Anuario de Psicología
2008, vol. 39, nº 2, 209-223

Children's academic development: Where evolution meets culture

David C. Geary
University of Missouri at Columbia

Schools are the interface between evolution and culture. They are the contexts in which children's evolved learning and motivational biases intersect with the need to learn the vast array of evolutionarily-novel skills (e.g., reading) and knowledge (e.g., geometric concepts) needed to function as adults in modern societies. The rapid cross-generational accumulation of knowledge during the past several millennia has created a gap between children's evolved learning and motivational biases and the types of learning needed to master evolutionarily-novel skills and knowledge. I provide a brief overview of these evolved learning and motivational biases, and place them in the context of children's learning and motivation to learn in modern-day schools.
Key words: *evolution, development, cognitive development, academic learning.*

Desarrollo académico infantil: donde la evolución se encuentra con la cultura

Las escuelas constituyen el punto de encuentro entre la evolución y la cultura. Son los contextos donde los aprendizajes y motivaciones infantiles predispuestos durante la evolución se entrecruzan con la necesidad de aprender una gran cantidad de habilidades (e.g., leer) y conocimientos (e.g., conceptos geométricos) evolutivamente nuevos, precisos para el funcionamiento adulto en las sociedades modernas. La rápida acumulación de conocimientos durante los pasados milenios ha producido un vacío entre estas predisposiciones de aprendizaje y motivación infantiles generadas durante la evolución, y los tipos de aprendizaje requeridos para dominar las habilidades y conocimientos evolutivamente nuevos. Aquí se realiza una breve descripción de estas predisposiciones de aprendizaje y motivación evolutivas, y se las sitúa en el contexto de los aprendizajes y la motivación para aprender de los niños en las escuelas modernas.
Palabras clave: *evolución, desarrollo, desarrollo cognitivo, aprendizaje académico.*

Author's address: Department of Psychological Sciences. 210 McAlester Hall. Columbia. MO 65211-2500. United States. E-mail: GearyD@Missouri.edu
Original recibido: marzo 2008. *Aceptado:* junio 2008.

Schooling is at the interface between evolved biases in children's learning and the processes through which culturally-important knowledge and skills are transmitted across generations. An understanding of this interface is especially critical for societies with vast and rapidly accumulating stores of knowledge (e.g., in books). These are societies in which a gap has emerged –and is rapidly widening– between what children find easy to learn and are motivated to learn based on human evolutionary history, and what they need to learn to be successful adults in these societies. Unfortunately, the distinction between evolved biases in children's learning and motivation to learn and their ability and motivation to learn cultural knowledge that has accumulated during the past several millennia has not been made in educational research or practice. In fact, the application of insights from evolutionary theory has not frequently occurred at all in the field of education, despite increasing acceptance among psychological scientists (e.g., Buss, 2005). In this article, I provide a brief introduction to the interface between evolved aspects of children's development and their schooling in modern societies (see also Geary, 2007, in press). In the first two sections, I outline the evolved cognitive, developmental, and motivational foundations for learning in evolutionarily-novel contexts, and in the third I discuss implications for children's motivation and learning in modern schools.

Evolution of the human mind

The mechanisms that drove the evolution of the human mind and brain and the corresponding ability to learn throughout the lifespan are vigorously debated. The proposals range from the ability to anticipate and adjust to climatic fluctuations (Ash & Gallup, 2007; Kanazawa, 2004) to learning complex hunting skills (Kaplan, Hill, Lancaster, & Hurtado, 2000) to the demands of living in large, dynamic social groups (Alexander, 1989; Dunbar, 1998; Flinn, Geary, Ward, 2005; Geary, 2005; Humphrey, 1976). At the core of all of these proposals is the ability to anticipate changing conditions (e.g., climate or social relationships) and then to generate and mentally rehearse potential behavioral responses to these changes. The mechanisms that resulted in our ability to anticipate and cope with change are also the mechanisms that now allow us to create culture and to accumulate a wealth of evolutionarily-novel knowledge (Geary, 2005). The corresponding cognitive systems support children's ability to learn evolutionarily-novel information (e.g., sum of the interior angles of a triangle is 180) and skills (e.g., reading) in school, and the evolved motivational components influence their motivation, or lack thereof, to engage in school learning.

Learning in school

All theories on how the human mind evolved focus on our ability to cope with conditions that were not entirely predictable from one situation to the next and had the potential to influence survival or reproductive prospects during our evolutionary history. As an example, there are features of social life –marriage, investment in children, competition with other groups– that are found in all human cultures and presumably during human evolution (Brown, 1991), but the specifics differ from one group to the next, from one person to the next and across time. This is true in other primates as well, but their social behavior is much more stereotypical than that found in humans. In Hamadryas baboons (*Papio hamadryas*), for instance, the behavior of subordinate individuals to dominant individuals follows the same script, more or less, across dyads (see Parker, 2004). The social behavior of chimpanzees (*Pan troglodytes*), and other great apes, is scripted to some extent but it is also more varied and flexible, requiring some degree of anticipation and planning. The latter requires a social apprenticeship whereby the scripts for some of the more complex features of social life are elaborated upon during development, with the aid of older group members. This pattern is taken to the extreme in humans, making scripted "hardwired" responses to social relationships maladaptive; people who always respond in the same way are easily out maneuvered socially and thus at a disadvantage.

I proposed in my 2005 book, *Origin of Mind: Evolution of Brain, Cognition, and General Intelligence*, that the mechanisms that allow people to cope with novelty and change include general fluid intelligence and the underlying ability to focus attention and inhibit irrelevant information from entering into working memory. These mechanisms use information generated from folk-modular systems (see below). The simultaneous representation of different pieces of information in working memory appears to be linked to the associated brain systems. In this way, evolved modular systems can be linked in novel ways (Sporns, Tononi, & Edelman, 2000), creating evolutionarily-novel abilities. For example, the linking of language systems to visual object-naming systems may contribute to our ability to read (Geary, 2007). Many modular systems are also internally modifiable in response to experience, especially early experience (Geary & Huffman, 2002); this means the systems can respond to a range of information, within constraints (Sperber, 1994).

Motivation to learn in school

The source or sources of the unpredictability that resulted in our ability to anticipate and adapt to novelty and change are predicted to have also resulted in motivational biases for the associated content. If anticipating and adapting to climatic change was a key evolutionary pressure, then humans are predicted to be biased to attend to corresponding information (e.g., cloud patterns) and engage in activities during development that facilitates the ability to predict climate change. In other words, if climatic variation was a selective pressure that drove the evolution of the human mind and brain, then children should be biased to learn about weather patterns. This knowledge cannot be "hardwired" because weather is too variable and thus a motivational bias to learn how to predict this variation should be part of children's natural development. If learning the nuances of social dynamics was the driving force in human cognitive evolution, then learning and motivational biases organized around common social relationships, such as parents and peers, should be found. In either case, the predicted motivational biases are for content that differs from much of that taught in modern schools.

Modular domains of mind

Whether the pressure were climatic, ecological, or social, the human mind and brain evolved to attend to, process, and guide behavioral responses to core types information: information that correlated with survival and reproductive prospects during our evolutionary history. Figure 1 shows a taxonomy of these *biologically primary* or core domains of human cognition (Geary, 2005).

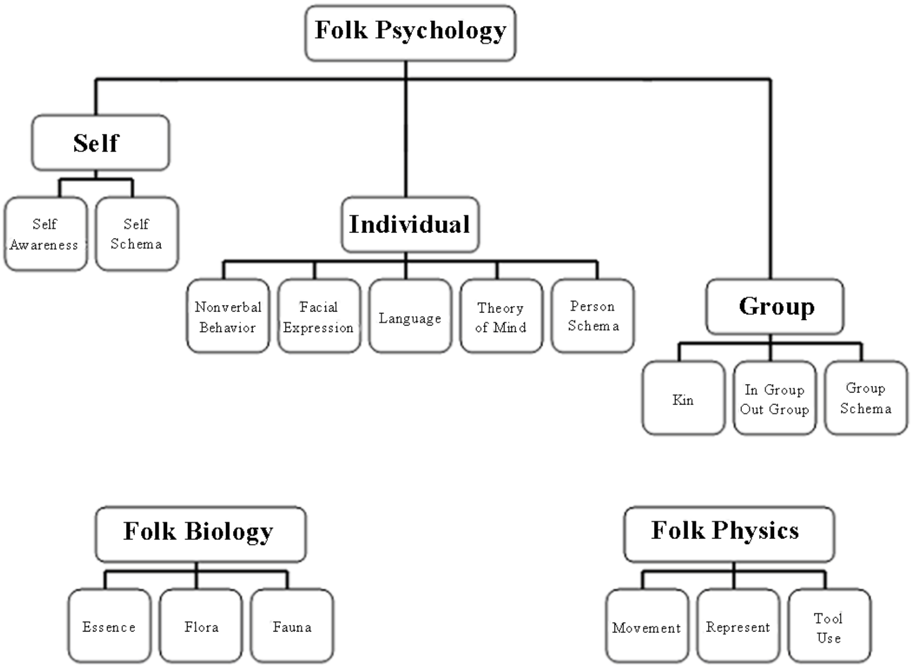

Figure 1: Evolutionarily salient information-processing domains, and associated cognitive modules that compose the domains of folk psychology, folk biology, and folk physics.

The domains coalesce around folk psychology, folk biology, and folk physics (Atran, 1998; Baron-Cohen, 1995; Geary, 1995; Leslie, Freidman, & German, 2004; Mithen, 1996; Wellman & Gelman, 1992); there is also evidence for an evolved set of quantitative abilities (Geary, 1995, R. Gelman, 1990; Spelke, 2000). I have suggested these folk systems are composed of a constellation of "soft" modular mechanisms. They are modular because they process specific forms of information and they are soft because they are sensitive to and change in response to variation in the corresponding information patterns. A bias to orient to the human face and to automatically process key pieces of facial information (e.g., eyes) is an example of a modular primary ability (Kanwisher, McDermott, & Chun, 1997). If the ability to discriminate one person from the next affords a social advantage over those who cannot make these discriminations, then evolution should produce a soft module, one with some degree of plasticity, but within constraints. Plasticity results in a capacity for the face-processing system to respond to experience with different people such that the system codes and stores information that allows people to discriminate one person from the next.

I have argued that the function of these folk competencies is to focus behavior on attempts to achieve access to and control of the social, biological, and physical resources that tended to enhance survival or reproductive prospects during human evolution (Geary, 2005). Achieving control is not guaranteed, and if it occurs it is typically without conscious awareness of the corresponding evolved function. Peer relationships are supported by folk-psychological competencies, and much of the corresponding social behavior is not explicitly guided by a motivation to control the behavior of friends. Children's peer relationships allow them to learn the nuances of social dynamics and to come to understand how they can influence other children and how others in the social group try to influence them. In traditional societies and during much of human evolution, these peers will become the adults with whom they will cooperate and compete for mates and other key resources. Early peer relationships become the social-reproductive milieu of adulthood, and thus early learning can have evolutionary outcomes. In other words, whether people are aware of the evolved function, friendships are social resources that can enhance survival and reproductive prospects under the types of conditions found in traditional societies and presumably throughout human evolution.

Folk systems

Folk psychology. The folk-psychological systems at the top of Figure 1 represent three sets of modules that process information related to the self, other individuals, and group dynamics, respectively. The first includes awareness of the self as a social being and awareness of one's relationships with other people (e.g., Harter, 2006). Self awareness is tied to the ability to mentally project the self backward in time to recall episodes that are of personal importance and to project oneself forward in time; to create a self-centered mental simulation of potential future states (Suddendorf & Corballis, 1997; Tulving, 2002). Individual level modules process the information need for one-on-one social dynamics and to maintain social relationships (Bugental, 2000). Group-level modules enable individuals to parse their social world into categories of kin, members of favored in-groups, and members of disfavored out-groups.

People also have the unique ability to form in-groups on the basis of ideology, such as nation (Alexander, 1989). These ideologies include moral edicts regarding the treatment of in-group members, and mechanisms for their enforcement (Haidt, 2007). These ideologies support the formation of large-scale cooperative communities, provide stability across generations, and support the cross-generational accumulation of cultural knowledge. These biases evolved because they allow the formation of large competitive groups that are better able to control ecologies and social politics than are poorly organized groups. These ideologies are the foundation for the emergence of modern societies. The formation of these societies supports the division of labor needed for the creation of vast amounts of evolutionarily-novel information and supports the development of schools. Most adults are freed from foraging and hunting demands and some specialize in generating new knowledge (e.g., scientists, poets). The formation of institutions that specialize in the creation of new knowledge, such as universities, has resulted in the exponential increase in evolutionarily-novel knowledge over the past several thousand years, and especially during the 20th century. This trend is only going to increase and will result in an even greater importance for children's schooling in the 21st century.

Folk biology and folk physics. Folk biological modules orient people to the biological world and result in the ability to develop taxonomies of other species and knowledge systems about their behavior, growth, and "essence" (Atran, 1998; New, Cosmides, & Tooby, 2007). In traditional societies, these competencies support behavioral activities that allow people to use ecological resources for survival or reproductive purposes, such as hunting and horticulture (Kaplan *et al.,* 2000). Folk physical systems support navigation, the formation of mental representations of physical features of the ecology, and the construction of tools (Pinker, 1997; Shepard, 1994).

Folk heuristics

The behavioral features of folk domains can be described as "rules of thumb" (Gigerenzer, Todd, & ABC Research Group, 1999). The corresponding information is processed implicitly and the behavioral component is more or less automatically executed (Simon, 1956). Returning to face processing, the pattern generated by the shape of the eyes and nose provides information on the sex of the individual, whereas the pattern generated by the configuration of the mouth provides information about the individual's emotional state (Schyns, Bonnar, & Gosselin, 2002). These patterns are automatically and implicitly processed by the receiver, who in turn expresses corresponding emotional and other social signals (e.g., smile). The receiver may also make implicit decisions regarding the interaction, but these do not need to be explicitly represented in working memory and made available to conscious awareness. These quick, rule-of-thumb decisions can be based on automatically generated feelings and other social information. Negative feelings, such as fear elicited by an angry expression, may prompt withdrawal; and positive feelings, such as happiness generated by a smile, a continuance of the interaction (Damasio, 2003).

Folk heuristics can also include explicit inferential and attributional biases. People often make attributions about the cause of their failures to achieve desired outcomes and often attribute such failures to bad luck or biases in other people. An evolved tendency to make attributions of this type has the benefit of maintaining effort and control-related behavioral strategies in the face of inevitable failures (Heckhausen & Schultz, 1995). Social attributional biases that favor members of the in-group and derogate members of out-groups are also well known (Fiske, 2002) and facilitate intergroup competition (Horowitz, 2001). Similar attributional biases have been identified in the areas of folk biology and folk physics (Atran, 1998; Clement, 1982).

These biases provide good enough explanations for day-to-day living and self-serving explanations for social and other phenomena. An evolved usefulness for everyday living does not mean the explanations are accurate from a scientific perspective. In fact, *descriptions* of psychological, physical, and biological phenomena are often correct (Wellman & Gelman, 1992), but many of the explicit explanations and attributional biases regarding the *causes* of these phenomena are objectively and scientifically inaccurate.

Evolution and cognitive development

From an evolutionary perspective, cognitive development is the experience-driven adaptation of biologically primary modular competencies to the nuances of the local social, biological, and physical ecologies (Geary & Bjorklund, 2000). As noted, modular systems are predicted to be open to experiential modification to the extent that sensitivity to variation within these domains has been of potential survival or reproductive significance during human evolution. At a macro level, prenatal brain organization provides the skeletal structure that comprises neural and perceptual modules that guide attention to and the processing of stable forms of information (e.g., the general shape of the human face) in the folk domains shown in Figure 1 (see also R. Gelman, 1990). In support of this proposal, studies of infants' attentional biases and preschool children's nascent and implicit knowledge are often focused on these three folk domains (S. Gelman, 2003; Keil, Levin, Richman, & Gutheil, 1999; Mandler, 1992; Wellman & Gelman, 1992).

The result are biases in postnatal attentional, affective, and information-processing capacities, and in self-initiated behavioral engagement of the environment (Bjorklund, 2007; Bjorklund & Pellegrini, 2002; Scarr, 1992). The latter generate evolutionarily-expectant experiences, that is, experiences that provide the social and ecological feedback needed to adjust modular architecture to variation in information patterns in these domains (Greenough, Black, & Wallace, 1987). These behavioral biases are expressed as common juvenile activities, such as social play and exploration of the ecology. Experience-expectant processes result in the modification of plastic features of the modular systems. The result is the ability to identify and respond to variation (e.g., to discriminate one individual from another) within folk domains, and the ability to create the forms of category shown in Figure 1, such as in-groups/out-groups or flora/fauna.

Folk domains

Folk psychology. Human infants' biases to attend to human faces, movement patterns, and speech reflects the initial and inherent organizational and motivational structure of folk psychological modules (Freedman, 1974). These biases reflect the evolutionary significance of social relationships and recreate the microconditions (e.g., parent-child interactions) associated with the evolution of the corresponding modules (Caporael, 1997). Attention to and processing of this information provides exposure to the within-category variation needed to adapt the architecture of these modules to variation in parental faces, behavior, and so forth (R. Gelman & Williams, 1998). One result is that infants are able to discriminate the voice of their parents from the voice of other potential parents with only minimal exposure. When human fetuses (~ 38 weeks gestation) are exposed in utero to human voices, their heart-rate patterns suggest they are sensitive to and learn the voice patterns of their mother, and discriminate her voice from that of other women (Kisilevsky, Hains, Lee, Xie, Huang, Ye *et al*., 2003).

Folk biology and folk physics. The complexity of hunting and foraging demands varies across ecologies and thus creates a situation that should select for plasticity in the folk biological and physical systems. Children's implicit folk biological knowledge and inherent interest in living things reflect a motivation to engage in experiences that automatically create taxonomies of local flora and fauna and result in the accrual of an extensive knowledge base of these species. In traditional societies, these experiences include assisting with foraging and play hunting (Blurton Jones, Hawkes, & O'Connell, 1997; Bock, 2005). Anthropological research indicates that it often takes many years of engaging in these forms of play and early work to master the skills and knowledge needed for successful hunting and foraging in many of these societies (Kaplan *et al.,* 2000).

Learning about the physical world is a complex endeavor for humans and requires an extended developmental period, in comparison with the more rapid learning that occurs in species that occupy a more narrow range of physical ecologies (Gallistel, 2000). The importance of early experience in this domain is illustrated by development of the ability to mentally form map-like representations of the large-scale environment. The initial ability to form these representations emerges by three years of age (DeLoache, Kolstad, & Anderson, 1991), improves gradually through adolescence, and often requires extensive exploration and exposure to the local environment to perfect (Matthews, 1992). Matthews' research shows that children automatically attend to geometric features of the environment and landmarks within this environment and at a later time can generate a cognitive representation of landmarks and their geometric relations. Children's skill at generating these representations increases with repeated explorations of the physical environment. Chen and Siegler's (2000) finding that 18-month-olds have an implicit understanding of how to use simple tools and with experience learn to use these tools in increasingly effective ways suggests that similar processes occur for tool use (see also Gredlein & Bjorklund, 2005).

Academic development

There is a cost to our extraordinary ability to create evolutionarily novel – *biologically secondary*– knowledge and competencies: During the last several thousand years the cross-generational accumulation of cultural knowledge (e.g., through books) has occurred at such a rapid pace (Richerson & Boyd, 2005), that the attentional and cognitive biases that facilitate the modification of folk abilities during children's natural activities do not have evolved counterparts to facilitate the learning of secondary abilities. A thorough discussion of the implications are elaborated elsewhere (Geary, 2007), but I highlight key aspects in the following sections.

Motivation to learn

Theoretical and empirical research on children's early attentional biases and activity preferences can be placed within an evolutionary perspective. And a broader understanding of these preferences and how they are expressed in school settings has the potential to significantly improve our understanding of children's motivation (or not) to learn biologically secondary material.

A core prediction is that children's evolved motivational biases will be focused on learning in folk domains and that they will prefer to engage in this learning through play and exploration. Children are also predicted to show a preference for the activities that promote the cross-generational transfer of knowledge in traditional societies. These activities involve stories to convey morals (i.e., cultural rules for social behavior) and other themes relevant to day-to-day living, and apprenticeships whereby culturally important skills (e.g., hunting, tool making) are learned through observation of or direct instruction by more skilled individuals (Brown, 1991). The specific content of these activities is centered on features of social living or the ecology that children will need to learn before assuming adult responsibilities. In other words, there are universal mechanisms that support the learning of culture-specific information (e.g., observational learning; Bandura, 1986), in addition to the attentional, motivational, and cognitive mechanisms described in Evolution and Cognitive Development. The combination results in human universals, such as face processing and language, as well as many cultural particulars that are variations on these themes.

From this perspective, it is not surprising many school children value achievement in sports –ritualized practice of organized in-group/out-group competition (Geary, Byrd-Craven, Hoard, Vigil, & Numtee, 2003)– more than achievement in core academic areas (Eccles, Wigfield, Harold, & Blumenfeld, 1993). It is also not surprising that many students report in-school activities to be a significant source of negative affect (Larson & Asmussen, 1991). Csikszentmihalyi and Hunter (2003) found that the lowest levels of happiness were experienced by children and adolescents while they were doing homework, listening to lectures, and doing mathematics, and the highest levels were experienced when they were talking with friends. For high-school students, the weekend is the highlight of their week, because they can socialize with their peers (Larson & Richards, 1998).

A preference for engagement in peer relationships might not be useful for mastery of many biologically secondary competencies taught in school, but it supports the prediction of an evolved bias for children to self-organize social activities during development; it is necessary to learn about one's specific peer group and how to manage and influence dynamics in this group. Schooling is not, however, at odds with all evolved learning and motivational biases. This is because a long developmental period is predicted to have co-evolved with an interest in and an ability to transfer culturally important information across generations (Bjorklund, 2007; Flinn, 1997; Richerson & Boyd, 2005). A species-typical curiosity about and an ability to learn evolutionarily-novel information is predicted, but so are substantive individual differences in the motivation and ability to learn this information. The gist is if there were not a gap between the secondary knowledge needed to function well in modern societies and evolved motivational and learning biases, then the motivational dispositions, interests, and abilities of the creative-productive individuals who developed this secondary knowledge (e.g., Murray, 2003) would be mundane and easily acquired without schooling. This is not the case.

If our goal is universal education that encompasses a variety of evolutionarily novel academic domains (e.g., mathematics) and abilities (e.g., phonetic decoding as related to reading), then we cannot assume that an inherent curiosity or motivation to learn will be sufficient for most children and adolescents. Children's and adolescent's explicit valuation of academic learning, the perceived utility of academic skills, and the centrality of these areas to their overall self esteem is predicted to be highly dependent on social-cultural valuation of academic competencies, such as explicit rewards for academic achievement (e.g., honor rolls) and valuation of cultural innovators (e.g., Edison). In contrast, the child's and adolescent's valuation and perceived efficacy of their physical traits or social relationships are implicit features of their evolved folk psychology and will manifest with or without cultural supports.

Learning in school

Biologically secondary learning is the acquisition of culturally important information and skills using the mechanisms that evolved to enable people to cope with novelty and change within lifetimes and that enable the cross-generational transfer of cultural knowledge. I provide the details of the mechanisms I suggest support secondary learning elsewhere (Geary, 2005, 2007). In the following sections, I use the relation between folk psychological modules and reading to illustrate how secondary abilities appear to be constructed from primary systems.

Folk psychology and learning to read

Writing is the primary means through which secondary knowledge has accumulated over the past several millennia and reading this material is the primary means for transmitting this knowledge across generations. From an evolutionary perspective, writing initially emerged from the motivation of people to communicate with and influence other people, and the desire to read from the benefits of learning from others. It has been proposed that reading is built upon evolved language systems (e.g., Mann, 1984; Rozin, 1976). I elaborate on this proposal by linking the learning of how to read and reading comprehension to several folk psychological domains.

Research on children's reading acquisition supports the prediction that many components of reading competency are dependent on language systems (Bradley & Bryant, 1983; Hindson, Byrne, Shankweiler, Fielding-Barnsley, Newman, & Hine, 2005; Wagner & Torgesen, 1987). Core early components include phonemic awareness –explicit awareness of distinct language sounds– and the ability to decode unfamiliar written words into basic sounds. Decoding requires an *explicit* representation of the sound (e.g., *ba*, *da*, *ka*) in phonemic working memory and the association of this sound and blends of sounds with corresponding visual patterns (Bradley & Bryant, 1983). The ease of learning basic word-decoding skills in first grade is predicted by the fidelity of children's phonological processing systems (e.g., skill at discriminating language sounds) in kindergarten (Wagner, Torgesen, & Rashotte, 1994). Children who show a strong explicit awareness of basic language sounds easily learn to associate these sounds with the symbol system of the written language. In contrast with natural language learning, the majority of children acquire these competencies most effectively with systematic, organized, and teacher-directed explicit instruction on phoneme identification, blending, and word decoding (e.g., Hindson *et al.,* 2005). Skilled reading also requires text comprehension which is dependent on several component skills, such as locating main themes and distinguishing relevant from less relevant passages. As with more basic reading skills, many children require explicit instruction in the use of these strategies to aid in text comprehension (Connor, Morrison, & Petrella, 2004).

From an evolutionary perspective, text comprehension will be dependent in part on theory of mind and other folk psychological domains, at least for genre that involve human relationships (Geary, 1998). Most of these stories involve the re-creation of social relationships, more complex patterns of social dynamics, and even elaborate person schema knowledge for main characters. The theme of many of the most popular genre involves the dynamics of mating relationships and competition for mates. One implication is that once people learn to read, they engage in this secondary activity because it allows for the representation of evolutionarily salient themes, particularly the mental representation and rehearsal of social dynamics. In addition, some people are predicted to be interested in reading about mechanical things and biological phenomena, reflecting interests associated with folk –physical and– biological systems.

Conclusion

People have evolved to create cultural ideologies and rules for social behavior. These provide the structure for the formation and stability of large cooperative groups (Baumeister, 2005; Richerson & Boyd, 2005). Children and adults have evolved corresponding learning and motivational mechanisms that support the cross-generational transfer of knowledge that is useful in their culture. In traditional societies, the mechanisms that support the cross-generational transfer of knowledge include child-initiated play, observational learning, and adults' use of stories and apprenticeships to teach cultural knowledge. These mechanisms may no longer be sufficient for preparing children for adulthood in modern societies, because of the vast amount of cultural knowledge that has accumulated during the past several thousand years and the array and complexity of secondary abilities (e.g., reading, algebra) needed to function in these societies. Schools emerged in modern societies to address the limitations of these mechanisms and to formalize the cross-generational transfer of knowledge. In other words, schools are the central interface between evolution and culture –they are the venues in which children's evolved biases in learning and motivation intersect with the need to learn the secondary abilities and knowledge needed to be successful in modern societies.

This perspective has the potential to answer many questions in instruction and learning that are not otherwise fully understandable. Why do most children need explicit instruction to learn word decoding and text comprehension but do not need instruction to produce and understand natural language? Why do most children value peer relationships more than they value academic learning? Among many implications, effective instruction in secondary academic domains will be dependant on the same attentional control and working memory systems that evolved to cope with variation and novelty within lifetimes (see Geary, 2005, 2007), and leads to the hypothesis that many children will need to have any associated problem-solving steps explicitly organized by instructional materials and extensively practiced for long-term retention (e.g., Sweller, 2004). Unlike the adaptation of primary systems (e.g., language, folk biology) to the nuances of the local social group and ecology, learning in these domains is not privileged by inherent attentional, cognitive, and motivational systems. Because of this, teachers must provide the structure and organization to secondary learning that has been provided to primary learning by our evolutionary history. With respect to motivation, children's natural curiosity and desire to learn cannot be assumed to be sufficient to support the long and effortful learning needed to master secondary domains, such as algebra.

REFERENCES

Alexander, R.D. (1989). Evolution of the human psyche. In P. Mellars & C. Stringer (Eds.), *The human revolution: Behavioural and biological perspectives on the origins of modern humans* (pp. 455-513). Princeton, NJ: Princeton University Press.

Ash, J., & Gallup, G.G.Jr. (2007). Paleoclimatic variation and brain expansion during human evolution. *Human Nature, 18,* 109-124.

Atran, S. (1998). Folk biology and the anthropology of science: Cognitive universals and cultural particulars. *Behavioral and Brain Sciences, 21*, 547-609.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press/Bradford Books.

Baumeister, R.F. (2005). *The cultural animal: Human nature, meaning, and social life.* New York: Oxford University Press.

Bjorklund, D.F. (2007). *Why youth is not wasted on the young: Immaturity in human development*. Malden, MA: Blackwell Publishing.

Bjorklund, D. F., & Pellegrini, A. D. (2002). *The origins of human nature: Evolutionary developmental psychology*. Washington, DC: American Psychological Association.

Blurton Jones, N. G., Hawkes, K., & O'Connell, J. F. (1997). Why do Hadza children forage? In N.L. Segal, G.E. Weisfeld, & C.C. Weisfeld (Eds.), *Uniting psychology and biology. Integrative perspectives on human development* (pp. 279-313). Washington, DC: American Psychological Association.

Bock, J. (2005). What makes a competent adult forager? In B. S. Hewlett & M. E. Lamb (Eds.), *Hunter-gatherer childhoods: Evolutionary, developmental & cultural perspectives* (109-128). New Brunswick, NJ: Transaction Publishers.

Bradley, L., & Bryant, P.E. (1983, February 3). Categorizing sounds and learning to read – A causal connection. *Nature, 301*, 419-421.

Brown, D.E. (1991). *Human universals*. Philadelphia, PA: Temple University Press.

Bugental, D.B. (2000). Acquisition of the algorithms of social life: A domain-based approach. *Psychological Bulletin, 126*, 187-219.

Buss, D.M. (Ed.) (2005). *The evolutionary psychology handbook*. Hoboken, NJ: Wiley & Sons.

Caporael, L.R. (1997). The evolution of truly social cognition: The core configurations model. *Personality & Social Psychology Review, 1*, 276-298.

Chen, Z., & Siegler, R.S. (2000). Across the great divide: Bridging the gap between understanding toddlers' and older children's thinking. *Monographs of the Society for Research in Child Development, 65* (No 2, serial no. 261).

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics, 50*, 66-71.

Connor, C.M., Morrison, F.J., & Petrella, J.N. (2004). Effective reading comprehension instruction: Examining child x instruction interactions. *Journal of Educational Psychology, 96*, 682-698.

Csikszentmihalyi, M., & Hunter, J. (2003). Happiness in everyday life: The uses of experience sampling. *Journal of Happiness Studies, 4*, 185-199.

Damasio, A. (2003). *Looking for Spinoza: Joy, sorrow, and the feeling brain.* Orlando, FL: Harcourt, Inc.

DeLoache, J.S., Kolstad, D.V., & Anderson, K.N. (1991). Physical similarity and young children's understanding of scale models. *Child Development, 62*, 111-126.

Dunbar, R.I.M. (1998). The social brain hypothesis. *Evolutionary Anthropology*, 6, 178-190.

Eccles, J., Wigfield, A., Harold, R.D., & Blumenfeld, P. (1993). Age and gender differences in children's self- and task perceptions during elementary school. *Child Development, 64*, 830-847.

Fiske, S.T. (2002). What we know now about bias and intergroup conflict, the problem of the century. *Current Directions in Psychological Science, 11*, 123-128.

Flinn, M.V. (1997). Culture and the evolution of social learning. *Evolution and Human Behavior, 18*, 23-67.

Flinn, M.V., Geary, D.C., & Ward, C.V. (2005). Ecological dominance, social competition, and coalitionary arms races: Why humans evolved extraordinary intelligence. *Evolution and Human Behavior, 26,* 10-46.

Freedman, D.G. (1974). *Human infancy: An evolutionary perspective*. New York: John Wiley & Sons.

Gallistel, C.R. (2000). The replacement of general-purpose learning models with adaptively specialized learning modules. In M.S. Gazzaniga (Ed.), *The new cognitive neurosciences* (second edition) (pp. 1179-1191). Cambridge, MA: Bradford Books/MIT Press.

Geary, D.C. (1995). Reflections of evolution and culture in children's cognition: Implications for mathematical development and instruction. *American Psychologist, 50*, 24-37.

Geary, D.C. (1998). *Male, female: The evolution of human sex differences*. Washington, DC: American Psychological Association.

Geary, D.C. (2005). *The origin of mind: Evolution of brain, cognition, and general intelligence*. Washington, DC: American Psychological Association.
Geary, D.C. (2007). Educating the evolved mind: Conceptual foundations for an evolutionary educational psychology. In J.S. Carlson & J.R. Levin (Eds.), *Educating the evolved mind* (pp. 1-99, Vol. 2, Psychological perspectives on contemporary educational issues). Greenwich, CT: Information Age.
Geary, D.C. (in press). An evolutionarily informed education science. *Educational Psychologist*.
Geary, D.C., & Bjorklund, D.F. (2000). Evolutionary developmental psychology. *Child Development, 71*, 57-65.
Geary, D.C., Byrd-Craven, J., Hoard, M. K., Vigil, J., & Numtee, C. (2003). Evolution and development of boys' social behavior. *Developmental Review, 23*, 444-470.
Geary, D.C., & Huffman, K.J. (2002). Brain and cognitive evolution: Forms of modularity and functions of mind. *Psychological Bulletin, 128*, 667-698.
Gelman, R. (1990). First principles organize attention to and learning about relevant data: Number and animate-inanimate distinction as examples. *Cognitive Science, 14*, 79-106.
Gelman, R., & Williams, E.M. (1998). Enabling constraints for cognitive development and learning: Domain-specificity and epigenesis. In D. Kuhl & R.S. Siegler (Vol. Eds.), *Cognition, perception, and language, Vol 2* (pp. 575-630). W. Damon (Gen. Ed.), *Handbook of child psychology* (Fifth Ed.). New York: John Wiley & Sons.
Gelman, S.A. (2003). *The essential child: Origins of essentialism in everyday thought*. New York: Oxford University Press.
Gigerenzer, G., Todd, P.M., & ABC Research Group (Eds.) (1999). *Simple heuristics that make us smart.* New York: Oxford University Press.
Gredlein, J.M., & Bjorklund, D.F. (2005). Sex differences in young children's use of tools in a problem-solving task. *Human Nature, 16*, 211-232.
Greenough, W.T., Black, J.E., & Wallace, C.S. (1987). Experience and brain development. *Child Development, 58*, 539-559.
Haidt, J. (2007, May 18). The new synthesis in moral psychology. *Science, 316*, 998-1002.
Harter, S. (2006). The self. In N. Eisenberg (Vol. Ed.), *Social, emotional, and personality development, Vol* 3 (pp. 505-570). W. Damon & R. M. Lerner (Gen. Eds.), *Handbook of child psychology* (6th Ed.). New York: John Wiley & Sons.
Heckhausen, J., & Schulz, R. (1995). A life-span theory of control. *Psychological Review, 102*, 284-304.
Hindson, B., Byrne, B., Shankweiler, D., Fielding-Barnsley, R., Newman, C., & Hine, D.W. (2005). Assessment and early instruction of preschool children at risk for reading disability. *Journal of Educational Psychology, 97*, 687-704.
Horowitz, D. L. (2001). *The deadly ethnic riot*. Berkeley, CA: University of California Press.
Humphrey, N.K. (1976). The social function of intellect. In P.P.G. Bateson & R.A. Hinde (Eds.), *Growing points in ethology* (pp. 303-317). New York: Cambridge University Press.
Kanazawa, S. (2004). General intelligence as a domain-specific adaptation. *Psychological Review, 111*, 512-523.
Kanwisher, N., McDermott, J., & Chun, M.M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience, 17*, 4302-4311.
Kaplan, H., Hill, K., Lancaster, J., & Hurtado, A.M. (2000). A theory of human life history evolution: Diet, intelligence, and longevity. *Evolutionary Anthropology, 9,* 156-185.
Keil, F.C., Levin, D.T., Richman, B.A., & Gutheil, G. (1999). Mechanism and explanation in the development of biological thought: The case of disease. In D.L. Medin & S. Atran (Eds.), *Folkbiology* (pp. 285-319). Cambridge, MA: MIT Press/Bradford Book.
Kisilevsky, B.S., Hains, S.M.J., Lee, K., Xie, X., Huang, H., Ye, H.H. *et al.* (2003). Effects of experience on fetal voice recognition. *Psychological Science, 14*, 220-224.
Larson, R., & Asmussen, L. (1991). Anger, worry, and hurt in early adolescence: An enlarging world of negative emotions. In M.E. Colten & S. Gore (Eds.), *Adolescent stress: Causes and consequences* (pp. 21-41). New York: Aldine de Gruyter.
Larson, R., & Richards, M. (1998). Waiting for the weekend: Friday and Saturday night as the emotional climax of the week. *New Directions for Child and Adolescent Development, 82*, 37-51.
Leslie, A.M., Friedman, O., & German, T. P. (2004). Core mechanisms in 'theory of mind'. *Trends in Cognitive Science, 8*, 528-533.
Mandler, J.M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review, 99*, 587-604.
Mann, V.A. (1984). Reading skill and language skill. *Developmental Review, 4*, 1-15.
Matthews, M.H. (1992). *Making sense of place: Children's understanding of large-scale environments*. Savage, MD: Barnes & Noble Books.
Mithen, S. (1996). *The prehistory of the mind: The cognitive origins of art and science*. New York: Thames and Hudson, Inc.

Murray, C. (2003). *Human accomplishment: The pursuit of excellence in the arts and sciences, 800 B.C. to 1950*. New York: HarperCollins.

New, J., Cosmides, L., & Tooby, J. (2007). Category-specific attention for animals reflects ancestral priorities, not expertise. *Proceedings of the National Academy of Sciences USA, 104*, 16598-16603.

Parker, S.T. (2004). The cognitive complexity of social organization and socialization in wild baboons and chimpanzees: Guided participation, socializing interactions, and event representation. In A.E. Russon and D.R. Begun (Eds.), *The evolution of thought: Evolutionary origins of great ape intelligence* (pp. 45-60). Cambridge, UK: Cambridge University Press.

Pinker, S. (1997). *How the mind works*. New York: W. W. Norton & Co.

Richerson, P.J., & Boyd, R. (2005). *Not by genes alone: How culture transformed human evolution*. Chicago, IL: University of Chicago Press.

Rozin, P. (1976). The evolution of intelligence and access to the cognitive unconscious. In J.M. Sprague & A.N. Epstein (Eds.), *Progress in psychobiology and physiological psychology* (Vol. 6, pp. 245-280). New York: Academic Press.

Scarr, S. (1992). Developmental theories of the 1990s: Developmental and individual differences. *Child Development, 63*, 1-19.

Schyns, P.G., Bonnar, L., & Gosselin, F. (2002). Show me the features! Understanding recognition from the use of visual information. *Psychological Science, 13,* 402-409.

Shepard, R.N. (1994). Perceptual-cognitive universals as reflections of the world. *Psychonomic Bulletin & Review, 1*, 2-28.

Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review, 63,* 129-138.

Spelke, E. S. (2000). Core knowledge. *American Psychologist, 55*, 1233-1243.

Sperber, D. (1994). The modularity of thought and the epidemiology of representations. In L.A. Hirschfeld & S.A. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 39-67). New York: Cambridge University Press.

Sporns, O., Tononi, G., & Edelman, G.M. (2000). Connectivity and complexity: The relationship between neuroanatomy and brain dynamics. *Neural Networks, 13*, 909-922.

Suddendorf, T., & Corballis, M.C. (1997). Mental time travel and the evolution of the human mind. *Genetic, Social, and General Psychology Monographs, 123*, 133-167.

Sweller, J. (2004). Instructional design consequences of an analogy between evolution by natural selection and human cognitive architecture. *Instructional Science, 32*, 9-31.

Wagner, R.K., & Torgesen, J.K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101*, 192-212.

Wagner, R.K., Torgesen, J.K., & Rashotte, C.A. (1994). Development of reading-related phonological processing abilities: New evidence of bidirectional causality from a latent variable longitudinal study. *Developmental Psychology, 30*, 73-87.

Wellman, H.M., & Gelman, S.A. (1992). Cognitive development: Foundational theories of core domains. *Annual Review of Psychology, 43*, 337-375.