated greater test anxiety at the end of preschool. Although children whose mothers were rated high on an adult instruction scale showed higher academic achievement in preschool, these effects disappeared in kindergarten, and such children showed less creativity than their peers. Additionally, children who attended high-academic preschools showed greater school-related anxiety throughout the study and maintained a less positive attitude toward school in general. Although the negative effects of this study were small in magnitude, the long-term positive effects were nonexistent, prompting the authors to state that, "it may be developmentally prudent to let children explore the world at their own pace rather than impose our adult timetables and anxieties on them" (Hyson et al., 1990, p. 421).

We share these sentiments. We do not, of course, wish to suggest that all cases of early learning are maladaptive for infants and very young children; indeed, infants begin learning while still in utero, and learning will continue to be the most critical exercise for decades to come. We only wish to suggest that nature has created a developmental range within which these early learning experiences should proceed logically, and by artificially accelerating some forms of learning, parents and educators might, through tinkering with complicated developmental systems, unknowingly put their children at a later disadvantage.

The effects of adult-directed versus child-centered instruction have also been examined in a longitudinal assessment of preschool programs for disadvantaged children (Weikart & Schweinhart, 1991). When interviewed at age 15, children who had attended a child-centered preschool program felt less alienation from school, home, and society relative to 15-year-olds who had experienced teacher-directed instruction. Although there were no differences in IQ or school performance between the two groups, children who had attended the child-centered programs engaged in half the number of delinquent acts, participated more in sports, and had higher educational expectations than did those who had attended the teacher-directed programs.

The relative paucity of empirically solid studies on the topic of the effects of adult-directed learning on young children's subsequent development requires that the extant findings be interpreted cautiously. Nevertheless, they are consistent with an evolutionary developmental psychological perspective that proposes that young children learn best in a more "natural" environment rather than one that stresses teacher-directed instruction. Young children's cognitive systems are adapted for contexts far different from the formal classroom, and it is in such environments that learning will be optimized. The intellectual abilities of young children may be ideally suited for solving the problems that juveniles have faced, and continue to face, since the early days of our species, and we should think twice about hurrying children through a childhood that has purposes in and of itself.

7. Evolution, children, and educability

Educability is our species claim to fame. The suite of social, cognitive, and communicative abilities that characterize *H. sapiens* has permitted the creation and transmission of culture to an extent that far exceeds that seen in any other species. These abilities evolved, and evolutionary psychologists propose, rightly we believe, that understanding the behavior of contemporary people requires understanding the problems that the mind evolved to solve. Evolutionary *developmental* psychologists further propose that the minds and actions of children also had to pass through the sieve of natural selection and that many of the adaptations of children are specific to the infancy or juvenile periods of ontogeny and are directly pertinent to issues of educability. Humans' large brains and extended childhoods provide them the wherewithal to master the complexities of their social and technological environments (and their extended lifespans make it worth the effort to do such learning). Education may be a lifelong phenomenon, but natural selection has given children a "head start" on the road to acquiring the social and technological know-how to survive and prosper in any human culture.

We do not claim that children today have it any easier or any harder in mastering the demands of their culture than did children 10,000 or even 100,000 years ago. However, many of the technological skills that children have to master today are qualitatively different than the skills that their juvenile ancestors had to learn. Reading and mathematics, in particular, are abilities that are not performed (or at least not initially learned) to solve a real-world problem. They are skills that people need in order to solve a host of unrelated problems throughout life. They require specific instruction and cannot be learned readily "on the job" as other technological skills are. They require formal schooling, which is an evolutionarily novel phenomenon.

We make no claims that an evolutionary developmental perspective (or an evolutionary educational perspective) is a panacea for the problems of modern education. In fact, despite the appeal that evolutionary theory has for us, we caution the overapplication of such theory to explain development or education. Proponents of evolutionary theory have sometimes engaged in speculation about what the ancient pressures might have been and how certain contemporary dispositions might have come about over the course of our species' phylogeny. Speculation in any science is apt to be fruitful only when it is based on a corpus of known facts and when it is subject to empirical verification (or, more properly, falsification), and in the absence of such a foundation, evolutionary speculation amounts to the weaving of "just so" stories. But even evolutionary psychological theory properly done should not be seen as replacing other accounts of development/education, but rather as an overarching perspective in which theories addressing the more proximal causes of behavior can be applied. It is within this framework that we argue that understanding the nature of children and childhood, and thinking about how children's social and cognitive abilities may

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