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Introduction to the Special Section on The Effects of Early Experience on Development

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One cardinal principle in developmental psychology is that early experience has a profound effect upon human development. Infants, once viewed as passive recipients of stimulation, are now understood to be active participants in the physical and social world that surrounds them. Learning takes place from a very early age and sets the course for trajectories of either adaptive or maladaptive behavior. A corollary to this principle is that there are certain periods during early development when experiences have a more significant effect than others. These periods, called sensitive or critical periods, are thought of as windows of opportunity during which certain types of experience have a foundational effect upon the development of skills or competencies. This special section of *Child Development* takes advantage of major advances in neuroscience, genetics, and improved developmental and statistical methods for studying the effects of early experience to provide readers with a broad range of review and empirical studies on this general topic. The special section is divided into seven parts: the first comprises two invited articles (Fox, Levitt, & Nelson, 2010; Meaney, 2010) that lay out important advances in neuroscience and molecular genetics. The second part provides five articles on fetal development and early experience. The third part contains three articles on perinatal experiences including low birth weight and long-term consequences on health and development, while the fourth part contains four articles on the effects of severe psychosocial deprivation, neglect, and abuse. The fifth part provides the reader with two articles on early experience and stress reactivity, while the sixth part presents three empirical articles examining basic mechanisms linking early experiences including poverty and adoption to behavior. Finally, Jack Shonkoff provides a commentary on the section with an eye toward thinking about the policy implications of the science.

The importance of early experience and the identification of sensitive or critical periods have a long history within developmental research. Much of the early work was on the effects of early handling and stress reactivity by developmental psychobiologists such as Seymour Levine (Levine, 1957) and Victor Denenberg (Denenberg, 1964). Their work, primarily in the rodent, illustrated the effects of early handling on later learning and reactivity. The notion of critical periods was introduced to developmental psychology by ethologists, such as Hess and Lorenz (e.g., Hess, 1964) with work on imprinting. Thinking about the effects of early experience on development has been solidified with advances in neuroscience that have described the pattern of brain development during the early months and years of life and the role that experience has in shaping development. Two areas of research have changed the way we conceptualize the effects of early experience and the influences of biology and nurture. The first is the work in neuroscience, done almost exclusively in rodents and nonhuman primates, on the effects of early experience on brain development. The second area is the revolution in our thinking about the role of experience in the action of genes and molecular genetics.

Neuroscience has provided an important foundation for our thinking about the role of early experience. Two lines of investigation are notable here. First, the descriptive work of Huttenlocher (Huttenlocher & Dabholkar, 1997) and Rakic (Granger, Tekaia, Le Sourd, Rakic, & Bourgeois,

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1995) illustrated changes in synaptic density, increases in neural connections, and the subsequent pruning or decreases in synaptic number that occurred during the postnatal period and differed in timing of occurrence as a function of brain region. Sensory and perceptual regions displayed these changes early in life while these changes occurred later in areas of the brain involved in higher cognition. Neuroscientists such as Greenough (Greenough, Black, & Wallace, 1987) argued that the pattern of synaptic ''blooming'' and ''pruning'' was in part a function of experience and the quality of stimulation that the organism was exposed to during specific time periods. A second and related line of work in the area of perceptual development by Hubel and Wiesel (1970) described in specific detail how certain types of sensory/perceptual experience were necessary, at particular early periods of postnatal development, for the mature functioning of the visual cortex. The animal had to engage actively in the perceptual world to stimulate the development of neural structures that underlay typical depth perception and other perceptual abilities. Suffice it to say, these studies and others supported what developmental psychologists thought for many years—that the quality and timing of early experience was critical for typical brain and behavioral development. The article by Fox et al. (2010) in this special issue provides the reader with an overview of these issues and a foundation for understanding the effects of both timing and quality of experience on psychological development.

Since the discovery and description of DNA, the importance of genes for understanding human behavior has been a continued subject of debate. For many years, this debate was informed by twin and adoption studies and the field of behavioral genetics. Data from these studies provided estimates of heritability of specific human personality traits or cognitive processes and at the same time, attempted to model the effects of shared and nonshared experience on the developing child. This work has been useful in maintaining a voice in the debate as to whether development was more influenced by ''nature'' versus nurture. Two recent approaches, however, illustrate that framing the question about early experience in this manner may no longer be valid. The first approach is one that models the different ways in which gene and environment can interact (Rutter, 2007). Among these possibilities is the interaction between individuals with a particular genotype and experience. Individuals carrying a particular allelic structure (e.g., if they are homozygous for the short allele of the 5HTT gene) are more susceptible to certain types of experiences and when exposed to these events have trajectories of development that are different from individuals with similar genetic makeup but different experience. A classic study by Caspi et al. (2003) illustrated this gene by environment interaction within the realm of psychiatric disorders. Individuals who were homozygous for the short allele of 5HTT and who experienced heightened life stress were more likely to have a diagnosis of depression compared to individuals with the same genetic makeup but who experienced less life stress. The obvious implications are that both gene AND environment are playing critical synergistic roles in understanding developmental outcome.

A second, more recent approach is one driven by advances in molecular biology and encompasses the field of epigenetics. Research in this area, initially the result of work on the genetics of cancer, argues that experience influences the cellular machinery of the gene, changing in some instances, the expression of the gene and the genome itself. It is the essence of a gene by environment interaction. Experience modifies the gene and its actions creating changes in behavior and in some instances being transmitted down through genetic action to subsequent generations. This work has been brought to the field of developmental psychology by Michael Meaney and his colleagues (Meaney, 2001). Their research has illustrated at the behavioral and genetic levels how variations in caregiving experiences affect stress reactivity and learning in the rodent. Meaney's article in this special section (Meaney, 2010) is an attempt to provide the readers of *Child Development* with a basic introduction to the field of epigenetics and to the power and potential of this approach to studying the effects of early experience on development.

Research into the development of the central nervous system (CNS) has focused, as well, on the period between conception and birth. By the time a full-term infant is born the basic wiring of the CNS has been completed, the neurons that form the different layers of the CNS have all reached their destinations, and a good deal of the basic wiring in the brain has been achieved. Whereas much of the ontogeny of CNS during fetal development is under genetic control, these genes and their actions are affected by the fetal environment. At one time, this environment was thought to be protected by an impervious placenta, but we now know that exposure to a range of substances can have neurotoxic effects and that maternal psychological state

as well affects fetal development. Although much of developmental psychology's efforts have been toward describing learning and development and the effects of experience on cognitive and social development postbirth, the quality of the fetal environment and the timing of exposure during fetal development to a wide range of substances appear to play a significant role in typical or atypical postnatal and human development. Five articles are included in the special section illustrating the importance of the fetal environment on subsequent development. DiPietro et al. (2010) provide the reader with a roadmap to how one studies typical fetal development across pregnancy and the meaning of variability in fetal responses for newborn CNS maturation. Two articles (Price, Grosser, Plomin, & Jaffee, 2010; D'Onofrio et al., 2010) provide readers with an example of the consequences of fetal exposure to maternal smoking. D'Onofrio et al. (2010) examine the long-term consequences on academic achievement for children whose mothers smoked during pregnancy, with the important finding that the supposed prenatal environmentally mediated effects are probably largely a function of a shared genetic liability. Price et al. (2010) demonstrate an important gene by environment mechanism for understanding the effects on intrauterine growth, and D'Onofrio et al. (2010) examine the long-term consequences on academic achievement for children whose mothers smoked during pregnancy, with the important finding that the supposed prenatal environmentally mediated effects are probably largely a function of a shared genetic liability. Davis and Sandman (2010), using data from an ongoing longitudinal study, found that the timing of cortisol levels during gestation were associated with differences in the babies' developmental level at 12 months. Finally, Hay, Pawlby, Waters, Perra, and Sharp (2010) examine the effects of maternal antenatal depression on children's antisocial behavior. Remarkably, maternal depression during pregnancy above other risk factors during pregnancy and after birth significantly predicted child psychiatric problems.

Basic research into brain development in the human fetus prior to term delivery has also informed thinking about the role of early experience amongst infants born early. Neonatology has developed the methods to increase the survival of very low birth weight infants who are, in most cases, also very premature. Although mortality has decreased in this population, morbidity due to prenatal or neonatal complications is a major issue for this population of children. But even among those very low birth weight infants who do not undergo significant medical complications, the nonfetal environment into which they are born and the stimulation of the neonatal intensive care unit are clearly nonintended with regard to typical biological growth of the CNS. Two articles in this special section directly address these questions. Ronald, Happe, Dworzynski, Bolton, and Plomin (2010) provide evidence for the very weak effects of both prenatal and neonatal complications on the incidence of autistic like features in young children. Schmidt, Miskovic, Boyle, and Saigal (2010) report on the consequences, in adult life, of being born with very low birth weight in a nonmedically comprised sample. A third article by Grosse (2010) examines the consequences of late-treated phenylketonuria on cognitive development.

Much of the work on the effects of early experience and sensitive periods on later development has been with rodents or nonhuman primates. Data in human infants have been primarily in visual perceptual development (e.g., the work of Maurer, Lewis, Brent, & Levin, 1999) or auditory perceptual development and language (e.g., the work of Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Neville & Bavelier, 1998). Maurer's research examined perceptual development of infants born with bilateral cataracts, studying the effect of age at which the infant had surgery to remove the cataract on subsequent perceptual processes. Neville's work examined changes in brain organization and language abilities in infants born deaf. Kuhl showed how exposure to one's native language in the first months of life determines perceptual abilities to distinguish among different phonemic contrasts during later infancy and childhood. In the case of Maurer or Neville's work, use of subjects whose sensory faculties (either vision or hearing) were severely impaired allowed exploration of the effects of early experience and timing of those experiences on development. Examination of the effects of more general psychosocial deprivation and neglect in human infants has until recently been missing from the research field.

Studies of infants who have been abandoned at birth and placed into institutions where they received minimum basic care but have been deprived of typical psychosocial stimulation have filled the gap in our knowledge about the effects of these experiences on later cognitive and social development. These studies have been in the literature for some time (e.g., Tizard & Rees, 1974) but only recently has there been a systematic attempt to examine issues of timing and sensitive periods across a wide array of domains of cognitive and

socioemotional behavior. A pioneering study in the United Kingdom (Rutter, O'Connor, and the ERA, 2004) tracked the cognitive and social development of a large group of children who were abandoned at birth into the institutions that existed in Romania. A series of articles from this study illustrated the effects of early severe psychosocial deprivation and neglect on children's subsequent development—as well as the importance of timing of intervention. Three articles in the current special section follow in this model: Pollak et al. (2010) present data from a large study of postinstitutionalized children adopted by families in the United States; Dobrova-Krol, van IJzendoorn, Bakermans-Kranenburg, and Juffer (2010) examine the consequences of institutionalization and HIV infection in infants in the Ukraine, and Smyke, Zeanah, Fox, Nelson, and Guthrie (2010) present evidence on the effects on social development of a foster care/family intervention within the context of the Bucharest Early Intervention Project. Of course, one does not have to study children in institutions to examine the effects of abuse and neglect on development. There is a long history of research into the consequences of physical and sexual abuse on children's development, exemplified in the current issue by a study by Cicchetti, Rogosch, Gunnar, and Toth (2010).

Two articles in this special section examine the effects of different early experiences on children's stress reactivity. Obradović, Bush, Stamperdahl, Adler, and Boyce (2010) use a model of biological sensitivity to context in which they examine whether certain contexts and early adversity are actually advantageous for some children while detrimental to others. In a similar vein, O'Neal et al. (2010) study the effects of a randomized clinical intervention trial aimed at reducing child aggression and stress reactivity. Their findings illustrate that often one particular intervention does not affect all children in the same way.

In the sixth part of this special section three articles illustrate both the mechanism and the importance of individual differences in temperament and genetics in predicting cognitive and socioemotional development. Bernier, Carlson, and Whipple (2010) nicely demonstrate how differences in maternal behavior can enhance the emergence of executive functioning in young children. This article serves as a reminder that brain areas continue to mature well into childhood and possibly adolescence, and that experiences can enhance the emergence of functions that are subsumed by these important late maturing brain regions. Leve et al. (2010) using a longitudinal design, including a prospective adoption cohort, examine both the genetic and caregiving effects predicting externalizing behaviors. Their findings illustrate both the unique and interactive effects of maternal caregiving and infant genetic makeup in predicting behavioral outcomes. The third article in this section (Duncan, Ziol-Guest, & Kalil, 2010) examines data from the Panel Study of Income Dynamics assessing the long-term effects of poverty on adult achievement, health, and behavioral outcomes. The study confirms the fact that early experience of poverty (in this case between children's prenatal to 5th year of life) has long-term consequences on a number of health and income outcomes.

The final article of this special section is a commentary by Shonkoff (2010) that lays out the relations between basic research into the effects of early experience and constructive social policy for the welfare and good of children. Shonkoff argues that the scientific evidence—as presented in the articles in this special issue—warrants innovative approaches to creating effective and novel prevention and intervention programs for children. He presents arguments for new strategies that can reduce the effects of disadvantage and early experience with ''toxic'' stress. His commentary demonstrates the importance of integrating established scientific evidence from brain and behavioral sciences, benefit–cost data, and the results of randomized controlled trials on intervention/prevention. It provides the link between the articles in this special section to important policy initiatives for the good of all children.

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