Incorporating Development Into Evolutionary Psychology: Evolved Probabilistic Cognitive Mechanisms

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Abstract
Developmental thinking is gradually becoming integrated within mainstream evolutionary psychology. This is most apparent with respect to the role of parenting, with proponents of *life history theory* arguing that cognitive and behavioral *plasticity* early in life permits children to select different life history strategies, with such strategies being adaptive solutions to different fitness trade-offs. I argue that adaptations develop and are based on the highly plastic nature of infants' and children's behavior/cognition/brains. The concept of *evolved probabilistic cognitive mechanisms* is introduced, defined as information processing mechanisms evolved to solve recurrent problems faced by ancestral populations that are expressed in a probabilistic fashion in each individual in a generation and are based on the continuous and bidirectional interaction over time at all levels of organization, from the genetic through the cultural. Early perceptual/cognitive biases result in behavior that, when occurring in a species-typical environment, produce continuous adaptive changes in behavior (and cognition), yielding adaptive outcomes. Examples from social learning and tool use are provided, illustrating the development of adaptations via evolved probabilistic cognitive mechanisms. The integration of developmental concepts into mainstream evolutionary psychology (and evolutionary concepts into mainstream developmental psychology) will provide a clearer picture of what it means to be human.

I'm a developmental psychologist by training, but I always had an interest in evolution. At one level, development (ontogeny) and evolution (phylogeny) are both concerned with changes over time, the only difference is the magnitude—a single lifetime versus a species' history. When evolutionary psychology hit the mainstream in the late 1980s, I thought I'd spend some of my scholarly efforts integrating the two disciplines, figuring after writing a couple of papers on evolutionary approaches to developmental psychology, or developmental approaches to evolutionary psychology, I'd get back to my primary research interests of children's memory and strategy development.

The task was more difficult than I thought. Some of the underlying assumptions of developmental and evolutionary psychology, circa 1990s, were fundamentally at odds. Evolutionary psychology had adopted Richard Dawkins's gene's-eye view, which implied to many developmental psychologists, rightly or wrongly, a form of genetic determinism. Developmentalists, particularly, those adopting a developmental contextual perspective, argued that genes are only a single component in complex developmental systems, and any perspective, such as evolutionary psychology, that invoked a central role to evolved psychological mechanisms in determining behavior was wrong-headed in that it gave little more than lip service to the role of experience in the production of adult phenotypes (Lickliter & Honeycutt, 2003). Moreover, evolutionary psychologists sensibly focused on the behavior of adults—the ones that do the status striving, mating, and parenting central to getting copies of one's genes into the next generation—and saw little reason to focus on development. Dating back to Weissman at the turn of the 20th

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century, a central tenet of evolutionary theory is that what happens during the lifetime of an animal can have no effect on evolution. No matter how many generations of mice have their tails snipped off, mice will still be born with tails. Consciously or not, this made development an epiphenomenon for many evolutionary psychologists—vitally important to the individual but of no consequence to the evolution of the species.

My guess is that both evolutionary and developmental psychologists would chaff at such depictions, arguing, on the one hand, that experience does indeed play a role in evolutionary explication and, on the other hand, that evolutionary accounts are not necessarily incompatible with developmental contextual viewpoints of ontogeny. Yet, it became clear to me that there would be no simple rapprochement between these two historical accounts of humanity, and a new discipline was required to bridge the gap. My colleagues and I believed that the role of the emerging field of *evolutionary developmental psychology* was, primarily, to answer two questions: "How can an understanding of our species' phylogeny help us better understand our current ontogeny?" and "How do evolved, inherited information processing mechanisms become expressed in the phenotypes of adults?" (Bjorklund & Pellegrini, 2000, 2002). I am pleased to say that both the developmental and evolutionary psychological landscapes have changed over the last quarter century, and although evolutionary ideas are not fully integrated into developmental psychology nor are developmental ideas fully integrated into evolutionary psychology, they are no longer foreigners, each speaking a language incomprehensible to the other.

Although there is still overt antagonism to evolutionary psychological thinking among some developmentalists today (e.g., Lickliter & Honeycutt, 2003; Overton, 2015), evolutionary thinking has gained at least a passing acceptance among developmental psychologists, particularly among those studying social–cognitive development (e.g., Nielsen, 2012; Tomasello, 2009; Whiten & Flynn, 2010); but evolutionary thinking has also caught the attention of scholars concerned with cognitive development (e.g., Geary, 1995, 2005; Spelke & Kinzler, 2007) and educational psychology (e.g., Geary & Berch, 2016; Gray, 2016). Here, however, I focus on the incorporation of ideas from developmental biology and psychology into mainstream evolutionary psychology, particularly the concept of *developmental plasticity*, and propose a developmental model for understanding adaptations.

Evolutionary and Developmental Psychology: Some Common Ground

Mainstream evolutionary psychology, if not fully incorporating a developmental perspective into evolutionary theory, has tacitly acknowledged the existence of evolutionary developmental psychology, with chapters related to development being included in both the first and second editions of Buss's *Handbook of Evolutionary Psychology* (2005, 2016), as well as in the *Oxford Handbook of Evolutionary Psychology* (Barrett & Dunbar, 2007). Chapters written from an evolutionary developmental perspective have frequently been included in edited

volumes dealing with specific aspects of evolutionary psychology (e.g., *The Oxford Handbook of Evolutionary Family Psychology*, Salmon & Shackelford, 2011; *The Evolution of Violence*, Shackelford & Hansen, 2014; *Evolutionary Perspectives on Social Psychology*, Zeigler-Hill, Welling, & Shackelford, 2015; *Evolutionary Medicine,* Alvergne, Jenkinson, & Faurie, 2016), and research topics related to developmental theory are frequently found in the mainstream evolutionary psychology journals (e.g., *Evolution and Human Behavior*, *Evolutionary Psychology*, and *Evolutionary Behavioral Sciences*).

One area of mutual interest of evolutionary and developmental psychology is parenting. Developmental psychologists have long looked at individual differences in parenting, and early experience in general, as the source of individual differences in emotional, cognitive, and social development in children and the adults they will become. For example, children whose parents are described as authoritarian, involving strict control and critical evaluation of children's behavior, are more likely to be withdrawn, discontented, and distrustful of others compared to children whose parents' style is described as authoritative, involving warmth and promoting self-regulation (e.g., Baumrind, 1967; Pettit, Dodge, & Brown, 1988); children from intellectually stimulating homes perform better in school and have higher IQs than children from less-stimulating homes (e.g., Brooks-Gunn, Linver, & Fauth, 2005; NICHD Early Child Care Research Network, 2002), and children from impoverished homes with little emotional support are more likely to engage in high-risk behaviors as adolescents and young adults than children growing up in resource-rich and emotionally supportive homes (e.g., O'Connor, 2003). The implication of these lines of research is that children are sensitive to early environmental conditions, with adult cognitive, social, and emotional outcomes being shaped by early experiences.

On the surface, such findings seem at odds with the thinking of many evolutionary psychologists, who, while not denying the role of experience in forming adult personality and outcomes, would place greater emphasis on evolved psychological mechanisms in shaping behavior and less on individual differences in early rearing environments. In fact, behavioral genetic research has shown that a greater proportion of individual differences in personality and IQ, for example, is attributed to genetics than to within-family environmental (i.e., parenting) factors (e.g., Harris, 1998; McCartney, Harris, & Bernieri, 1990). However, individual differences in early experience are of central importance in at least one major evolutionary account, *life history theory* (Del Giudice, Gangestad, & Kaplan, 2015; Hill & Kaplan, 1999; Stearns, 1992), and a cadre of psychologists have applied developmental thinking to this theory to provide a research literature that not only applies evolutionary concepts to explain development but also integrates developmental theory into evolutionary psychology.

Life History Theory

Life history theory examines decisions organisms make in allocating time and energy to various aspects of their development.

For example, in Trivers's (1972) parental investment theory, individuals have conflict between how much time and effort they invest in mating versus parenting. Life history theory takes this further, including a developmental aspect. How much energy should be devoted to somatic growth versus reproduction, for example, and how much effort and energy should be devoted to current development (or reproduction) versus later development (or reproduction)? How individuals respond to life history trade-offs (e.g., more energy devoted to bodily growth vs. more energy devoted to reproduction) constitutes an organism's life history strategy, with such strategies being adaptive solutions to different fitness trade-offs. At the broadest level of analysis, life history strategies vary on a dimension of *slow* versus *fast*. Do individuals reach physical maturity early or late? Do they reproduce early and often, investing little in individual offspring, or later and less often, investing more in each offspring? And is life expectancy short or long? How many years can an individual expect to live?

Some evolutionary developmental psychologists adopted variants of life history theory to propose that children are sensitive to early environmental conditions and adjust important aspects of their developmental trajectory in anticipation of future environments. The first to do this were Belsky, Steinberg, and Draper (1991) who proposed that

> a principal evolutionary function of early experience—the first 5–7 years of life—is to induce in the child an understanding of the availability and predictability of resources (broadly defined) in the environment, of the trustworthiness of others, and of the enduringness of close interpersonal relationships, all of which will affect how the developing person apportions reproductive effort. (p. 650)

Basically, Belsky and his colleagues argued that children evolved the neural and behavioral plasticity necessary to adjust important aspects of their development to match current and anticipated environmental conditions. Subsequent research has shown that children growing up in homes with harsh child-rearing practices, low resources, and exposure to violence adopt fast life history strategies, with children engaging in more aggressive and risky behavior, establishing unstable pair bonds, providing less parental investment per offspring, and girls achieving menarche and engaging in sex earlier than children growing up in less harsh and more predictable environments (e.g., Ellis, 2004; Ellis, Figueredo, Brumbach, & Schlomer, 2009; Nettle, 2010; Nettle & Cockerill, 2010; Placek & Quinlan, 2012). For instance, Simpson and his colleagues (2012) reported that children living in highly unpredictable environments (e.g., different adult males living in the household, parental job changes, changes in residences) during their first 5 years of life had their first sexual encounter earlier, had more sex partners, and engaged in higher levels of risk-taking and delinquent behavior at age 23 than children growing up in more predictable homes. Most developmental and clinical psychologists adopt the traditional developmental psychopathology perspective in making sense of these outcomes, interpreting this pattern of development as reflecting maladaptive behavior, which it is from a strictly societal perspective. However, from an evolutionary developmental perspective, it represents potentially adaptive outcomes for children growing up in harsh and unpredictable circumstances (Ellis et al., 2009, 2012).
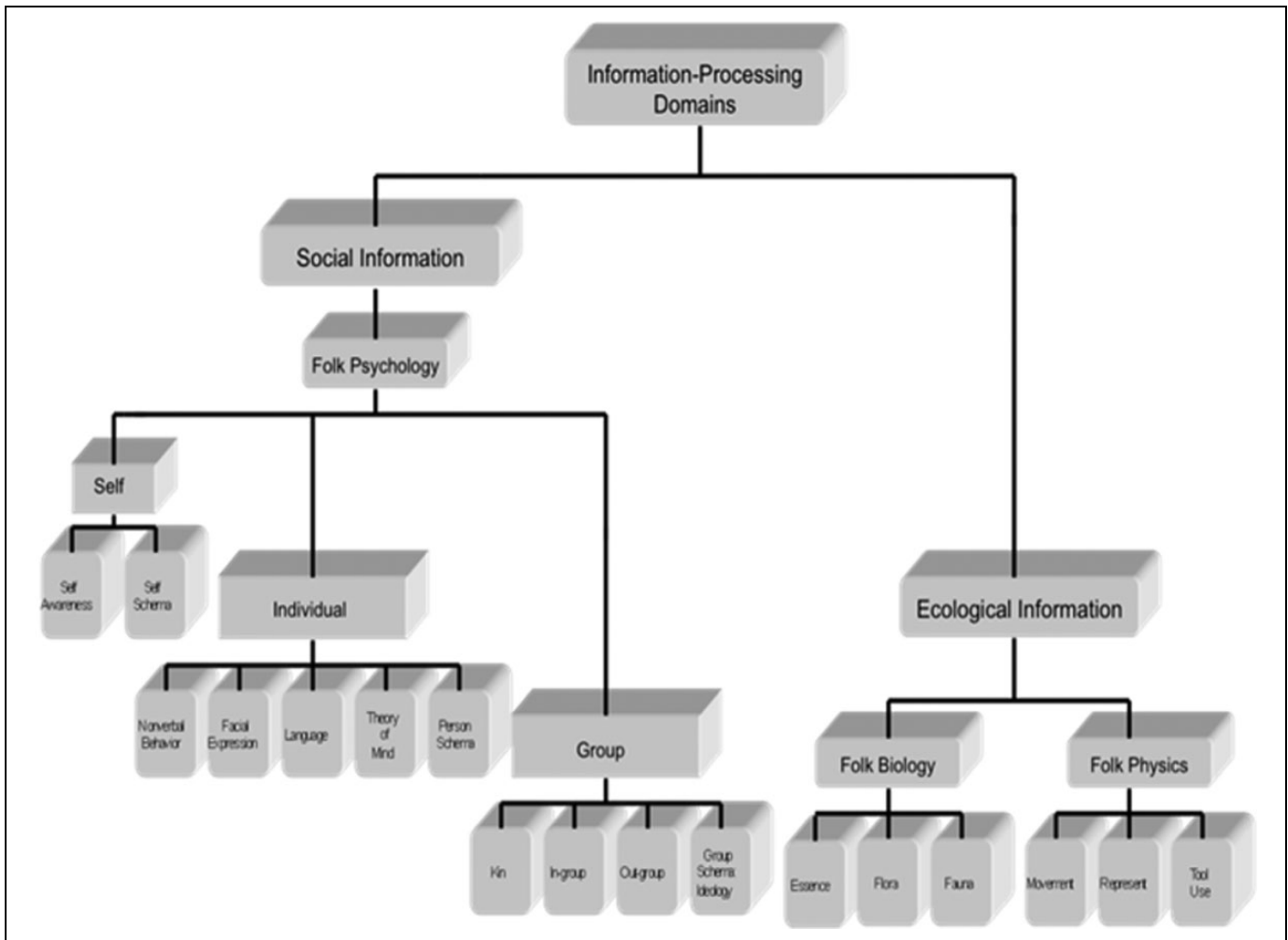
Developmental Plasticity

A major theme in developmental research stemming from life history theory is that natural selection has favored developmental plasticity. Children are sensitive to their early environments and adjust their behaviors and cognitions accordingly—often, but not always, in adaptive ways. This is captured by the concept of *conditional adaptations*, defined as

> evolved mechanisms that detect and respond to specific features of childhood environments—features that have proven reliable over evolutionary time in predicting the nature of the social and physical world into which children will mature—and entrain developmental pathways that reliably matched those features during a species' natural selective history. (Boyce & Ellis, 2005, p. 290)

Current conditions serve as cues for future conditions. So, for example, children growing up in resource-rich homes with secure attachments to parents and reliable social relations will adopt a slow life history strategy, delaying maturation and sexual behavior and investing much in few offspring (a quality over quantity approach), whereas it would be more advantageous for children growing up in less supportive environments to adopt a fast life history strategy.

Developmental plasticity is central to the thinking of developmentally oriented evolutionary biologists and psychologists who argue that natural selection has favored plasticity and sensitivity to local environments (Bjorklund, 2006; Ploeger, van der Maas, & Raijmakers, 2008; West-Eberhard, 2003). Such responsivity to early environments is especially important for humans whose prolonged period of immaturity requires them to adjust to variations in social environments and anticipate future ones.

My colleagues and I have argued that developmental plasticity should be considered when examining the evolved cognitive mechanisms that underlie psychological adaptations. *Evolved cognitive mechanisms* are a central tenet of mainstream evolutionary psychology, defined as information processing mechanisms shaped by natural selection over phylogeny to solve recurrent problems faced by our ancestors associated with survival and reproduction (Buss, Haselton, Shackelford, Bleske, & Wakefield, 1998; Pinker, 1997; Tooby & Cosmides, 1992, 2005). Yet, a missing component in evolutionary psychology's explication of evolved cognitive mechanism is development. Adaptations develop, as do the cognitive mechanisms that underlie them. Recall earlier I stated that one of the key questions for evolutionary developmental psychology was "How do evolved, inherited information processing

Figure 1. Geary's hierarchically organized system.

mechanisms become expressed in the phenotypes of adults?'' My colleagues and I have argued that such mechanisms develop and can be better explained via the concept of *evolved probabilistic cognitive mechanisms* (Bjorklund, 2015; Bjorklund & Ellis, 2014; Bjorklund, Ellis, & Rosenberg, 2007).

Evolved Probabilistic Cognitive Mechanisms

Geary (1995, 2005) argue that children are born with *skeletal competencies*, information processing biases, or constraints that are fleshed out over the course of development principally via play. These perceptual biases and abilities are the lowest levels of a hierarchically organized system in the evolutionarily relevant domains of folk psychology, folk biology, and folk physics (see Figure 1). It is through experience in species-typical environments that children develop the higher-order adaptations that have been favored by natural selection. Bjorklund, Ellis, and Rosenberg (2007) proposed that skeletal competencies evolved because of selectively structured Gene × Environment × Development interactions, which arise in each generation and are influenced by prenatal and postnatal

environments, reflecting the inheritance not only of genes but of entire developmental systems. This is reflected by the concept of evolved probabilistic cognitive mechanisms defined as,

> information-processing mechanisms that have evolved to solve recurrent problems faced by ancestral populations; however, they are expressed in a probabilistic fashion in each individual in a generation, based on the continuous and bidirectional interaction over time at all levels of organization, from the genetic through the cultural. These mechanisms are universal, in that they will develop in a species-typical manner when an individual experiences a species-typical environment over the course of ontogeny. (Bjorklund et al., 2007, p. 22)

Evolved probabilistic cognitive mechanisms assume that natural selection has operated not only on genes but on entire developmental systems, of which genes are an integral part, but only a part. For example, neurons generated from stem cells move to their ''proper'' place in the brain directed not by a complicated genetic program so much as by the activation of adjacent neurons and the presence of neurotransmitters. Neurons that fire

together, whether due to external stimulation or internally generated activity, recruit additional neurons, resulting in canalization of neural systems. For example, the timing of the development of sensory parts of the brain is coordinated with perceptual experiences such that the development of one sensory system (e.g., audition) does not compete for neurons with another system (e.g., vision; Turkewitz & Kenny, 1982). This pattern can be disturbed, however, when an animal receives stimulation in one sense modality in excess or earlier than "expected" (i.e., when sensory and neural development are uncoupled). This has been well documented in research with precocial birds that receive visual stimulation while still in the egg, days before they would normally have such experience (see Bjorklund, 1997, for a review). After hatching, these animals' auditory abilities are hampered (i.e., they fail to display species-appropriate auditory imprinting), although they show greater than typical visual discrimination abilities (Lickliter, 1990). Essentially, receiving species-atypical experience interferes with the choreographed dance between gene-influenced neural maturation and perceptual experience, producing species-atypical behavior. From this perspective, adaptive cognitive mechanisms are not "instincts" in the way that they are typically thought of, but rather the result of selection not only of genes, but of genes expressed in a species-typical environment developing on a species-typical schedule.

In previous papers, we provided examples of evolved probabilistic cognitive mechanisms for the development of the other race effect for face discrimination in infants and the development of fear of snakes (Bjorklund, 2015; Bjorklund & Ellis, 2014). In each case, infants' initial low-level perceptual biases, in interaction with species-typical experience, produce species-typical, adaptive behavior. For instance, infants are initially biased to attend to physical stimuli that have many of the features of primate faces (e.g., top-heavy configuration, vertical symmetry, and eyespots) and are initially able to discriminate equally well among monkey and human faces, male and female faces, and faces from their own and other races. However, with experience, perceptual ability narrows, with infants by 9 months of age being increasingly able to discriminate among faces from their own race, for example, but no longer among faces from other races (Kelly et al., 2007, 2009), unless they have experience viewing faces from other races (Anzures et al., 2012). Concerning fear of snakes, infants and children have no initial fear of snakes but, like adults (Öhman, Flykt, & Esteves, 2001), more easily identify snakes (and spiders) embedded in a background of flowers and mushrooms than vice versa (LoBue, 2010; LoBue & DeLoache, 2010) and, like monkeys (Cook & Mineka, 1989), more easily associate a fearful voice to videos of snakes than to other potentially dangerous animals (DeLoache & LoBue, 2009). It is apparently the snake's unique sinusoidal movement that is the feature producing special attention to them, in that the effect disappeared when videos of snakes were replaced by photographs. Consistent with the concept of evolved probabilistic cognitive mechanisms, infants and young children appear to have perceptual biases that, in interaction with maturationally paced

events and species-typical experiences, produce species-typical adaptions. These adaptations are not inevitable and will not emerge should children experience a species-atypical environment (e.g., frequently seeing faces of monkeys; Pascalis et al., 2005). Such observations obviate the need to propose a "fear of snake" instinct or a module dedicated to discriminating especially well faces from one's own race.

In the next two sections, I present evidence for evolved probabilistic cognitive mechanisms in two other evolutionarily relevant domains: social learning and tool use.

Social Learning

Humans are the most social of animals. We live in complex societies with diverse roles and rules, cooperate and compete with one another (and with other groups of people), try to read the minds and behaviors of other people, and learn from one another via teaching or simply by watching. In fact, according to the social brain hypothesis, it was social pressures—having to deal with conspecifics—that drove ancestral humans' to evolve increasingly complex cognition (Alexander, 1989; Dunbar, 2003; Hare, 2011). Alexander (1989) went so far as to state that *Homo sapiens* invented a new natural selection pressure: ourselves.

Much research and theorizing in evolutionary psychology pivots around human social cognition and behavior. Whether it be making deals with others without being cheated, recognizing and enforcing moral codes, cooperating with other people and groups of people, or effectively competing for resources or status within a variety of different groups, the ability to deal effectively with other thinking and emoting individuals is central to success. All of these social skills have their origins in childhood.

One important aspect of human social cognition is *social learning*. At its most general, social learning can be defined as occurring in a situation "in which one individual comes to behave similarly to another" (Boesch & Tomasello, 1998, p. 598). Social learning allows an animal to acquire behaviors by observing others, avoiding the costs and energy expenditure used in trial-and-error learning. Consistent with the concept of evolved probabilistic cognitive mechanisms, there are basic-level processes that promote the development of social learning, beginning in infancy. Moreover, many of these low-level processes are also likely precursors to most, if not all, adult social–cognitive abilities.

Social Responsivity in Young Infants

Humans are born with limited motor, perceptual, and cognitive abilities, and although these abilities show rapid improvement over the first year of life, young humans remain highly dependent on adult care for survival for longer than any other mammal. Natural selection has shaped both infant and adult psychology to foster positive social relations between infants and their parents. In fact, Bowlby's (1969) attachment theory

was predicated on the idea that infants evolved certain signals and abilities to promote social relations with their parents.

Infants' social orientation begins at birth. For example, neonates will preferentially look at light displays that depict biological motion (Bardi, Regolin, & Simion, 2011, 2014; Bertenthal, Proffitt, & Cutting, 1984). To assess this, infants watch moving light displays, some of which depict a person walking (10–12 light patches placed at joints), whereas other light displays include an upside down walking person or randomly moving patterns of light. From birth, infants attend longer to light patterns generated by an upright walking person than to other patterns, although they do not seem to treat it as a person until about 9 months (Bertenthal, 1996).

Newborns look longer at face-like stimuli (e.g., two dots placed over a single dot within a headlike figure) than nonface-like stimuli (Easterbrook, Kisilevsky, Hains, & Muir, 1999; Johnson, Dziurawiec, Ellis,& Morton, 1991; Mondloch et al., 1999) and will also match certain facial gestures of adult models, such as tongue protrusion (neonatal imitation; Meltzoff & Moore, 1977; but see Oostenbroek et al., 2016), although such "imitation" is at chance levels by 2 month of age, not to reappear until the latter part of the first year (Abravanel & Sigafoos, 1984; Jacobson, 1979). Rather than representing a true form of social learning, several researchers have proposed that neonatal imitation reflects an ontogenetic adaptation, serving to foster social communication between infant and parent at a time when infants cannot exert intentional control over their social reactions (Bjorklund, 1987; Byrne, 2005). Consistent with this argument, Heimann (1989) reported that infants' social interaction with their mothers at 3 months of age was positively related to the amount of neonatal imitation they displayed at birth.

Young infants' social orientation not only serves to promote strong social bonds with their caregivers but also serves as the basis of later social relationships (see Simpson & Belsky, 2008; Thompson, 2006). For instance, infants who are slow to develop typical signs of sociality (e.g., eye contact, cooing, and social smiles) are more likely to be victims of abuse later in life (e.g., Martin, Breezley, Conway, & Kempe, 1974; Sherrod, O'Connor, Vietze, & Altemeier, 1984).

Viewing Others as Intentional Agents

Being attentive to social others will get a child only so far. The basis for human social interaction is viewing others as intentional agents. People's behavior is motivated by what they want and what they know, making their actions not random or impossible to anticipate, but goal directed. Infants do not enter the world with this knowledge. The first signs of viewing others as intentional beings can be seen in *shared attention*, which involves a triadic interaction between an infant, another person, and an object. For instance, a father may point toward the family cat while getting the infant's attention, drawing the infant into a social relationship that extends beyond the father–infant dyad (Tomasello, 2009; Tomasello & Carpenter, 2007). Although preliminary signs of shared attention may be found in the first months of life (e.g., Csibra, 2008; Kovács,

Téglás, & Endress, 2010), it is not until about 9 months of age before infants actively engage in shared attention, when they will look in the direction someone else is looking or pointing, engage in repetitive interaction with an adult and an object, and hold up or point to objects for another person to see (see Carpenter, Nagell, & Tomasello, 1998; Tomasello, 2016). During shared attention, the two participants experience the same thing at the same time and realize they are experiencing this together (Tomasello & Carpenter, 2007).

Shared attention abilities improve over the next year. For instance, by 10 months, infants seem to understand social gaze and expect partners in conversation to look at one another (Beier & Spelke, 2012). By 12 months, infants will point to inform others about events they are not aware of (Liszkowski, Carpenter, & Tomasello, 2007), and over the second year of life infants will use another person's gaze to direct their own attention (Brooks & Meltzoff, 2002) and point to objects an adult is searching for (Liszkowski et al., 2007).

Although sharing a perceptual experience may not appear to be a great social–cognitive feat, it has substantial consequences for the ability to learn from others (and for other aspects of social cognition). Moreover, shared attention is a skill that is not readily observed in other primates. Although chimpanzees and some monkeys will follow another's gaze and point out objects to others (Bräuer, Call, & Tomasello, 2005; Leavens, Hopkins, & Bard, 2005), most researchers agree that there is no evidence of shared attention in mother-reared great apes (Herrmann, Call, Hernández-Lloreda, Hare, & Tomasello, 2007; Russell, Mauthner, Sharpe, & Tidswell, 1991; Tomasello & Carpenter, 2005; but see Leavens et al., 2005).

Learning by Observing

Infants' and young children's social orientation and their belief that others behave as intentional agents make social learning highly likely and a powerful mechanism for acquiring information. Infants in the latter part of the first year and early into the second year begin to display signs of social learning, copying the actions of adults to acquire new behaviors (e.g., Barr & Hayne, 2003; Piaget, 1962). However, infants and toddlers are more likely to copy the actions of adult models when those actions were executed intentionally rather than by accident (Carpenter, Akhtar, & Tomasello, 1998; Hamlin, Hallman, & Woodward, 2008). That is, the intention of the model seems more important to an infant observer than the actual behavior. In a study that illustrated this, 14- to 18-month-old infants observed an adult engage in a series of complex actions, all intentional, but some successful and others unsuccessful (Meltzoff, 1995). For example, in one task, a model made intentional movements to remove cubes at the end of a dumbbell (successful condition); whereas in another task, the infant watched as the model attempted to remove the ends of the dumbbell but failed (unsuccessful condition). When later given the dumbbells, infants who watched either the successful or unsuccessful attempts removed the ends of the dumbbell more often than infants in control conditions, who did not see a

demonstration of the dumbbell. They apparently understood the *intentions* of the model and executed the model's goal (remove the ends) rather than the exact behavior (in the unsuccessful condition).

From at least 3 years of age, children readily acquire the actions of both adult (e.g., Horner & Whiten, 2005; Nagell, Olguin, & Tomasello, 1993) and child (e.g., Flynn & Whiten, 2012; Hopper, Flynn, Wood, & Whiten, 2010; Whiten & Flynn, 2010) models from observation of tool use on novel tasks. But there are different forms of social learning, and children will use the different types depending on the nature of the task and their age. *Emulation* is the most frequently used form of social learning for children 2 years of age and younger, in which children attempt to achieve the goal of a model but do not necessarily copy the exact behaviors of a model to achieve that goal (Nielsen, 2006). Emulation can be contrasted with *imitation*, in which the child uses the same or similar behavior as a model to achieve the model's goal (Tomasello, 2000). Beginning around age 3, children take imitation to an extreme, engaging in what has been termed *overimitation*—copying all actions of a model, even those obviously irrelevant to attaining the goal (Lyons, Young, & Kiel, 2007; Nielson, 2006). For instance, in one study, preschool children watched as a model made of series of actions to get a toy out of a locked box. Some of the actions were necessary and others were clearly unnecessary to achieve the goal. When later given the chance to open the box themselves, children were even told to avoid "silly" unnecessary actions. Nonetheless, children generally copied all the actions of the model, both those relevant and irrelevant (Lyons et al., 2007). Children are not necessarily oblivious to the irrelevant behaviors of a model and will sometimes omit unnecessary actions when they know about an object's causal structure (Schulz, Hooppell, & Jenkins, 2008), when they know the goal of a task beforehand (Williamson & Markman, 2006), or when they have some awareness of the specific intentions of the model (Gardiner, 2014; Gardiner, Grief, & Bjorklund, 2011). Despite the contextual nature of overimitation, it is the primary social-learning strategy for preschoolers and persists into adulthood in some contexts (McGuigan, Makinson, & Whiten, 2011). Overimitation is not limited to children from Western cultures but has also been observed in 2- to 6-year-old Kalahari Bushman children (Nielsen & Tomaselli, 2010).

Overimitation appears not to be a cognitive "error" that children overcome with age and experience, but an evolved adaptation for learning about cultural artifacts and their uses (Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009). Although some animals build nests, dams, or hives, and others modify sticks, stones, or various parts of plants to use as tools, humans' lives are filled with artifacts, all cultural inventions, and an economic way to learn about them is to assume that a more-informed member of the species knows how to use them and to copy a model's action as precisely as possible. This may result in acquiring some irrelevant actions, but these can be weeded out via individual learning. In support of this argument, children believe that a model's actions are normative—how one is "supposed" to interact with artifacts. For instance,

preschool children corrected a puppet who eliminated irrelevant actions previously performed by a model, stating that the puppet was "doing it wrong" (Kenward, 2012; see also Keupp, Behne, & Rakoczy, 2013). In a similar vein, Gergely and Csibra (2005; Csibra & Gergely, 2011) proposed that children's overimitation is a human adaptation permitting fast and accurate transmission of information between people, which they refer to as *natural pedagogy*, which may facilitate perhaps the most potent form of social learning, *teaching*. Although explicit teaching has been observed in limited degrees in some large-brain mammals (e.g., Bender, Herzing, & Bjorklund, 2009; Boesch, 1991), it is an especially powerful form of transmitting information in humans (although Lancy, 2015, notes that parent–child teaching is rare in traditional cultures).

Humans, of course, are not the only animals that engage in social learning, with our close relatives chimpanzees (*Pan troglodytes*) and bonobos (*Pan paniscus*) also displaying substantial levels of learning by observation (see Whiten, 2010). However, chimpanzees' preferred mode of social learning appears to be emulation rather than imitation (e.g., Horner & Whiten, 2005; Nagell et al., 1993), the exception being enculturated apes—animals raised much as a human child would be raised (e.g., Bering, Bjorklund, & Ragan, 2000; Buttelmann, Carpenter, Call, & Tomasello, 2007; Tomasello, Savage-Rumbaugh, & Kruger, 1993). This suggests that humans' common ancestor with chimpanzees and bonobos also likely had the basic cognitive abilities for advanced social learning and the plasticity necessary to modify their developmental trajectory in response to changes in environment (Bjorklund, 2006). There is also no evidence of overimitation in chimpanzees (see Nielsen, 2012), possibly because chimpanzees do not differentiate between intentional versus accidental actions as well as human children do.

Despite the wide range of cultures humans live in, most adults master the requisite skills necessary to navigate their social environment, and they attain these skills following a universal, species-typical developmental pathway. As I've outlined here, social learning (and likely other forms of social cognition) is based on exercising low-level biases and social–cognitive abilities, beginning with attention to faces (or face-like stimuli), matching facial expressions, and shared attention/viewing others as intentional agents. These early biases and abilities increase the chance that children will be attentive to others when they engage in important (as well as trivial) actions, with many of these actions being associated with the use of artifacts. Young children's tendency to overimitate and to assume that a model's actions are normative become especially important when related to tools, which are ubiquitous in all human environments. Natural selection has seemingly prepared children to become tool users through the exercise of evolved probabilistic cognitive mechanisms, the topic of the next section.

Children, the Tool Users

All animals must learn to deal with objects in their physical world, but, as noted earlier, many, perhaps most, of the objects

that humans encounter are *cultural artifacts*, things made by people for a specific purpose. One large category of cultural artifacts is *tools*, devices used for "doing work" or solving specific problems. Humans' bipedal style of locomotion freed hands with opposable thumbs not only to carry things but also to use and to create objects to help solve problems.

Exploration and Object Play

But it is not just manual dexterity that makes *H. sapiens* master tool users and makers. Beginning in infancy, humans are biased first to explore and then to play with objects. At birth and for several months after, infants' limited motor abilities prevent them from actively interacting with objects, but this changes beginning around 4 or 5 months, as babies reach for and grasp objects within arm's length (Harris, 2005). Infants learn the affordances of objects through their manual exploration. For example, 6-, 8-, and 10-month-old infants interacted with water, discontinuous netting, a flexible sponge, and a rigid wood cube differently, banging the rigid cube and pressing the flexible sponge (Bourgeois, Khawar, Neal, & Lockman, 2005). According to Lockman (2000, p. 137), "the origins of tool use in humans can be found during much of the first year of life, in the perception-action routines that infants repeatedly display as they explore their environments."

Object exploration (What can the object do) is followed by object play ("What can *I* do with the object?" Hutt, 1966). Whereas most of an infant's interactions with objects in the first 9 months can likely be described as exploration, most interactions with objects after this time are better described as object play (Belsky & Most, 1981)—the active manipulation of objects, such as banging them and throwing them, but also the use of objects to build something, in a playful context. Although estimates vary, approximately one third of children's activity during the preschool years involves playing with objects (see Pellegrini, 2016; Pellegrini & Bjorklund, 2004; Rubin, Fein, & Vandenberg, 1983, for reviews), with similar values being reported for children in hunter gatherer societies (e.g., Bakeman, Adamson, Konner, & Barr, 1990; Bock, 2005; Sigman et al., 1988). Researchers have provided similar estimates of object play to that of children for chimpanzees, the nonhuman primates that use tools most often in the wild (Ramsey & McGrew, 2005).

One purported purpose of object play is to allow children to discover the affordances of objects, which may facilitate subsequent tool use. For example, researchers reported that 5- and 6-year-old children were more likely to appropriately modify a tool (bend a pipe cleaner, so it can be used as a hook) when they were given the chance to explore the properties of the object beforehand, in conjunction with observing a model use the tool, than children not permitted to manipulate the materials (Cutting, Apperly, Chappell, & Beck, 2014). Several early studies reported that children given the opportunity to play with objects (e.g., sticks and clamps) that were subsequently used in a tool task (e.g., retrieving a box from the end of a table) performed better on the tool-use tasks than children who observed the problem being solved (e.g., Cheyne & Rubin,

1983; Smith & Dutton, 1979; Sylva, Bruner, & Genoa, 1976), although these findings were not replicated when potential experimenter bias was eliminated (e.g., Simon & Smith, 1983, 1985; Smith & Whitney, 1987). Subsequently, Gredlein and Bjorklund (2005) measured amount of object-oriented play in 3-year-old children in free-play sessions and then, in a separate session, assessed children's ability to select and use a proper tool to retrieve an out-of-reach toy. They reported that boys performed the tool retrieval task better than girls (although girls performed comparably after a simple hint, cf. Chen & Siegler, 2000) and that there was a positive correlation ($r = .59$) between the amount of object-oriented play during the previous free-play sessions and performance on the tool retrieval task for boys but not for girls, causing Gredlein and Bjorklund (2005) to suggest that boys may be more sensitive to such environmental experiences than girls. These findings are consistent with Geary's (2005, 2010) proposal that sex differences in early behavior interact with skeletal but still developing folk physics systems, accounting for different behavioral competencies in males and females.

Through exploration and object play, children may discover the causal structure of complex objects. Although such structure may be obvious for simple tools, causal relations must be inferred for some human inventions. For example, pressing a button on the TV remote to turn on or off the television involves an invisible chain of events that includes mechanisms inside both the remote and the television. When causal structure is hidden, children can discover the actions needed to solve a problem through play and may indeed be motivated to focus their exploration on discovering causal structure. For example, when preschool children were presented with a box with two levers, moving some combinations of which resulted in a toy popping out of the box, they explored the box, discovering in the process the steps needed to make the toy pop out (Schulz & Bonawitz, 2007). Young children understand cause and effect, and through object exploration and play, they may be able to draw accurate conclusions about the causal structure of artifacts and how they can be used (Schulz, Gopnik & Glymour, 2007).

Developing the Design Stance

Infants and young children are not only motivated to interact with objects, but early in development they learn that an artifact that is used to solve a problem was in fact designed for a specific function, referred to as the *design stance* (Dennett, 1990). For example, one of the tools that infants in Western cultures first learn to use is the spoon. Over the course of their first 2 years of life, infants learn how to grip spoons properly (Connolly & Dalgleish, 1989) and often use this action plan rigidly, even when alternative actions with a spoon would produce desired results. This was illustrated in a study in which 12- to 18-month-old infants were given a spoon or an unfamiliar spoon-like tool to use to solve a novel problem (Barrett, Davis, & Needham, 2007). Infants sat in front to a box with a light display. The box had a small hole on one side, and the light

could be turned on by inserting the handle end of the spoon (or the novel tool) into the hole. An experimenter demonstrated how the tools could be used to turn on the light by holding the bowl end of the spoon and inserting the handle and then giving infants the opportunity to use the tool to turn on the light themselves. The infants rarely grasped the bowl end of the spoon to solve the problem, although they did so more frequently for the unfamiliar tool. They were experienced spoon users, knew that spoons were to be held by the handle, and showed a lack of flexibility in using the spoon in a novel way. They were able to identify the affordances of objects to solve this task, however, as reflected by their successful use of the similarly shaped novel tool. Their prior knowledge of what spoons are "for" resulted in what is referred to as *functional fixedness*, a lack of flexibility when it comes to using a familiar tool.

Functional fixedness was first identified in adults (Duncker, 1945) and is generally thought of as a "mental block" that hinders effective problem-solving. However, the design stance, though sometimes resulting in overly rigid behavior, more typically results in adaptive outcomes. By identifying what a particular artifact is for, children (and adults) can more efficiently use tools that were in fact designed for a specific purpose.

Children acquire the design stance for new tools relatively early. For example, when shown a new object and told its function (e.g., a box-like object used for catching bugs), 3-year-old children are less likely to see an alternative use for the object (e.g., collecting raindrops), associating it with its originally designed purpose (e.g., Bloom & Markson, 1998; Casler & Kelemen, 2005; German & Johnson, 2002). According to the Casler and Kelemen (2005, p. 479), "young children exhibit rapid learning for artifact function, already possessing an early foundation to some of our most remarkable capacities as tool manufacturers and users." Kelemen (2004) proposed that the tendency to attribute purpose or design to objects and events is characteristics of the preschool child and extends to natural events (e.g., rocks are "for climbing") as well as human artifacts. Kelemen refers to this tendency as *promiscuous teleology*.

The design stance may be unique to humans (Ruiz & Santos, 2013). For example, although chimpanzees have been observed to use tools in the wild, they (along with bonobos and gorillas) seem not to realize that a tool freely chosen to solve a task was more likely to be effective in achieving a goal than a tool someone was obliged to use. In contrast, 14-month-old human infants were more likely to select the tool that was freely chosen by a model to solve a task, a reflection of the design stance (Buttelmann, Carpenter, Call, & Tomasello, 2008). Interestingly, orangutans performed more like children than the other great apes on this task, suggesting that hints of the design stance can be found in the great apes. This is especially interesting in that orangutans are less likely to use tools in the wild than gorillas, bonobos, or chimpanzees.

Tools as Social Objects

Children's biases to manipulate and play with objects to discover their affordances and their early design-stance orientation are coupled with social-learning abilities in acquiring proper tool use. As we noted in the previous section, by 3 years of age children readily learn to use tools from watching others, and in fact tend to copy all behaviors associated with a model, whether relevant or not (i.e., overimitation). Children also assume that all of a model's behaviors are normative and that someone would not purposefully perform unnecessary actions. In fact, observation seems to be a more effective means for learning about tools than manipulation for young children. This was illustrated in a study in which 2- and 3-year-old children actively manipulated tools to subsequently retrieve a toy from an apparatus or observed an adult demonstrate how to use the tool or both (Gardiner, Bjorklund, Greif, & Gray, 2012). Children learned about the tools better through observation than by manual exploration. The authors argued that, "Evolutionarily, learning tool use through observation would have been selected over modes of independent learning for the efficient and accurate transmission of crucial, adaptive tool-use knowledge" (p. 252).

The Ineluctable Road to Tool Use

Effective tool use in humans in nearly inevitable, but it is not based on an innate "tool use" adaptation unique to our species. Rather, infants have biases to manipulate objects, with the purpose of both seeing what objects can do (exploration) and what they can do with the objects (play). In the process, they discover affordances of the objects and develop action plans for using them. As children's basic cognitive abilities develop, their general tendency to see purpose in the objects and events in the world (the design stance and promiscuous teleology) make it increasingly likely that they will learn to use objects as culturally prescribed. This is further facilitated by social-learning biases that result in children viewing the actions of others as normative and worthy of often precise imitation. Human infants and children share some of these perceptual, motor, and cognitive biases with other great apes, but some seem unique to our species (Bjorklund & Gardiner, 2011) and best described in terms of evolved probabilistic cognitive mechanisms.

Conclusions

Natural selection has operated at all stages of the life span but perhaps has operated most profoundly during the early years. In contemporary hunter-gatherer societies, and surely for our ancestors, approximately 50% of children failed to survive beyond their fifth year, making infancy and childhood the "crucible for natural selection" (Volk & Atkinson, 2013). Although many of these adaptations served simply to foster immediate survival, others set the stage for the acquisition of adaptations that would be functional in both contemporary and future environments.

Learning becomes important for a long-lived, slow-developing organism as *H. sapiens*, and learning requires plasticity, the ability to modify one's behavior and cognition in

response to environmental demands. To this end, an important evolved feature of many animals, but especially humans, is plasticity. Human infants and children evolved to be sensitive to early environmental conditions and to adjust their ontogenetic trajectories accordingly, both to deal with current conditions and to anticipate future ones. Plasticity is an evolved feature of our species and is especially evident in youth. Many mainstream evolutionary psychologists have recognized this, as reflected by recent findings derived from life history theory; but evolutionary developmental psychologists posit that evolved plasticity is "the rule" rather than the exception and that most if not all adaptations of adulthood should be viewed through a developmental lens. More specifically, I propose that most adaptations have their origins in low-level perceptual and cognitive biases/abilities that, in interaction with maturationally paced development and species-typical experience, produce adaptive, species-typical behavior, as reflected by the concept of evolved probabilistic cognitive mechanisms. Many of the low-level biases/abilities may be domain specific in nature, as proposed by mainstream evolutionary psychologists (Tooby & Cosmides, 1992), for example, the design stance for tool use. Others may be related to a single broad domain, such as social relations (e.g., viewing others as intentional agents), or be domain general in nature (e.g., perceptual narrowing, important in acquiring the other race effect in face discrimination but also important in phoneme discrimination; Kuhl et al., 2006). Natural selection works with what is available and is as capable of making use of existing mechanisms for new purposes as it is of evolving new ones.

Evolutionary developmental psychology has made substantial strides over the past quarter century, and research and theory in this subdiscipline of both developmental and evolutionary psychology will surely continue. My hope, however, is that evolutionary developmental psychology will not simply sit between mainstream evolutionary and developmental psychology, perhaps serving as a translator for one discipline to the other when the need arises. Rather, my hope is that developmental concepts can be fully incorporated into mainstream evolutionary psychology and evolutionary concepts can be fully incorporated into developmental psychology. These two historical behavioral sciences have much more in common than most practitioners believe, and their integration will result in a greater understanding of what it means to be human.

Declaration of Conflicting Interests

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References

Abravanel, E., & Sigafoos, A. D. (1984). Explaining the presence of imitation during early infancy. *Child Development*, *55*, 381–392.

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

Alvergne, A., Jenkinson, C., & Faurie, C. (Eds.) (2016). *Evolutionary medicine: A guide for researchers, practitioners and policy-makers*. Oxford, England: Springer.

Anzures, G., Wheeler, A., Quinn, P. C., Pascalis, O., Slater, A, M., Heron-Delaney, M., . . . Lee, K. (2012). Brief daily exposure to Asian females reverses perceptual narrowing for Asian faces in Caucasian infants. *Journal of Experimental Child Psychology*, *112*, 484–495.

Bakeman, R., Adamson, L. B., Konner, M., & Barr, R. G. (1990).! Kung infancy: The social context of object exploration. *Child Development*, *61*, 794–809.

Bardi, L., Regolin, L., & Simion, F. (2011). Biological motion preference in humans at birth: Role of dynamic and configural properties. *Developmental Science*, *14*, 353–359.

Bardi, L., Regolin, L., & Simion, F. (2014). The first time ever I saw your feet: Inversion effect in newborns' sensitivity to biological motion. *Developmental Psychology*, *50*, 986–993.

Barr, R., & Hayne, H. (2003). It's not what you know, it's who you know: Older siblings facilitate imitation during infancy. *International Journal of Early Years Education*, *11*, 7–21.

Barrett, L., & Dunbar, R. (Eds.). (2007). *Oxford handbook of evolutionary psychology*. Oxford, England: Oxford University Press.

Barrett, T. M., Davis, E. F., & Needham, A. (2007). Learning about tools in infancy. *Developmental Psychology*, *43*, 352–368.

Baumrind, D. (1967). Child care practices anteceding three patterns of preschool behavior. *Genetic Psychology Monographs*, *75*, 43–88.

Beier, J. S., & Spelke, E. S. (2012). Infants' developing understanding of social gaze. *Child Development*, *83*, 486–496.

Belsky, J., & Most, R. K. (1981). From exploration to play: A cross-sectional study of infant free play behavior. *Developmental Psychology*, *17*, 630–639.

Belsky, J., Steinberg, L., & Draper, P. (1991). Childhood experience, interpersonal development, and reproductive strategy: An evolutionary theory of socialization. *Child Development*, *62*, 647–670.

Bender, C. E., Herzing, D. L., & Bjorklund, D. F. (2009). Evidence of teaching in Atlantic Spotted Dolphins (*Stenella frontalis*) by mother dolphins foraging in the presence of their calves. *Animal Cognition*, *12*, 43–53.

Bering, J. M., Bjorklund, D. F., & Ragan, P. (2000). Deferred imitation of object-related actions in human-reared juvenile chimpanzees and orangutans. *Developmental Psychobiology*, *36*, 218–232.

Bertenthal, B. I. (1996). Origins and early development of perception, action, and representation. *Annual Review of Psychology*, *47*, 431–435.

Bertenthal, B. I., Proffitt, D. R., & Cutting, J. E. (1984). Infant sensitivity to figural coherence in bio-mechanical motions. *Journal of Experimental Child Psychology*, *37*, 213–230.

Bjorklund, D. F. (1987). A note on neonatal imitation. *Developmental Review*, *7*, 86–92.

Bjorklund, D. F. (1997). The role of immaturity in human development. *Psychological Bulletin*, *122*, 153–169.

Bjorklund, D. F. (2006). Mother knows best: Epigenetic inheritance, maternal effects, and the evolution of human intelligence. *Developmental Review*, *26*, 213–242.

Bjorklund, D. F. (2015). Developing adaptations. *Developmental Review*, *38*, 13–35.

Bjorklund, D. F., & Ellis, B. J. (2014). Children, childhood, and development in evolutionary perspective. *Developmental Review*, *34*, 225–264.

Bjorklund, D. F., Ellis, B. J., & Rosenberg, J. S. (2007). Evolved probabilistic cognitive mechanisms: An evolutionary approach to gene × environment × development interactions. In R. V. Kail (Ed.), *Advances in child development and behavior* (vol. *35*, pp. 1–39). Oxford, England: Elsevier.

Bjorklund, D. F., & Gardiner, A. K. (2011). Object play and tool use: Developmental and evolutionary perspectives. In A. D. Pellegrini (Ed.), *Oxford handbook of play* (pp. 153–171). Oxford, England: Oxford University Press.

Bjorklund, D. F., & Pellegrini, A. D. (2000). Child development and evolutionary psychology. *Child Development*, *71*, 1687–1798.

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

Bloom, P., & Markson, L. (1998). Capacities underlying word learning. *Trends in Cognitive Science*, *2*, 67–73.

Bock, J. (2005). Farming, foraging, and children's play in the Okavango Delta, Botswana. In A. D. Pellegrini & P. K. Smith (Eds.), *The nature of play: Great apes and humans* (pp. 254–281). New York, NY: Guilford Press.

Boesch, C (1991). Teaching in wild chimpanzees. *Animal Behavior*, *41*, 530–532.

Boesch, C., & Tomasello, M. (1998). Chimpanzee and human cultures. *Current Anthropology*, *39*, 591–614.

Bourgeois, K. S., Khawar, A. W., Neal, S. A., & Lockman, J. L. (2005). Infant manual exploration of objects, surfaces, and their interrelations. *Infancy*, *8*, 233–252.

Bowlby, J. (1969). *Attachment and loss: Vol. 1: Attachment*. London, England: Hogarth.

Boyce, W. T., & Ellis, B. J. (2005). Biological sensitivity to context: I. An evolutionary-developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*, *17*, 271–301.

Bräuer, J., Call, J., & Tomasello, M. (2005). All great ape species follow gaze to distant locations and around barriers. *Journal of Comparative Psychology*, *119*, 145–154.

Brooks, R., & Meltzoff, A. N. (2002). The importance of eyes: How infants interpret adult looking behavior. *Developmental Psychology*, *38*, 958–966.

Brooks-Gunn, J., Linver, M. R., & Fauth, R. C. (2005). *Children's competence and socioeconomic status in the family and neighborhood*. New York, NY: Guilford.

Buss, D. (Ed.). (2005). *Evolutionary psychology handbook* (1st ed.). New York, NY: Wiley.

Buss, D. (Ed.). (2016). *Evolutionary psychology handbook* (2nd ed.). New York, NY: Wiley.

Buss, D. M., Haselton, M. G., Shackelford, T. K., Bleske, A. L., & Wakefield, J. C. (1998). Adaptations, exaptations, and spandrels. *American Psychologist*, *53*, 533–548.

Buttelmann, D., Carpenter, M., Call, J., & Tomasello, M. (2007). Enculturated chimpanzees imitate rationally. *Developmental Science*, *10*, F31–F38.

Buttelmann, D., Carpenter, M., Call, J., & Tomasello, M. (2008). Rational tool use and tool choice in human infants and great apes. *Child Development*, *79*, 609–626.

Byrne, R. W. (2005). Social cognition: Imitation, imitation, imitation. *Current Biology*, *15*, R489–R500.

Carpenter, M., Akhtar, N., & Tomasello, M. (1998). 14- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior & Development*, *21*, 315–330.

Carpenter, M., Nagell, K., & Tomasello, M. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, *63*, 1–143.

Casler, K., & Kelemen, D. (2005). Young children's rapid learning about artifacts. *Developmental Science*, *8*, 472–480.

Chen, Z., & Siegler, R. S. (2000). Across the great divide: Bridging the gap between understanding of toddlers' and older children's thinking. *Monographs of the Society for Research in Child Development*, *65*, 1–96.

Cheyne, J. A., & Rubin, K. H. (1983). Playful precursors of problem solving in preschoolers. *Developmental Psychology*, *19*, 577–584.

Connolly, K., & Dalgleish, M. (1989). The emergence of a tool-using skill in infancy. *Developmental Psychology*, *25*, 894–912.

Cook, M., & Mineka, S. (1989). Observational conditioning of fear to fear-relevant versus fear-irrelevant stimuli in rhesus monkeys. *Journal of Abnormal Psychology*, *98*, 448–459.

Csibra, G. (2008). Goal attribution to inanimate agents by 6.5-month-old infants. *Cognition*, *107*, 705–717.

Csibra, G., & Gergely, G. (2011). Natural pedagogy as evolutionary adaptation. *Philosophical Transactions of the Royal Society of London, Biological Sciences*, *366*, 1149–1157.

Cutting, N., Apperly, I. A., Chappell, C., & Beck, S. R. (2014). The puzzling difficulty of tool innovation: Why can't children piece their knowledge together? *Journal of Experimental Child Psychology*, *125*, 110–117.

Del Giudice, M., Gangestad, S. W., & Kaplan, H. S. (2015). Life history theory and evolutionary psychology. In D. Buss (Ed.), *Evolutionary psychology handbook* (Vol. *2*, pp. 88–114). New York, NY: Wiley.

DeLoache, J. S., & LoBue, V. (2009). The narrow fellow in the grass: Human infants associate snakes and fear. *Developmental Science*, *12*, 201–207.

Dennett, D. (1990). The interpretation of texts, people, and other artifacts. *Philosophy and Phenomenological Quarterly*, *1*, 177–194.

Dunbar, R. I. M. (2003). The social brain: Mind, language, and society in evolutionary perspective. *Annual Review of Anthropology*, *32*, 163–181.

Duncker, K. (1945). On problem solving. *Psychological Monographs*, *58*, 5.

Easterbrook, M. A., Kisilevsky, B. S., Hains, S. M. J., & Muir, D. W. (1999). Faceness or complexity: Evidence from newborn visual tracking of facelike stimuli. *Infant Behavior and Development*, *22*, 17–35.

Ellis, B. J. (2004). Timing of pubertal maturation in girls: An integrated life history approach. *Psychological Bulletin*, *130*, 920–958.

Ellis, B. J., Del Giudice, M., Dishion, T. J., Figueredo, A. J., Gray, P., Griskevicius, V., . . . Wilson, D. S. (2012). The evolutionary basis of risky adolescent behavior: Implications for science, policy, and practice. *Developmental Psychology*, *48*, 598–623.

Ellis, B. J., Figueredo, A. J., Brumbach, B. H., & Schlomer, G. L. (2009). Fundamental dimensions of environmental risk: The impact of harsh versus unpredictable environments on the evolution and development of life history strategies. *Human Nature*, *20*, 204–268.

Flynn, E., & Whiten, A. (2012). Experimental "microcultures" in young children: Identifying biographic, cognitive, and social predictors of information transmission. *Child Development*, *83*, 911–925.

Gardiner, A. K. (2014). Beyond irrelevant actions: Understanding the role of intentionality in children's imitation of relevant actions. *Journal of Experimental Child Psychology*, *119*, 54–72.

Gardiner, A., Bjorklund, D. F., Greif, M. L., & Gray, S. K. (2012). Choosing and using tools: Prior experience and task difficulty influence preschoolers' tool-use strategies. *Cognitive Development*, *27*, 240–254.

Gardiner, A., Greif, M., & Bjorklund, D. F. (2011). Guided by intention: Preschoolers' imitation reflects inferences of causation. *Journal of Cognition and Development*, *12*, 355–373.

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. (2005). *The origin of mind: Evolution of brain, cognition, and general intelligence*. Washington, DC: American Psychological Association.

Geary, D. C. (2010). *Male, female: The evolution of human sex differences* (2nd ed.). Washington, DC: American Psychological Association.

Geary, D. C., & Berch, D. B. (Eds.). (2016). *Evolutionary perspectives on education and child development*. New York, NY: Springer.

Gergely, G., & Csibra, G. (2005). The social construction of the cultural mind: Imitative learning as a mechanisms of human pedagogy. *Interaction Studies*, *6*, 463–481.

German, T. P., & Johnson, S. (2002). Function and the origins of the design stance. *Journal of Cognition and Development*, *3*, 279–300.

Gray, P. (2016). Children's natural ways of educating themselves still works: Even for the three Rs. In D. C. Geary & D. B. Berch (Eds.), *Evolutionary perspectives on education and child development* (pp. 66–94). New York, NY: Springer.

Gredlein, J. M., & Bjorklund, D. F. (2005). Sex differences in young children's use of tools in a problem-solving task: The role of object-oriented play. *Human Nature*, *16*, 211–232.

Hamlin, J. K., Hallinan, E. V., & Woodward, A. L. (2008). Do as I do: 7-month-old infants selectively reproduce others' goals. *Developmental Science*, *11*, 487–494.

Hare, B. (2011). From hominoid to hominid mind: What changes and why? *Annual Review of Anthropology*, *40*, 293–309.

Harris, J. (1998). *The nurture assumption: Why children turn out the way the do*. New York, NY: Free Press.

Harris, L. J. (2005). Handedness. In B. Hopkins (Ed.), *The Cambridge encyclopedia of child development* (pp. 321–326). New York, NY: Cambridge University Press.

Heimann, M. (1989). Neonatal imitation gaze aversion and mother–infant interaction. *Infant Behavior & Development*, *12*, 495–505.

Herrmann, E., Call, J., Hernández-Lloreda, M. V., Hare, B., & Tomasello, M. (2007). Humans have evolved specialized skills of social cognition: The cultural intelligence hypothesis. *Science*, *317*, 1360–1366.

Hill, K., & Kaplan, H. (1999). Life history traits in humans: Theory and empirical studies. *Annual Review of Anthropology*, *28*, 397–430.

Hopper, L. M., Flynn, E. G., Wood, L. A. N., & Whiten, A. (2010). Observational learning of tool use in children: Investigating cultural spread through diffusion chains and learning mechanisms through ghost displays. *Journal of Experimental Child Psychology*, *106*, 82–97.

Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Animal Cognition*, *8*, 164–181.

Hutt, C. (1966). Exploration and play in children. *Symposia of the Zoological Society of London*, *18*, 61–81.

Jacobson, S. W. (1979). Matching behavior in the young infant. *Child Development*, *50*, 425–430.

Johnson, M. H., Dziurawiec, S., Ellis, H. D., & Morton, J. (1991). Newborns' preferential tracking of faces and its subsequent decline. *Cognition*, *40*, 1–19.

Kelemen, D. (2004). Are children "intuitive theists"? Reasoning about purpose and design in nature. *Psychological Science*, *15*, 295–301.

Kelly, D. J., Liu, S., Lee, K., Quinn, P. C., Pascalis, O., Slater, A. M., & Ge, L. (2009). Development of the other-race effect in infancy: Evidence toward universality? *Journal of Experimental Child Psychology*, *104*, 105–114.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007). The other-race effect develops during infancy. *Psychological Science*, *18*, 1084–1089.

Kenward, B. (2012). Over-imitating preschoolers believe unnecessary actions are normative and enforce their performance by a third party. *Journal of Experimental Child Psychology*, *112*, 195–207.

Keupp, S., Behne, T., & Rakoczy, H. (2013). Why do children over-imitate? Normativity is crucial. *Journal of Experimental Child Psychology*, *116*, 392–406.

Kovács, Á. M., Téglás, E., & Endress, A. D. (2010). The social sense: Susceptibility to others' beliefs in human infants and adults. *Science*, *330*, 1830–1834.

Kuhl, P. K., Stevens, E., Hayashi, A., Deguchi, T., Kiritani, S., & Iverson, P. (2006). Infants show a facilitation effect for native language phonetic perception between 6 and 12 months. *Developmental Science*, *9*, F13–F21.

Lancy, D. (2015). *The anthropology of childhood* (2nd ed.). Cambridge, England: Cambridge University Press.

Leavens, D. A., Hopkins, W. D., & Bard, K. A. (2005). Understanding the point of chimpanzee pointing: Epigenesis and ecological validity. *Current Directions in Psychological Science*, *14*, 185–189.

Lickliter, R. (1990). Premature visual stimulation accelerates intersensory functioning in bobwhite quail neonates. *Developmental Psychobiology*, *23*, 15–27.

Lickliter, R., & Honeycutt, H. (2003). Developmental dynamics: Towards a biologically plausible evolutionary psychology. *Psychological Bulletin*, *129*, 819–835.

Liszkowski, U., Carpenter, M., & Tomasello, M. (2007). Reference and attitude in infant pointing. *Journal of Child Language*, *34*, 1–20.

LoBue, V. (2010). And along came a spider: An attentional bias for the detection of spiders in young children and adults. *Journal of Experimental Child Psychology*, *107*, 59–66.

LoBue, V., & DeLoache, J. S. (2010). Superior detection of threat-relevant stimuli in infancy. *Developmental Science*, *13*, 221–228.

Lockman, J. J. (2000). A perception-action perspective on tool use development. *Child Development*, *71*, 137–144.

Lyons, D. E., Young, A. G., & Keil, F. C. (2007). The hidden structure of overimitation. *Proceedings of the National Academy of Sciences of the USA*, *104*, 19751–19756.

Martin, H., Breezley, P. C., Conway, E., & Kempe, H. (1974). The development of abused children: A review of the literature. *Advances in Pediatrics*, *21*, 119–134.

McCartney, K., Harris, M. J., & Bernieri, F. (1990). Growing up and growing apart: A developmental meta-analysis of twin studies. *Psychological Bulletin*, *107*, 226–237.

McGuigan, N., Makinson, J., & Whiten, A. (2011). From over-imitation to super-copying: Adults imitate causally irrelevant aspects of tool use with higher fidelity than young children. *British Journal of Psychology*, *102*, 1–18.

Meltzoff, A. N. (1995). Understanding the intentions of others: Reenactment of intended acts by 18-month-old children. *Developmental Psychology*, *31*, 838–850.

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science*, *198*, 75–78.

Mondloch, C. J., Lewis, T. M., Budreau, D. R., Maurer, D., Dannemiller, J., L., Stephens, B. R., & Kleiner-Gathercoal, K. A. (1999). Face perception during early infancy. *Psychological Science*, *10*, 419–422.

Nagell, K., Olguin, K., & Tomasello, M. (1993). Processes of social learning in the tool use of chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Journal of Comparative Psychology*, *107*, 174–186.

Nettle, D. (2010). Dying young and living fast: Variation in life history across English neighborhoods. *Behavioral Ecology*, *21*, 387–395.

Nettle, D., & Cockerill, M. (2010). Development of social variation in reproductive schedules: A study of an English urban area. *PLoS ONE*, *5*, e12690.

NICHD Early Child Care Research Network. (2002). Child-care structure → process → outcome: Direct and indirect effects of child-care quality on young children's development. *Psychological Science*, *13*, 199–206.

Nielsen, M. (2006). Copying actions and copying outcomes: Social learning through the second year. *Developmental Psychology*, *42*, 555–565.

Nielsen, M. (2012). Imitation, pretend play, and childhood: Essential elements in the evolution of human culture? *Journal of Comparative Psychology*, *126*, 170–181.

Nielsen, M., & Tomaselli, K. (2010). Over-imitation in the Kalahari Desert and the origins of human cultural cognition. *Psychological Science*, *5*, 729–736.

O'Connor, T. G. (2003). Early experiences and psychological development: Conceptual questions, empirical illustrations, and implications for intervention. *Development and Psychopathology*, *15*, 671–690.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*, 466–478.

Oostenbroek, J., Suddendorf, T., Nielsen, M., Redshaw, J., Kennedy-Costantini, S., Davis, J., . . . Slaughter, V. (2016). Comprehensive longitudinal study challenges the existence of neonatal imitation in humans. *Current Biology*, *26*, 1334–1338.

Overton, W. F. (2015). Processes, relations, and relational-developmental-systems. In W. F. Overton & P. C. M. Molenaar (Vol. Eds.) & R. M. Lerner (Editor-in-Chief), *Handbook of child psychology and developmental science. Vol. 1: Theory & method* (7th ed., pp. 9–62). Hoboken, NJ: Wiley.

Pascalis, O., Scott, L. S., Kelly, D. J., Shannon, R. W., Nicholson, E., Coleman, M., & Nelson, C. A. (2005). Plasticity of face processing in infancy. *Proceeding of the National Academy of Science*, *102*, 5297–5300.

Pellegrini, A. D. (2016). Object use in childhood: Development of possible functions. In D. C. Geary & D. B. Berch (Eds.), *Evolutionary perspectives on education and child development* (pp. 95–115). New York, NY: Springer.

Pellegrini, A. D., & Bjorklund, D. F. (2004). The ontogeny and phylogeny of children's object and fantasy play. *Human Nature*, *15*, 23–43.

Pettit, G. S., Dodge, K. A., & Brown, M. M. (1988). Early family experience, social problem solving patterns, and children's social competence. *Child Development*, *59*, 815–882.

Piaget, J. (1962). *Play, dreams, and imitation in childhood*. New York, NY: Norton.

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

Placek, C. D., & Quinlan, R. J. (2012). Adolescent fertility and risky environments: A population-level perspective across the lifespan. *Proceedings of the Royal Society B*, *279*, 4003–4008.

Ploeger, A., van der Maas, H. L. J., & Raijmakers, M, E. J. (2008). Is evolutionary psychology a metatheory for psychology? A discussion of four major issues in psychology from an evolutionary developmental perspective. *Psychological Inquiry*, *19*, 1–18.

Ramsey, J. K., & McGrew, W. C. (2005) Object play in great apes: Studies in nature and captivity. In A. D. Pellegrini & P. K. Smith (Eds.), *The nature of play: Great apes and humans* (pp. 89–112). New York, NY: Guilford Press.

Rubin, K. H., Fein, G., & Vandenberg, B. (1983). Play. In E. M. Hetherington (Ed.), *Handbook of child psychology: Vol. IV. Socialization, personality and social development* (pp. 693–774). New York, NY: Wiley.

Ruiz, A. M., & Santos, L. R. (2013). Understanding differences in the way human and non-human primates represent tools: The role of

teleological-intentional information. In C. M. Sanz, J. Call, & C. Boesch (Eds.), *Tool use in animals: Cognition and ecology* (pp. 119–133). Cambridge, England: Cambridge University Press.

Russell, J., Mauthner, N., Sharpe, S., & Tidswell, T. (1991). The "windows tasks" as a measure of strategic deception in preschoolers and autistic subjects. *British Journal of Developmental Psychology*, *9*, 331–349.

Salmon, C., & Shackelford, T. K. (Eds.) (2011) *The Oxford handbook of evolutionary family psychology*. Oxford, England: Oxford University Press.

Schulz, L. E., & Bonawitz, E. B. (2007). Serious fun: Preschoolers engage in more exploratory play when evidence is confounded. *Developmental Psychology*, *43*, 1045–1050.

Schulz, L. E., Gopnik, A., & Glymour, C. (2007). Preschool children learn about causal structure from conditional interventions. *Developmental Science*, *10*, 322–332.

Schulz, L. E., Hooppell, C., & Jenkins, A. C. (2008). Judicious imitation: Children differentially imitate deterministically and probabilistically effective actions. *Child Development*, *79*, 395–410.

Shackelford, T. K., & Hansen, R. D. (Eds.) (2014). *Evolution of violence*. New York, NY: Springer.

Sherrod, K. B., O'Connor, S., Vietze, P. M., & Altemeier, W. A. (1984). Child health and maltreatment. *Child Development*, *55*, 1174–1183.

Sigman, M., Newmann, C., Carter, E., Cattle, D., D'Souza, S., & Bwido, N. (1988). Home interactions and the development of Embu toddlers in Kenya. *Child Development*, *59*, 1251–1261.

Simon, T., & Smith, P. K. (1983). The study of play and problem solving in preschool children: Have experimenter effects been responsible for previous results? *British Journal of Developmental Psychology*, *1*, 289–297.

Simon, T., & Smith, P. K. (1985). Play and problem solving: A paradigm questioned. *Merrill-Palmer Quarterly*, *31*, 265–277.

Simpson, J. A., & Belsky, J. (2008). Attachment theory within a modern evolutionary framework. In P. R. Shaver & J. Cassidy (Eds.), *Handbook of attachment: Theory, research, and clinical application* (pp. 131–157). New York: Guilford.

Simpson, J. A., Griskevicius, V., Kuo, S., Sung, S., & Collins, W. A. (2012). Evolution, stress, and sensitive periods: The influence of unpredictability in early versus late childhood on sex and risky behavior. *Developmental Psychology*, *48*, 674–686.

Smith, P. K., & Dutton, S. (1979). Play training in direct and innovative problem solving. *Child Development*, *50*, 830–836.

Smith, P. K., & Whitney, S. (1987). Play and associative fluency: Experimenter effects may be responsible for previous positive findings. *Developmental Psychology*, *23*, 49–53.

Spelke, E. S., & Kinzler, K. D. (2007). Core knowledge. *Developmental Science*, *10*, 89–96.

Stearns, S. (1992). *The evolution of life histories*. Oxford, England: Oxford University Press.

Sylva, K., Bruner, J. S., & Genova, P. (1976). The role of play in the problem-solving of children 3-5 years old. In J. Bruner, A. Jolly, & K. Sylva (Eds.), *Play: Its role in development and evolution* (pp. 244–257). New York, NY: Penguin.

Thompson, R. A. (2006). The development of the person: Social understanding, relationships, conscience, self. In W. Damon & R. M. Lerner (Gen. Eds.), *Handbook of child psychology (6th edition),* N. Eisenberg (Vol. Ed.), Vol. *3*, *Social, emotional, and personality development* (pp. 24–98). New York, NY: Wiley.

Tomasello, M. (2000). Culture and cognitive development. *Current Directions in Psychological Science*, *9*, 37–40.

Tomasello, M. (2009). *Why we cooperate*. Cambridge, MA: MIT Press.

Tomasello, M. (2016). Cultural learning redux. *Child Development*, *87*, 643–653.

Tomasello, M., & Carpenter, M. (2005). The emergence of social cognition in three young chimpanzees. *Monographs of the Society for Research in Child Development*, *70*, 1–154.

Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental Science*, *10*, 121–125.

Tomasello, M., Savage-Rumbaugh, S., & Kruger, A. C. (1993). Imitative learning of actions on objects by children, chimpanzees, and enculturated chimpanzees, *Child Development*, *64*, 1688–1705.

Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In L. Cosmides, J. Tooby, J., & J. H. Barkow (Eds.), *The adapted mind* (pp. 19–136). New York, NY: Oxford University Press.

Tooby, J., & Cosmides, L. (2005). Conceptual foundations of evolutionary psychology. In D. M. Buss (Ed.), *Handbook of evolutionary psychology* (pp. 5–67). New York, NY: Wiley.

Trivers, R. (1972). Parental investment and sexual selection. In B. Campbell (Ed.), *Sexual selection and the descent of man* (pp. 136–179). New York, NY: Aldine de Gruyter.

Turkewitz, G., & Kenny, P. (1982). Limitations on input as a basis for neural organization and perceptual development: A preliminary theoretical statement. *Developmental Psychobiology*, *15*, 357–368.

Volk, A. A., & Atkinson, J. A. (2013). Infant and child death in the human environment of evolutionary adaptation. *Evolution and Human Behavior*, *34*, 182–192.

West-Eberhard, M. J. (2003). *Developmental plasticity and evolution*. New York, NY: Oxford University Press.

Whiten, A. (2010). Ape behavior and the origins of human culture. In P. M. Kappler & J. B. Silk (Eds.), *Mind the gap: Tracing the origins of human universals* (pp. 429–450). New York, NY: Springer.

Whiten, A., & Flynn, E. G. (2010). The transmission and evolution of experimental 'microcultures' in groups of young children. *Developmental Psychology*, *46*, 1694–1709.

Whiten, A., McGuigan, N., Marshall-Pescini, S., & Hopper, L. M. (2009). Emulation, imitation, over-imitation and the scope of culture for child and chimpanzee. *Philosophical Transactions of the Royal Society of London: Biological Sciences*, *364*, 2417–2428.

Williamson, R. A., & Markman, E. M. (2006). Precision of imitation as a function of preschoolers' understanding of the goal of the demonstration. *Developmental Psychology*, *42*, 723–731.

Zeigler-Hill, V., Welling, L., & Shackelford, T. (Eds.). (2015). *Evolutionary perspectives on social psychology*. New York, NY: Springer.