

Symposium Articles

Bridging Developmental Neuroscience and the Law: Child-Caregiver Relationships

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Advances in neuroscience are changing understanding of the biological foundations of human development and have implications for legal analysis. As with any period of rapid scientific progress, however, new ideas are subject to misinterpretation and errors in application. This Article offers guidance on how to avoid such problems and consider carefully the applications of developmental neuroscience to legal policy and practice, with a particular emphasis on caregiver-child relationships. Three principles are discussed. First, the most confident applications of developmental neuroscience to legal policy occur when the conclusions of neuroscience are consistent with those of behavioral research. This is because their convergence across different levels of analysis strengthens confidence in their validity. Concerning caregiver-child relationships, studies of brain and behavior are consistent in emphasizing the importance of early experience, the significance of caregiving quality for buffering stress, and the enduring consequences of early adversity. Second, complex interactions between brain maturation and experience over time are likely to be typical, not exceptional, in the development of competencies relevant to legal policy and practice. The development of “responsibility” is, for example, a dynamic process involving maturation of multiple brain areas interacting with experiential history. Third, applications of developmental neuroscience to law and policy must take seriously the importance of brain plasticity and its implications for children’s behavioral adaptation to new opportunities. Neuroplasticity accounts for the efficacy of preventive and intervention efforts targeted to children in adversity, but it also underscores the biological and economic benefits of beginning early in life when brain plasticity is greatest.

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INTRODUCTION

This is an historic period of change in our understanding of human behavior. Unprecedented scientific advances in studies of brain development, structure, and functioning are changing how we understand the origins of human functioning.¹ The mapping of the human genome and documentation of epigenetic processes are further revolutionizing our knowledge of the biological foundations of behavior and their interaction with experience.² Theoretical and technological innovations in scientific study are rapidly advancing, offering the prospect of significant progress in the years ahead. These scientific insights already are making their way into popular culture, as seniors are urged to “exercise the brain” while mothers and teachers are offered “brain-based” educational curricula for children.³ Beyond specific knowledge of the biological bases of human behavior, these scientific advances are also ushering in a new materialistic conception of human behavior that is changing how we think about ourselves.⁴

1. Advances in neuroscience are appearing weekly on the pages of scientific journals. For a recent, scholarly compendium of this science, consult *THE COGNITIVE NEUROSCIENCES* (Michael S. Gazzaniga ed., 4th ed. 2009). For an accessible and readable review by a noted scholar in this field, consult MICHAEL S. GAZZANIGA, *HUMAN: THE SCIENCE BEHIND WHAT MAKES US UNIQUE* (2008).

2. Epigenetics is the study of heritable changes in gene expression that occur not because of changes in the structure of DNA, but rather because of changes in cellular processes that cause genes to become active or inactive as the consequence of experience, among other things. See TOM STRACHAN & ANDREW READ, *HUMAN MOLECULAR GENETICS* 365 (4th ed. 2011). The science of molecular genetics, building on the mapping of the human genome, is advancing significantly as the field of epigenetics unfolds. See generally *id.*

3. The “Baby Einstein” collection of baby toys is one of many examples of the marketing of products to parents based on their alleged success in stimulating brain growth. BABY EINSTEIN, <http://www.babyeinstein.com/home/> (last visited July 1, 2012).

4. See generally ROSS A. THOMPSON, *EARLY BRAIN DEVELOPMENT, THE MEDIA, AND PUBLIC*

As with any period of rapid scientific progress, new ideas are subject to misinterpretation, overextension, and errors in application. One reason is that new scientific discoveries are prone to be viewed within old interpretive frameworks. The research in developmental neuroscience and molecular genetics, for example, challenges traditional ways of thinking about the biology of human behavior, such as the dichotomy between nature and nurture, biological determinism, and “critical period” thinking. Until a new understanding of gene-environment interaction, epigenetics, and brain plasticity reshapes our framework for understanding human behavior, these old interpretive frameworks are likely to continue to mislead.⁵ Moreover, one of the most important and far-reaching effects of the new biological science of human behavior is how it may transform traditional ways of conceptualizing human cognition, personality, and psychopathology. As researchers in molecular genetics discover, for example, that the human characteristics associated with gene alleles may not readily map onto traditional conceptualizations of human personality or psychopathology,⁶ it may require reconsidering the diagnostic

POLICY (forthcoming 2014).

5. Research on gene-environment interaction undermines the traditional nature-nurture dichotomy by showing that the behavioral effects of genetic influences vary depending on environmental conditions (and that environmental influences depend, in part, on the nature of genetic influences). As one illustration, researchers found that a program designed to improve maternal care to offspring with behavioral problems worked best for children with a particular gene that is associated with problem behavior, aggression, and hyperactivity. Genetic vulnerability in the child, in other words, interacted with the environmental intervention to alter behavioral outcomes for the child. Marian J. Bakermans-Kranenburg et al., *Experimental Evidence for Differential Susceptibility: Dopamine D₄ Receptor Polymorphism (DRD₄ VNTR) Moderates Intervention Effects on Toddlers' Externalizing Behavior in a Randomized Controlled Trial*, 44 *DEVELOPMENTAL PSYCHOL.* 293, 293–300 (2008). The field of epigenetics undermines traditional ideas of biological determinism by showing that experience can alter gene expression, figuratively “turning on” and “turning off” genes in a manner that has significant implications for behavior and development. Thus biology is not deterministic, because its influence on behavior is, to some extent, experientially mediated. For an accessible introduction to epigenetics research, consult Michael J. Meaney, *Epigenetics and the Biological Definition of Gene x Environment Interactions*, 81 *CHILD DEV.* 41, 41–79 (2010). Research on brain plasticity undermines traditional concepts of “critical periods” in development by highlighting the continuing susceptibility of the brain to experiential influences throughout life, which is why developmental researchers typically substitute the term “sensitive period” for “critical period,” with the former term denoting periods of greater sensitivity to environmental influences, but without the abrupt closing-off of environmental influence at a critical age as is indicated by critical period concepts. See Marc H. Bornstein, *Sensitive Periods in Development: Structural Characteristics and Causal Interpretations*, 105 *PSYCHOL. BULL.* 179, 179–97 (1989). Taken together, traditional views that emphasize a sharp distinction between biological and environmental influences on behavior and development are gradually being superseded by more contemporary views emphasizing the inextricable interaction of biology and experience.

6. Some aspects of human personality and psychopathology, such as sensation seeking, impulsive aggression, and behavioral inhibition, have been well modeled in studies of molecular genetics. But many behavioral characteristics associated with specific genes do not fit into conventional personality or psychopathology categories, and researchers have not yet found genetic markers for many of the most commonly identified adult personality characteristics. There is also controversy over the methodologies that are currently used to associate specific genes with behavioral

categories that have guided psychological therapy for more than a century. As neuroscientists discover that neural networks are not necessarily organized according to our familiar categories of human experience, it may require a reconceptualization of how knowledge is organized in the brain and mind.

Another reason that misinterpretation can occur is that, as practitioners in diverse fields seek to apply the insights of neuroscience, differences in orientation and even language can obscure understanding. An educator and a neuroscientist have different implicit conceptions of terms—“learning,” for example—based on the very different levels of analysis they take to this process. This complicates educational applications of developmental neuroscience. Similarly, legal experts and developmental scientists have different understandings of terms like “responsibility” and “competence” because of their different analytical models. Tackling the challenge of carefully translating terms and concepts from one field to another is vital for creating appropriate and responsible applications of brain science to other fields.

This Article provides some suggestions on how to minimize such problems and consider more carefully and thoughtfully the implications of developmental neuroscience for legal policy and practice. Although it focuses on the neuroscience of caregiver-child relationships, this Article also draws from other areas in which developmental neuroscience is being applied to legal policy and practice to draw lessons on how the most responsible and informative applications of neuroscience to the law can be made.

The purpose is not to offer a comprehensive review of research in these fields, but rather to enlist relevant research findings to illustrate three general principles related to the applications of developmental neuroscience to the law. Part I of this Article discusses the first of these principles: The most confident applications occur when the findings of developmental neuroscience are consistent with those of behavioral research. This is because convergent conclusions across these different levels of analysis contribute to confidence in their validity and a greater understanding of the associations between brain and behavior. It is when there is a divergence between the conclusions of behavioral research and the findings of developmental neuroscience that applications of the latter must be most cautious and careful.

Part II begins by explaining the second principle: Complex interactions between brain maturation and experience are likely to be typical, not exceptional, in the development of competencies relevant to

characteristics. It is important to note, however, that work on molecular genetics in behavior and development is still at an early stage. *See generally* MOLECULAR GENETICS AND THE HUMAN PERSONALITY (Jonathan Benjamin et al. eds., 2002); Kurtis L. Noblett & Emil F. Coccaro, *Molecular Genetics of Personality*, 7 CURRENT PSYCHIATRY REP. 73, 73–80 (2005).

legal policy and practice. As the analysis indicates, multiple integrated neural and behavioral systems are most often required to characterize legally relevant capabilities and characteristics, and these systems develop in continuous interaction with experience over time. This Article concludes that such interactions between experience and brain development are especially important to consider in light of the plasticity of the developing brain. Further examining this interaction in the context of children who live in adverse environments, Part II concludes with the third principle: Application of developmental neuroscience to law and policy *must* account for brain plasticity and its implications for children's behavioral adaptation to new opportunities. Brain plasticity provides a scientific basis for rejecting undue emphasis on the determination of long-term outcomes from early influences, and it provides a foundation for implementing carefully designed interventions to improve human outcomes from unfortunate early beginnings. However, research on brain plasticity also indicates that it becomes more biologically and economically costly to improve human welfare the later interventions occur.

In the end, although biologically based concepts are undeniably destined to influence legal policy and practice, we are not yet at a point where the best applications of developmental neuroscience are readily apparent. Developmental neuroscience is still a very young field, and the translational work is just beginning. I hope that these comments will contribute to this important work.

I. INTEGRATING DEVELOPMENTAL NEUROSCIENCE AND BEHAVIORAL RESEARCH

Scientific research can be a humbling endeavor, and the classic fable of the blind men and the elephant resonates with many scientists. In this fable, each man touches a different part of the elephant and comes to a different conclusion about the nature of the animal. In a similar manner, scientists study particular determinants of a chosen phenomenon while recognizing that the whole story is far more multifaceted and complex, requiring the contributions of scientists in allied fields of inquiry. This is particularly true of the study of human behavior and development, which requires the integration of insights from biological, behavioral, sociological, cultural, and comparative animal behavioral (among others) perspectives to human functioning.⁷

For developmental neuroscience, one of the most important challenges is integrating neurobiology with behavior. This is especially

7. This is illustrated by the multi-volume *HANDBOOK OF CHILD PSYCHOLOGY*, a compendium of developmental science that incorporates research in each of these areas. See generally *HANDBOOK OF CHILD PSYCHOLOGY* (William Damon & Richard M. Lerner eds., 6th ed. 2008).

challenging in developmental analysis. One reason is that documenting changes in brain structure or function over the course of development that coincide with concurrent changes in behavior simply identifies the correlation of changes in the brain and behavior. What is needed is an explanation of *how* they are associated.⁸ In themselves, these correlated changes do not show that maturational changes in the brain account for changes in behavior.⁹ Indeed, the opposite might be true: The brain may be changing in *response* to changes in behavior and experience that arise for other reasons, such as instruction and practice in new skills. Because we now understand that there are continuous, mutual influences between brain development and experience, either explanation is reasonable, and both require further study.¹⁰ For example, the explosive growth in synaptic proliferation in the developing brain during the prenatal and early postnatal period is consistent with the newborn infant's hunger for novelty, attention to sensory experience, and preference for social stimulation.¹¹ These changes in neurobiology and experience are mutually influential: The brain's maturational growth fuels attention to novelty, and these experiences of novel stimulation contribute to the brain's growth.¹² Research in developmental neuroscience typically involves coordinated assessments of neurobiology and behavior, but identifying causal associations between correlated brain and behavioral changes is difficult, and the connections between brain and behavior still remain uncertain and speculative in many areas. Integrating research on neuroscience and behavioral development is crucial to understanding their causal association, and it is thus important to denoting the relevance of this research to practice and policy.

Integrating neuroscience and behavior is important for another reason. Researchers know quite a lot about behavioral development, having studied the origins of behavioral changes and individual differences for many decades.¹³ Developmental neuroscience, by contrast, is a relatively new field.¹⁴ Consequently, the most confident applications of

8. The recognition that correlated changes are not necessarily causal is a fundamental, but often overlooked, principle in developmental science. See Donald P. Hartmann et al., *Design, Measurement, and Analysis in Developmental Research*, in *DEVELOPMENTAL SCIENCE: AN ADVANCED TEXTBOOK* 109, 117–18 (Marc H. Bornstein & Michael E. Lamb eds., 6th ed. 2011).

9. *Id.* at 136.

10. See generally JOAN STILES, *THE FUNDAMENTALS OF BRAIN DEVELOPMENT: INTEGRATING NATURE AND NURTURE* (2008).

11. Ross A. Thompson, *Development in the First Years of Life*, 11 *FUTURE CHILDREN* 21, 28–30 (2001).

12. *Id.*

13. See generally *HANDBOOK OF CHILD PSYCHOLOGY*, *supra* note 7.

14. In contrast with more than a century of scientific inquiry into behavioral development, the modern era of developmental neuroscience dates back only a few decades. See CHARLES A. NELSON ET AL., *NEUROSCIENCE OF COGNITIVE DEVELOPMENT: THE ROLE OF EXPERIENCE AND THE DEVELOPING BRAIN* 2 (2006).

developmental neuroscience to policy and practice are when the conclusions of neuroscience are consistent with those of behavioral research. When each field points to similar conclusions from different levels of analysis, this convergence adds to confidence that the applications of this knowledge are valid and reliable.

Ascertaining convergent conclusions between behavioral science and developmental neuroscience is not necessarily as easy as it might seem. One reason is that each field is advancing rapidly, revising and updating knowledge almost continuously and, in so doing, posing further questions about brain-behavior connections. Another reason is that where the study of human behavior and development is concerned, it is easy to substitute assumptions about behavioral development gleaned from intuition or the popular media for a hard-nosed examination of the behavioral evidence. Popular stereotypes about the characteristics of elderly people,¹⁵ differences between men and women,¹⁶ and teenage behavior,¹⁷ for example, are often quite different from what research evidence shows, and these stereotypes sometimes lead to misleading applications of neuroscience to explain behavior that is consistent with these stereotypes.

To illustrate, almost everybody knows—especially those who have been parents of teenagers—that adolescence is a developmental period characterized by sensation seeking, risk taking, and poor judgment, and this portrayal has been confirmed in television and movies about rebellious teenagers and delinquent adolescents.¹⁸ But the behavioral research offers a much more nuanced picture of adolescence: It shows that the widely popularized use of hard drugs, sexual risk taking, and delinquency characterizes only a very small proportion of adolescents, and that serious problems during this period are often secondary to family difficulties, developing psychopathology, or other issues—not adolescence *per se*.¹⁹ If most adolescents make their way through this developmental period fairly smoothly (for example, working at jobs, going to school, preparing for higher education),²⁰ this should be consistent with

15. See generally Mary Lee Hummert, *Age Stereotypes and Aging*, in HANDBOOK OF THE PSYCHOLOGY OF AGING 249, 249–62 (K. Warner Schaie & Sherry L. Willis eds., 7th ed. 2011).

16. See generally CAROL TAVRIS, *THE MISMEASURE OF WOMAN* (1992).

17. See generally Elisheva F. Gross & Curtis D. Hardin, *Implicit and Explicit Stereotyping of Adolescents*, 20 SOC. JUST. RES. 140 (2007).

18. *Id.* at 140–41.

19. See generally JOHN C. COLEMAN, *THE NATURE OF ADOLESCENCE* (4th ed. 2011); LAURENCE STEINBERG, *ADOLESCENCE* (8th ed. 2008).

20. In the concluding words of one authority:

The view has been advanced here that adolescence is not a stage of trauma or disorder. Theories which suggest such an idea do not accord with the empirical evidence. It seems that the majority of young people cope reasonably well with the normative risks and stresses which are inherent in the adolescent transition.

the portrayal of adolescent competencies yielded by research on brain development in adolescence. By contrast, it is unclear what comprehensive brain-based accounts of impaired judgment, poor self-regulation, or sensation-seeking in adolescence need to explain, even though these accounts have become influential in public and legal discourse.²¹ Applications to legal policy must therefore cautiously evaluate how behavioral and brain research is interpreted and whether these applications lead to convergent conclusions.

A. CHILD-CAREGIVER RELATIONSHIPS

Fortunately, the convergence of conclusions from neurobiology and developmental psychology about child-caregiver relationships is strong, providing a basis for careful thinking about applications to legal policy and practice. Evidence from both fields indicates that the quality of care in the early years, beginning prenatally and extending throughout childhood, is important to healthy physical and behavioral development, and that abusive or neglectful treatment early in life can create enduring developmental problems.²²

These conclusions are consistent with ideas from life history theory, which is becoming an increasingly influential framework for understanding the impact of early experience on life span development.²³ According to this view, developing brains and neurobiological systems grow in accordance with signals from the caregiving system (that is, the quality of care and the context in which it occurs) about the adaptive requirements of everyday life.²⁴ These signals are conveyed in a variety of ways, from the sensitivity of care to the language that adults speak.²⁵ The caregiving system thus helps prepare developing brains and behavioral systems for future life.

The processes by which these signals influence neurobiological and behavioral development begin prenatally and continue throughout childhood.²⁶ A well-known illustration concerns early language

COLEMAN, *supra* note 19, at 224.

21. Neurobiologically based accounts of adolescents' impaired judgment and sensation seeking have been influential in legal contexts, particularly as they relate to death penalty sentencing of minors convicted of capital offenses. See Laurence Steinberg & Elizabeth S. Scott, *Less Guilty by Reason of Adolescence: Developmental Immaturity, Diminished Responsibility, and the Juvenile Death Penalty*, 58 AM. PSYCHOLOGIST 1009, 1009–18 (2003); Laurence Steinberg, *Should the Science of Adolescent Brain Development Inform Public Policy?*, 64 AM. PSYCHOLOGIST 739, 739–50 (2009).

22. See *infra* notes 31–49 and accompanying text.

23. For an introduction to life history theory, see generally JAMES S. CHISHOLM, *DEATH, HOPE, AND SEX: STEPS TO AN EVOLUTIONARY ECOLOGY OF MIND AND MORALITY* (1999); STEPHEN C. STEARNS, *THE EVOLUTION OF LIFE HISTORIES* (1992).

24. See generally CHISHOLM, *supra* note 23; STEARNS, *supra* note 23.

25. See generally CHISHOLM, *supra* note 23; STEARNS, *supra* note 23.

26. See generally CHISHOLM, *supra* note 23; STEARNS, *supra* note 23.

acquisition.²⁷ The developing brain at birth cannot know whether the accident of birth has landed the newborn in Paris, Seoul, London, Moscow, or elsewhere in the world, and consequently the brain must be prepared to potentially learn any human language. As a reflection of this, infants at six months can discriminate a far wider variety of human speech phonemes than can their parents—they are figuratively “citizens of the world” prepared to learn any language.²⁸ But this universal perceptual ability is lost by age one as speech perception becomes reoriented to the phonemes of the language (or languages) that the infant has been overhearing and as the brain becomes reorganized to learn that specific language.²⁹ The speech sounds conveyed by caregivers signal to the developing brain the language learning that is required for the child to function successfully in the world.³⁰

It is now becoming clear that language learning is one of many behavioral systems whose development is altered—neurobiologically and behaviorally—by caregiving experience. Most pertinent to legal policy is the development of stress responding. The developing brain cannot know whether the accident of birth has landed the newborn in Berlin or Beirut, in the West Bank or the East Side, or in a secure or abusive family environment. Yet it is important for survival that children become capable of responding adaptively to environments that pose threats and danger rather than promote safety and security. Consequently, developing neurobiological stress systems become calibrated to signals from the caregiving system about stresses and threats in everyday life conveyed through maternal stress hormones in the intrauterine environment, through the poor quality of postnatal maternal care, and in other ways.³¹ Inadequate or aversive early care experiences are associated with the early development of abnormal stress reactivity in both humans and animals.³²

27. Patricia K. Kuhl, *Is Speech Learning “Gated” by the Social Brain?*, 10 DEVELOPMENTAL SCI. 110, 110–20 (2007).

28. Janet F. Werker, *Becoming a Native Listener*, 77 AM. SCIENTIST 54, 54–59 (1989).

29. Patricia K. Kuhl et al., *Infants Show a Facilitation Effect for Native Language Phonetic Perception Between 6 and 12 Months*, 9 DEVELOPMENTAL SCI. F13, F13–21 (2006); Werker, *supra* note 28, at 56.

30. Janet F. Werker, *Baby Steps to Learning Language*, 143 J. PEDIATRICS S62, S62–69 (2003).

31. See Megan R. Gunnar et al., *Bringing Basic Research on Early Experience and Stress Neurobiology to Bear on Preventive Interventions for Neglected and Maltreated Children*, 18 DEV. & PSYCHOPATHOLOGY 651, 651–77 (2006); Michelle M. Loman & Megan R. Gunnar, *Early Experience and the Development of Stress Reactivity and Regulation in Children*, 34 NEUROSCI. & BIOBEHAV. REVS. 867, 867–76 (2010).

32. Sonia J. Lupien et al., *Effects of Stress Throughout the Lifespan on the Brain, Behaviour and Cognition*, 10 NATURE REVS. NEUROSCI. 434, 434–45 (2009). Heightened stress reactivity is especially characteristic for children who have experienced chronic, severe, or unpredictable stress, such as from abusive care. *Id.* at 438. Moreover, as described below, children in institutional care or foster care can develop abnormally blunted or suppressed recovery of the stress system, reflected in atypical diurnal patterns of cortisol responding, that may also derive from chronically active stress responding. See *infra* notes 90–100 and accompanying text.

Children in aversive circumstances, such as abusive care, often show heightened stress reactivity in the limbic-hypothalamic-pituitary-adrenocortical axis, the sympathetic adrenomedullary system, and other neurobiological systems that is manifested behaviorally in many ways.³³ Among them are more immediate and exaggerated emotional reactivity to perceptions of threat or danger (including minor cues of potential threat), heightened perceptual sensitivity to threat cues, and prolonged stress responding.³⁴ Although these behavioral characteristics can be dysfunctional in benign situations by causing children to overreact to minor provocations, it is also apparent that in conditions of recurrent threat they enable organisms to quickly and competently react to potential dangers.³⁵

The caregiving system—manifested primarily in the quality of maternal care—thus mediates between the quality of the postnatal environment and the developmental adaptation of biological and behavioral stress responsivity.³⁶ In circumstances characterized by sensitive, responsive maternal care, neurobiological stress systems develop appropriately, but in conditions characterized by unresponsive and aversive care, neurobiological stress systems can become hyper-responsive in preparation for life in a dangerous world.³⁷ Of course, the quality of care is important to developing stress reactivity in other ways besides serving as a signal of environmental threat or security. Caregivers can themselves be sources of stress, such as when they are abusive or neglectful, or they can provide support for the child's coping.³⁸ Concerning the latter, there is increasing evidence from human and animal research that sensitive, responsive care can buffer the impact of stressful events and cause well-supported children to respond more competently and adaptively than children who are in less supportive care.³⁹ Young children with secure attachments to their mothers have been found, for example, to show lower levels of cortisol in response to moderately stressful events than children with insecure attachment relationships, and in these situations they also show more competent behavioral coping and emotion

33. Lupien et al., *supra* note 32, at 434.

34. *Id.* at 436; Seth D. Pollak, *Mechanisms Linking Early Experience and the Emergence of Emotions: Illustrations from the Study of Maltreated Children*, 17 *CURRENT DIRECTIONS PSYCHOL. SCI.* 370, 370–75 (2008); Seth D. Pollak et al., *P3b Reflects Maltreated Children's Reactions to Facial Displays of Emotion*, 38 *PSYCHOPHYSIOLOGY* 267, 272 (2001).

35. Gunnar et al., *supra* note 31.

36. *See supra* notes 31–35 and accompanying text. *See generally* Regina M. Sullivan, *The Neurobiology of Attachment to Nurturing and Abusive Caregivers*, 63 *HASTINGS L.J.* 1553 (2012).

37. *See supra* notes 31–35 and accompanying text. *See generally* Sullivan, *supra* note 36.

38. *See* Loman & Gunnar, *supra* note 31, at 871.

39. *Id.*

regulation.⁴⁰ These findings are not surprising in light of the limited coping capacities of young children and their reliance on external support for managing stress.⁴¹ But these findings do suggest that over time caregiver support may be an important buffer for the adverse consequences of childhood stress as well as an essential support to developing adaptive stress responsiveness in the brain and behavior.

These conclusions take on added importance in light of research documenting the potentially long-term effects of early adversity in childhood.⁴² Increasing evidence for these consequences comes from the Adverse Childhood Experiences study, based on life history information from a sample of 17,000 adults. This study has documented significant associations between the frequency of childhood adversity and adult physical and mental health problems.⁴³ “Childhood adversity” is indexed in this study from health records as reports of childhood abuse or neglect, domestic violence, parental substance abuse, mental illness, criminal incarceration of a family member, or parental separation or divorce.⁴⁴ These circumstances are important not only for their direct impact on children, but also because they are likely to undermine the quality of care that children receive. In dose-response manner, the increased incidence of indicators of childhood adversity in this study predicted a greater likelihood of physical disorders, such as heart disease, cancer, diabetes, and stroke, and mental health problems, such as depression, drug use, and suicide risk.⁴⁵ A combination of biological, behavioral, and environmental risk factors helps to account for these associations.⁴⁶

Although these research conclusions about the effects of early stress are still being clarified and confirmed, they are already influencing policy and practice in other fields. For example, the American Academy of

40. See Megan R. Gunnar & Bonny Donzella, *Social Regulation of the Cortisol Levels in Early Human Development*, 27 *PSYCHONEUROENDOCRINOLOGY* 199, 199–220 (2002). Cortisol is one of the body’s stress hormones.

41. See Ross A. Thompson & Sara Meyer, *Socialization of Emotion Regulation in the Family*, in *HANDBOOK OF EMOTION REGULATION* 249, 249–68 (James J. Gross ed., 2007).

42. See *infra* notes 43–46 and accompanying text.

43. See, e.g., Robert F. Anda et al., *The Enduring Effects of Abuse and Related Adverse Experiences in Childhood: A Convergence of Evidence from Neurobiology and Epidemiology*, 256 *EUR. ARCHIVES PSYCHIATRY & CLINICAL NEUROSCI.* 174, 174–83 (2006); Vincent J. Felitti et al., *Relationship of Childhood Abuse and Household Dysfunction to Many of the Leading Causes of Death in Adults: The Adverse Childhood Experiences (ACE) Study*, 14 *AM. J. PREVENTIVE MED.* 245, 245–56 (1998).

44. See Anda et al., *supra* note 43, at 176; Felitti et al., *supra* note 43, at 248.

45. See Anda et al., *supra* note 43, at 180–83; Felitti et al., *supra* note 43, at 248–56.

46. Anda and his colleagues argue that the long-term effects of early childhood adversity are consistent with the research on the effects of stress neurobiology reviewed above, although the ACE study is weakest in identifying the mediating processes linking early childhood adversity and later adult outcomes. See Anda et al., *supra* note 43, at 180–83.

Pediatrics recently adopted a policy statement urging the involvement of pediatric practitioners in reducing childhood exposure to adversity and young children's exposure to toxic stress.⁴⁷ The statement defined toxic stress as "the excessive or prolonged activation of the physiologic stress response systems in the absence of the buffering protection afforded by stable, responsive relationships."⁴⁸ Toxic stress is thus defined by the chronicity, severity, and unpredictability of stressful experiences coupled with the absence of buffering influences by relational partners. The statement urges pediatricians to respond proactively to reduce children's exposure to toxic stress through parental education, developmental screening, and community advocacy. Pediatricians are urged to reduce the consequences of exposure for children, including "limited educational achievement, diminished economic productivity, criminality, and disparities in health."⁴⁹ These recommendations reflect the seriousness with which the effects of early childhood adversity and its consequences are regarded within the medical community.

B. IMPLICATIONS FOR LEGAL POLICY AND PRACTICE

The convergence of neurobiological and behavioral research concerning the enduring importance of child-caregiver relationships for behavioral and brain development raises several policy issues. These issues are not primarily focused on traditional concerns over how aversive early experiences may mitigate criminal responsibility or decisional competence, even though criminal defendants sometimes raise this issue. The current state of research in developmental neuroscience does not really permit confident conclusions concerning diminished adult responsibility based on the neurobiological consequences of early experience.⁵⁰ Instead, these research findings address two other issues related to child welfare: intergenerational risk transmission and biomarkers of risk.

47. Am. Acad. of Pediatrics, *Early Childhood Adversity, Toxic Stress, and the Role of the Pediatrician: Translating Developmental Science into Lifelong Health*, 129 PEDIATRICS e224, e224-31 (2012).

48. *Id.* at e225. It is important to emphasize that it is not just the severity of stressful experiences that characterizes certain stressors as toxic to a child, but also the absence of relational support that might buffer the impact of these stressful experiences. One implication, consistent with the findings of research on social support, is that individuals are more capable of adaptive coping in the context of relational support. See Ross A. Thompson et al., *Social Support and Developmental Psychopathology*, in DEVELOPMENTAL PSYCHOPATHOLOGY—VOL. III: RISK, DISORDER, AND ADAPTATION 1, 1-37 (Dante Cicchetti & Donald J. Cohen eds., 2d ed. 2006).

49. Am. Acad. of Pediatrics, *supra* note 47, at e228.

50. See generally MICHAEL S. GAZZANIGA, WHO'S IN CHARGE? FREE WILL AND THE SCIENCE OF THE BRAIN (2011); ROYAL SOC'Y, BRAIN WAVES MODULE 4: NEUROSCIENCE AND THE LAW (2011); *infra* notes 60-61 and accompanying text.

1. *Intergenerational Risk Transmission*

If early childhood adversity, particularly coming from the caregiving system, contributes to the development of heightened stress reactivity in children that can lead to impaired social functioning and long-term problems of physical and mental health, it is possible to see how inadequate caregiving becomes replicated in the next generation when these children become parents.⁵¹ This research suggests that the intergenerational transmission of inadequate caregiving can occur biologically as well as socially.⁵² There are other reasons why this is true. Considerable research documents the dangers of fetal malnutrition, exposure to hazardous drugs, and environmental teratogens, including many substances that constitute neurotoxins to the developing brain.⁵³ Although these prenatal and perinatal risks are widespread, exposure is particularly likely in conditions of socioeconomic disadvantage characterized by food insecurity, limited financial resources, and inadequate prenatal care.⁵⁴ Because of this, fetal exposure to neurotoxins is especially likely to occur in conditions of caregiving stress that may further contribute to impaired biological stress responding and threats to physical and mental health in children.⁵⁵ Viewed in this light, intergenerational influences begin prenatally.

Moreover, there is evidence that intergenerational influences may also occur through the effects of the quality of care on gene expression in offspring—consistent with the science of epigenetics.⁵⁶ Comparative research with rats has documented how variations in maternal care affect DNA methylation in such a manner that genes are chemically “turned on” or “turned off” as the result of caregiving experience, yielding heritable behavioral differences in offspring that are consistent with altered gene

51. The “intergenerational transmission” of parenting has been a topic of longstanding interest in developmental science. See, e.g., Jay Belsky et al., *The Intergenerational Transmission of Parenting: Introduction to the Special Section*, 45 *DEVELOPMENTAL PSYCHOL.* 1201, 1201–03 (2009).

52. It is important to note that a biological basis for intergenerational risk transmission is genetic, with parents and offspring sharing genes associated with characteristics like impulsivity, aggressiveness, and other behavioral tendencies associated with poor parenting. However, as noted in this Section, the science of epigenetics underscores that even hereditary characteristics are environmentally influenced, and thus both genetic transmission and environmental stresses and support in the parent-child relationships are likely to work together in shaping the behavioral characteristics of children. See *infra* notes 56–59 and accompanying text.

53. See generally Ctr. on the Developing Child, *Early Exposure to Toxic Substances Damages Brain Architecture* (Harvard Univ., Ctr. on the Developing Child, Working Paper No. 4, 2005), available at http://developingchild.harvard.edu/index.php/resources/reports_and_working_papers/working_papers/wp4.

54. See generally *id.*

55. See Arie Kaffman & Michael J. Meaney, *Neurodevelopmental Sequelae of Postnatal Maternal Care in Rodents: Clinical and Research Implications of Molecular Insights*, 48 *J. CHILD PSYCHOL. & PSYCHIATRY* 224, 224–44 (2007); Meaney, *supra* note 5, at 41–79 (2010).

56. See Kaffman & Meaney, *supra* note 55, at 224–44; Meaney, *supra* note 5, at 41–79.

expression.⁵⁷ This research program provides important evidence of the pervasiveness of gene-environment interaction at a chemical level affecting gene expression, and it is significant that the environmental variations affecting gene expression in these studies are associated with the quality of maternal care.⁵⁸ These studies have primarily been conducted with animals where the relevant chemical processes can be documented, but other studies with humans yield an empirical picture that is consistent with this epigenetic account.⁵⁹

It is important not to misinterpret the legal implications of these intergenerational processes by viewing them within a traditional framework of biological determinism. It would be inappropriate, for example, to conclude from this research that early adversity creates offspring with “damaged brains” that lead to enduring and irreversible deficits in behavioral functioning. The knowledge of gene-environment interaction throughout development and the plasticity of brain and behavior cast doubt upon such a rigid view of the influence of early experiences.⁶⁰ Indeed, the research evidence on the intergenerational transmission of risk finds that early adversity is not deterministic. Research on whether children who were abused grow up to become abusive parents, for example, finds that the majority do not, even though a history of abuse increases the risk of personal and parental difficulty.⁶¹ Early adversity poses significant challenges to healthy brain and behavioral development, but it does not make developmental dysfunction inevitable.

Instead, the most important legal implications concern the promotion of child welfare. If early experiences of care contribute to biological and behavioral trajectories of development that can become manifested in differentially adaptive patterns of physical, emotional, and social functioning as children mature, strengthening policies that contribute to the prevention and remediation of conditions of early adversity is warranted.⁶² These would include support for programs that focus on the early identification of families at risk, especially at the time that childbearing occurs, and the provision of supportive services to strengthen the quality of care such as home visitation programs, nutritional assistance, parental support, access to high quality child care,

57. See Elysia Poggi Davis et al., *Prenatal Maternal Stress Programs Infant Stress Regulation*, 52 J. CHILD PSYCHOL. & PSYCHIATRY 119, 119–29 (2011); Curt A. Sandman et al., *Prescient Human Fetuses Thrive*, 23 PSYCHOL. SCI. 93, 93–100 (2012).

58. See Davis et al., *supra* note 57, at 119–29; Sandman et al., *supra* note 57, at 93–100; see also Loman & Gunnar, *supra* note 31, at 871.

59. See *supra* notes 31–41 and accompanying text; see also Kaffman & Meaney, *supra* note 55.

60. See *infra* notes 83–86 and accompanying text.

61. See *infra* notes 101–103 and accompanying text.

62. See Lois A. Weithorn, *Developmental Neuroscience, Children's Relationships with Primary Caregivers, and Child Protection Policy Reform*, 63 HASTINGS L.J. 1487, 1537–41 (2012).

and other forms of “preventive family preservation.”⁶³ These would also include interventions for families adjudicated for child neglect or abuse that extend beyond parenting classes to include services to mitigate the effects of family adversity on children—such as well-designed early education programs that are supplemented by social-emotional support, and targeted programs to address the specific causes of parental inadequacy.⁶⁴ Such efforts are especially warranted in the context of scientific research on the plasticity of brain development.⁶⁵

2. *Biomarkers of Risk*

Another issue raised by the convergence of neurobiological and behavioral research on child-caregiver relationships concerns the identification of “biomarkers” of early risk for children. A biomarker is a measurable characteristic of an individual that indicates pathogenic processes or risk.⁶⁶ By indexing biological signs of vulnerability, biomarkers provide an individualized indicator of a child’s susceptibility to harm. When taken together with identified sources of environmental stress and support, biomarkers in early childhood could contribute to individualized estimates of vulnerability to difficulty that can potentially be used in the context of child welfare efforts. Biomarkers of this kind are provoking considerable discussion among developmental scientists,⁶⁷ although much research remains to validate such indicators and refine their use in field settings.

Candidate biomarkers come from various areas of developmental science. Children with certain gene alleles, such as the DRD4 seven-repeat polymorphism, which is associated with conduct problems, or the monoamine oxidase A gene, which is associated with aggression and antisocial behavior, could be regarded as genetically more vulnerable to psychosocial difficulties, especially in the context of environmental adversity.⁶⁸ Another kind of biomarker derives from the research,

63. Ross A. Thompson & Mary Fran Flood, *Toward a Child-Oriented Child Protection System*, in *TOWARD A CHILD-CENTERED, NEIGHBORHOOD-BASED CHILD PROTECTION SYSTEM: A REPORT OF THE CONSORTIUM ON CHILDREN, FAMILIES, AND THE LAW* 155, 155–94 (Gary B. Melton et al. eds., 2002).

64. *Id.*

65. See *infra* notes 83–86 and accompanying text.

66. Biomarkers are, of course, widely used in medicine. For example, the presence of antibodies in a blood sample can index infection, and the presence of a genetic risk factor can indicate a particular disease. Biomarkers are also used in environmental health sciences to index changes in health status in relation to environmental risks, such as toxins in air or water. Only recently have biomarkers been proposed for use in studies of psychological risk factors. See generally *BIOMARKERS: IN MEDICINE, DRUG DISCOVERY, AND ENVIRONMENTAL HEALTH* (V.S. Vaidya & J.V. Bonventre eds., 2010).

67. See, e.g., *Historical Context and the Need for Innovation*, CENTER ON THE DEVELOPING CHILD, http://developingchild.harvard.edu/topics/innovation/historical_context_and_the_need_for_innovation (last visited July 1, 2012).

68. See Jay Belsky & Michael Pluess, *Beyond Diathesis Stress: Differential Susceptibility to Environmental Influences*, 135 *PSYCHOL. BULL.* 885, 885–908 (2009).

discussed above, about the effects of early adversity on biological stress reactivity.⁶⁹ Heightened cortisol reactivity under controlled conditions of stress and deviations from normal diurnal patterns of cortisol activity each constitute biological markers of vulnerability based on stress hormones.⁷⁰ Concerning diurnal patterns of cortisol, it has long been known that, under typical conditions, humans normally have elevated levels of cortisol in the morning that gradually decline over the course of the day.⁷¹ Abnormally low morning cortisol levels, however, have been documented in children in stressful circumstances, such as those who are maltreated or who live in neglectful orphanage care, and seem to be a downregulation of a chronically active stress system.⁷² This abnormal diurnal pattern of cortisol activity may also be a biological marker of stress.

A third kind of biomarker consists of the constellation of physical health indicators that are sensitive to stress: blood pressure, urinary levels of stress hormones, catecholamines, and other measures.⁷³ They collectively index “allostatic load” because they reflect the demands on the body’s coping capacities in response to chronic stress.⁷⁴ Allostatic load is thus a multidimensional biological indicator of the extent to which stressful experiences are taking a physical toll on the body.

Research on biomarkers could potentially provide individualized, biologically based indicators of vulnerability to environmental adversity that can be used to advance child welfare, but we are years away from their use in applied settings. One problem is that many candidate biomarkers are multi-determined, making it unclear how reliable they are as indicators of vulnerability to stress in non-experimental contexts.⁷⁵ Another problem is that some biomarkers index biological systems that change rapidly with development and require an age-calibrated means of interpreting their meaning.⁷⁶ A third problem is that, although some biomarkers can be readily derived in laboratory settings, applications to

69. See *supra* notes 31–41 and accompanying text.

70. Lupien et al., *supra* note 32, at 436–37.

71. See Gunnar & Donzella, *supra* note 40, at 201–02; see also Megan R. Gunnar & Delia M. Vazquez, *Stress Neurobiology and Developmental Psychopathology*, in *DEVELOPMENTAL PSYCHOPATHOLOGY—VOL. II: DEVELOPMENTAL NEUROSCIENCE* 533, 533–77 (Dante Cicchetti & Donald J. Cohen eds., 2006).

72. See Gunnar & Donzella, *supra* note 40, at 211–15. See generally Megan R. Gunnar & Delia M. Vazquez, *Low Cortisol and a Flattening of Expected Daytime Rhythm: Potential Indices of Risk in Human Development*, 13 *DEV. & PSYCHOPATHOLOGY* 515, 515–34 (2001).

73. Bruce S. McEwen, *Stress, Adaptation, and Disease: Allostasis and Allostatic Load*, 840 *ANNALS N.Y. ACAD. SCI.* 33, 33–41 (1998).

74. *Id.*

75. For example, there are individual differences in the regularity of diurnal cortisol patterns that can also be affected by sleep disturbances. See Gunnar & Vazquez, *supra* note 72, at 515–34.

76. There are developmental changes in the diurnal cortisol pattern in the early years of life that require consideration in the interpretation of cortisol assays. See Gunnar & Donzella, *supra* note 40, at 205–06. See generally Gunnar & Vazquez, *supra* note 72, at 515–34.

field settings may be limited by cost or invasiveness.⁷⁷ Taken together, however, efforts to identify children at risk owing to family adversity for preventive or therapeutic interventions would be aided by measures that biologically index vulnerability in a manner that reflects each child's unique characteristics and developmental history.

II. COMPLEXITY AND PLASTICITY IN NEUROBIOLOGICAL AND BEHAVIORAL DEVELOPMENT

This Article has thus far highlighted the importance of convergence in the conclusions of developmental neuroscience and behavioral research when applying neuroscience to the law. The convergence between multiple perspectives to development and behavior derived from biological and behavioral studies—including human and animal research—adds to confidence in their common conclusions. By contrast, when the findings of neuroscience are interpreted independently of relevant behavioral research, or when the conclusions are markedly different from what behavioral studies show, there is more reason for interpretive caution.

This Article has also highlighted the complexity of the interactions between biological processes and experience, and the multiple brain systems incorporated into complex behavior. The discussion of children's "stress," for example, focused on two of the several neurobiological systems affecting stress responding, with some systems developing in a manner that incorporates experience with stress as well as the support for coping provided by the caregiving system. Each is manifested in behavior in multifaceted ways.⁷⁸ Complex interactions between biology and experience are also likely to characterize other developmental processes relevant to law and neuroscience. The growth of "responsibility," for example, includes growth in working memory, perspective taking, cognitive flexibility, social cognition, recursive thinking, and many other behavioral processes that develop according to different timetables and are based in different areas of the brain.⁷⁹ Neurobiologically, these

77. Some biomarkers can be readily indexed via urine or salivary samples, although assaying can be expensive; others require blood samples, which are invasive and frightening to young children. The cost of genotyping has declined in recent years but remains expensive, especially for the study of large samples.

78. See *supra* notes 31–41 and accompanying text. To add further complexity to the concept of stress, researchers recognize that experience with manageable levels of stress is not only helpful but essential to healthy neurobiological and behavioral development, with this "good stress" distinguished from "toxic stress" by its lower severity, chronicity, uncontrollability, and the availability of social support for effective coping. See Ctr. on the Developing Child, *Excessive Stress Disrupts the Architecture of the Developing Brain* (Harvard Univ., Ctr. on the Developing Child, Working Paper No. 3, 2005), available at http://developingchild.harvard.edu/index.php/resources/reports_and_working_papers/working_papers/wp3/.

79. The growth of moral responsibility is an extended developmental process involving these and other constituents. For a general overview, consult *HANDBOOK OF MORAL DEVELOPMENT* (Melanie Killen & Judith G. Smetana eds., 2006).

developing capacities are likely to involve widely distributed brain systems that are organized according to complex neural networks.⁸⁰ Both brain maturation and experience interact in the development of these cognitive and social capacities over time.⁸¹

Consequently, complex interactions between brain maturation and experience are likely to be typical, not exceptional, in the development of competencies relevant to legal policy and practice. The assumption that brain maturation alone provides a foundation for behavioral development overlooks this network of mutual influences between brain and experience. The expectation that complex psychological capacities can be found in a single, localized brain area (or a single gene) overlooks how genes typically interact with other genes and the brain enlists multiple regions into complex functioning.⁸²

The implications of this principle for understanding human behavior are important. Neuroscience and molecular genetics have contributed to the view that human capacities and dispositions are “hard wired” into the brain and DNA, and that positive or negative influences from brain chemistry or genetic characteristics determine human behavior. When researchers discover alterations in the brain chemistry of criminal offenders or that incarcerated individuals are high in a genetic predisposition to sensation-seeking, it sometimes leads to questions of whether those individuals are truly responsible for their conduct. But such questions are simplistic because of the complexities of human behavior discussed in this Section. First, complex behavior is based on multiple brain processes and multiple genetic influences acting in concert, which is why identified differences in brain chemistry or genes can increase the odds of certain behavioral tendencies but rarely make them inevitable because of the widely-distributed systems that are involved. Second, these neurobiological and genetic influences interact with the environment, which is why the odds of criminal offending are much higher for individuals who have been traumatized, chronically stressed, or subject to the ravages of poverty. Brain processes alone do not tell a complete story of how behavioral tendencies take shape. Third, this brain-experience and gene-environment interaction occurs throughout development, which means that brain chemistry and genetic

80. Simpler sensory, memory, attention, and language processes each enlist multiple brain regions specialized for specific components of these behavioral functions; the same principle is likely to prove even more apparent for psychologically complex functions. *See generally* MARK H. JOHNSON, DEVELOPMENTAL COGNITIVE NEUROSCIENCE (3d ed. 2011); HANDBOOK OF DEVELOPMENTAL COGNITIVE NEUROSCIENCE (Charles A. Nelson & Monica Luciana eds., 2d ed. 2008).

81. *See generally* STILES, *supra* note 10.

82. The study of gene-gene interactions, or epistasis, is a topic of vigorous research interest, especially by researchers concerned with human disease prevention. *See* Heather J. Cordell, *Epistasis: What It Means, What It Doesn't Mean, and Statistical Methods to Detect It in Humans*, 11 HUM. MOLECULAR GENETICS 2463, 2463–68 (2002).

influences also interact with multiple kinds of experiences over time. Indeed, the brain chemistry found to characterize individuals of concern may be the result of experiences of abuse and trauma that foreshadow criminal conduct, rather than the sole or primary cause of that conduct. Taken together, the complex interactions between brain and experience highlighted by this principle counsel caution about drawing simple, direct connections between specific brain areas or single genes and complex behavior.

A. NEUROPLASTICITY AND BEHAVIORAL ADAPTATION

The plasticity of the developing brain and behavior is another important consideration in understanding how each is affected by experience. “Plasticity” refers to the capacity of organisms to change based on experience.⁸³ The brain’s neuroplasticity is considerable early in life and gradually declines with increasing age and the consolidation of neural networks. But the brain always retains some adaptive plasticity that enables people to learn new things even at advanced age.⁸⁴ The brain’s continuing neuroplasticity enables us to learn, grow, and adjust to new experiences, and this is one reason for the human capacity for behavioral adaptation throughout life.

Human neuroplasticity helps to account for the efficacy of preventive and therapeutic interventions.⁸⁵ Even when developing neurobiology has been altered by early adversity, for example, changing those circumstances has the potential, over time, to result in further changes to neurobiological functioning that yield more typical and adaptive levels of stress responding.⁸⁶

One illustration of this is relevant to legal policy. Children in foster care placements have been found to exhibit an abnormal diurnal pattern of cortisol responding (as was discussed in Subpart I.B as a potential biomarker of stress).⁸⁷ Specifically, they show lower morning cortisol levels and little cortisol decline from morning to evening—a pattern that has also been observed in children who are maltreated, in orphanage care, or in other stressful circumstances.⁸⁸ However, placement programs that seek to reduce the stresses associated with foster care for children have been shown to mitigate this atypical pattern of stress responding.

83. Bryan Kolb et al., *Brain Plasticity and Behavior*, 12 *CURRENT DIRECTIONS PSYCHOL. SCI.* 1, 1 (2003).

84. Joan Stiles, *Neural Plasticity and Cognitive Development*, 18 *DEVELOPMENTAL NEUROPSYCHOL.* 237, 237–72 (2000).

85. See Kolb, *supra* note 83, at 1–5.

86. Gunnar et al., *supra* note 31, at 666–67.

87. See *id.* at 665; see also Gunnar & Vazquez, *supra* note 72, at 515–34.

88. See Gunnar & Vazquez, *supra* note 71, at 515–34; see also, Gunnar & Donzella, *supra* note 40, at 211–15.

In one study, three- to six-year-old children were randomly assigned to an intervention program designed to ease their transition to new foster care placements. The children's diurnal cortisol patterns, when compared to those of children assigned to regular foster care, increasingly resembled the normal pattern showed by children living in more typical family circumstances.⁸⁹ The same intervention program also has been found to increase secure attachments to caregivers⁹⁰ and to improve permanent placement success rates.⁹¹ In short, this intervention was successful in altering stress neurobiology to more typical patterns and also contributed to improved social-emotional functioning in children.

It is important to note that the intervention was neither simple nor inexpensive. Foster children received individualized treatment with child therapists, weekly therapeutic playgroup sessions, and other services to improve their social-emotional functioning as well as their school readiness.⁹² Foster parents completed intensive training prior to the children's placement, and they continued to receive support and supervision in daily phone contacts, weekly group meetings, and on-call assistance.⁹³ Special assistance was also provided to the child's "permanency placement resources" (for example, biological or adoptive parents) to establish consistency with the care provided by foster parents and to ease transitional adjustments.⁹⁴ The neurobiological and behavioral effects of the intervention were not immediate but gradually accrued over the typical six- to nine-month period of the intervention program.⁹⁵ Thus the time and effort required to change previously established behavioral and neurobiological patterns of responding should not be underestimated. At the same time, however, this program illustrates the potential for these patterns to be changed in a population of children facing serious difficulty and is consistent with the concept of behavioral and brain plasticity. This program is one of a growing number of early intervention efforts targeting neurobiological functioning and behavioral competence in at-risk children to illustrate that (a) the continuing plasticity of brain and behavior can be enlisted to improve children's functioning, and that

89. Philip A. Fisher et al., *Mitigating HPA Axis Dysregulation Associated with Placement Changes in Foster Care*, 36 *PSYCHONEUROENDOCRINOLOGY* 531, 531-39 (2011) [hereinafter Fisher et al., *Mitigating HPA*]; see also Philip A. Fisher et al., *Effects of a Therapeutic Intervention for Foster Preschoolers on Diurnal Cortisol Activity*, 32 *PSYCHONEUROENDOCRINOLOGY* 892, 892-905 (2007) [hereinafter Fisher et al., *Effects*].

90. Philip A. Fisher & Hyoun K. Kim, *Intervention Effects on Foster Preschoolers' Attachment-Related Behaviors from a Randomized Trial*, 8 *PREVENTION SCI.* 161, 165-67 (2007).

91. Philip A. Fisher et al., *The Early Intervention Foster Care Program: Permanent Placement Outcomes from a Randomized Trial*, 10 *CHILD MALTREATMENT* 61, 66-68 (2005).

92. Fisher et al., *Effects*, *supra* note 89, at 894.

93. *Id.*

94. Fisher et al., *Mitigating HPA*, *supra* note 89, at 534.

95. Fisher et al., *Effects*, *supra* note 89, at 898.

(b) such efforts, especially for children experiencing long-term adversity, often require sustained attention.⁹⁶

Neuroplasticity is thus reflected in the efficacy of targeted intervention programs. It is also reflected in the changes that can occur in behavior without intervention, but rather with time and further experience—even in behavioral processes that we expect to be consolidated by early experience. These behavioral changes reflect the human capacity to adjust previously established ways of thinking or acting in response to new experiences, and they are important to understanding the flexibility of brain and behavior. This can be demonstrated with two illustrations of this capacity.

First, although psychological theory has traditionally held that the development of secure or insecure parent-child attachments early in life creates an enduring disposition toward other relationships and partners, developmental research shows that the security of attachment often changes during the early years.⁹⁷ Some children who were initially securely attached to their caregivers later become insecure, while some initially insecure children become securely attached over time.⁹⁸ These changes do not occur randomly, but rather in response to changes that occur in the family that can cause a reworking of familiar patterns of parent-child interaction, such as marital separation or a significant change in parental work obligations.⁹⁹ Developmental scientists describe such changes as examples of “lawful discontinuity.”¹⁰⁰ Although a secure attachment to a caregiver is an important cornerstone of healthy psychological development, there is no guarantee that, once it is developed, that sense of security will necessarily endure. It must continue to be sustained by sensitive, supportive adult care. Likewise, an initially insecure attachment can be changed when caregivers become more reliable sources of sensitive, responsive care.

Second, despite common expectations that abused children will themselves become abusive parents owing to the psychological effects of their trauma, research shows that only about thirty percent of physically abused children become abusive parents.¹⁰¹ This is not an insignificant

96. See, e.g., Dante Cicchetti & Megan R. Gunnar, *Integrating Biological Measures into the Design and Evaluation of Preventive Interventions*, 20 DEV. & PSYCHOPATHOLOGY 737, 737–43 (2008).

97. Ross A. Thompson, *The Legacy of Early Attachments*, 71 CHILD DEV. 145, 145 (2000).

98. Ross A. Thompson, *The Development of the Person: Social Understanding, Relationships, Self, Conscience*, in HANDBOOK OF CHILD PSYCHOLOGY—VOL. III: SOCIAL, EMOTIONAL, AND PERSONALITY DEVELOPMENT 24, 57–60 (Nancy Eisenberg ed., 6th ed. 2006).

99. *Id.*

100. Thompson, *supra* note 97, at 151; Mark J. Van Ryzin et al., *Attachment Discontinuity in a High-Risk Sample*, 13 ATTACHMENT & HUM. DEV. 381, 382 (2011).

101. Joan Kaufman & Edward Zigler, *Do Abused Children Become Abusive Parents?*, 57 AM. J. ORTHOPSYCHIATRY 186, 190 (1987). For an updated review of research that still unfortunately relies primarily on retrospective self-reports from abusive parents, see Penelope K. Trickett & Sonya

rate; it causes us to recognize that abused children face many difficulties as they grow up and that their emotional challenges sometimes affect the relationships they establish with partners and their own offspring.¹⁰² Nevertheless, strong arguments about intergenerational processes affecting risk transmission (such as those discussed above) must be interpreted in the context of the influences that can alter these intergenerational effects to create better outcomes. Research has shown that supportive social networks, a strong relationship with a partner, the incidence of stressful life events, and other factors besides the parent's own developmental past also affect the risk of becoming an abusive parent.¹⁰³ This too illustrates lawful discontinuity arising from neuroplasticity and the child's capacity for behavioral adaptation to new circumstances.

The plasticity of brain and behavior is important because it balances an appreciation of the potentially enduring effects of early influences with an awareness of the continuing flexibility of developing systems. With respect to public policy, it suggests that the neurobiological consequences of stress and adversity are not necessarily enduring and that creating opportunities for early prevention and treatment is warranted. An emphasis on beginning early is important for several reasons. First, because neuroplasticity is greatest early in life and declines gradually with increasing age, the early years offer the most promising opportunities for effective intervention. For example, the neural networks underlying behavioral dispositions, relational expectations, self-referential belief systems, stress responding, and other psychological processes have become more consolidated in a teenager with a ten year career in the foster care system than a three-year-old in his or her first foster care placement.¹⁰⁴

Second, with age it thus becomes biologically and economically more costly to improve developmental outcomes for children in difficulty. Although well-designed intervention efforts have the potential of being effective with sufficient time and intensity, they are likely to require greater time, effort, and expense when impacting neural networks and behavior that have become well-established over time. This does not mean

Negriff, *Child Maltreatment and Social Relationships*, in *SOCIAL DEVELOPMENT: RELATIONSHIPS IN INFANCY, CHILDHOOD, AND ADOLESCENCE* 403, 416–21 (Marion K. Underwood & Lisa H. Rosen eds., 2011).

102. Dante Cicchetti & Sheree L. Toth, *A Developmental Psychopathology Perspective on Child Abuse and Neglect*, 34 *J. AM. ACAD. CHILD & ADOLESCENT PSYCHIATRY* 541, 541–65 (1995).

103. Kaufman & Zigler, *supra* note 101, at 188–90; Trickett & Negriff, *supra* note 101, at 416–21. In part because of these findings, researchers are increasingly focusing on the factors mediating the intergenerational consistency in child maltreatment rather than overall rates at which maltreatment occurs in parent and child generations.

104. This conclusion derives from the increased consolidation of neural networks and the decreased plasticity of brain development in older compared to younger individuals, but it applies this conclusion to the relative effects of each child's experience in the foster care system.

that effective intervention is easy even when begun early. Young children in difficulty often face multiple challenges to healthy development that derive from family problems, risky neighborhoods, poor schools, and communities drained of resources. Well-designed and multifaceted early intervention programs can, however, identify opportunities for change in these conditions before these circumstances begin to create a developmental cascade of disadvantage leading to serious emotional and behavioral problems in children.

Consequently, applications of developmental neuroscience to legal policy and practice must take seriously the importance of brain plasticity and its developmentally changing implications for children's behavioral adaptation to new opportunities. Early experiences are influential but not determinative, and this understanding has led to new attention in science and practice to "neurorehabilitative" interventions informed by developmental neuroscience.¹⁰⁵

B. IMPLICATIONS FOR LEGAL POLICY AND PRACTICE

One reason why attention to neuroplasticity is important is that early childhood program evaluation research is currently yielding a clearer picture of the evidence-based intervention strategies that are most likely to be successful in improving outcomes for at-risk children.¹⁰⁶ Home visitation programs, for example, have been shown to be successful in providing developmental guidance and parenting support to vulnerable families beginning at the time of a child's birth, especially when home visitors are well trained to engage families and address specific parenting problems.¹⁰⁷ Tailoring intensive services for families adjudicated for child neglect or abuse to their specific parenting problems—for example, parental substance abuse, maternal depression, or domestic violence—is much more effective than generic abuse-prevention interventions.¹⁰⁸ Early education programs for children from socioeconomically disadvantaged families must be designed differently from those serving typical children because of the different forms of assistance they require, including attention to health and dental screening, nutrition, and social support, and because these programs

105. See, e.g., Richard L. Bryck & Philip A. Fisher, *Training the Brain: Practical Applications of Neural Plasticity from the Intersection of Cognitive Neuroscience, Developmental Psychology, and Prevention Science*, 67 *AM. PSYCHOL.* 87, 87–100 (2012).

106. *CTR. ON THE DEVELOPING CHILD, A SCIENCE-BASED FRAMEWORK FOR EARLY CHILDHOOD POLICY* (2007) [hereinafter *SCIENCE-BASED FRAMEWORK*].

107. David L. Olds et al., *Programs for Parents of Infants and Toddlers: Recent Evidence from Randomized Trials*, 48 *J. CHILD PSYCHOL. & PSYCHIATRY* 355, 362–83 (2007). See generally *SCIENCE-BASED FRAMEWORK*, *supra* note 106.

108. See, e.g., Mark Chaffin et al., *Parent-Child Interaction Therapy with Physically Abusive Parents: Efficacy for Reducing Future Abuse*, 72 *J. CONSULTING & CLINICAL PSYCHOL.* 500, 500–10 (2004). See generally *SCIENCE-BASED FRAMEWORK*, *supra* note 106.

must also better connect families to community services and supports. Taken together, the scientific advances in developmental neuroscience and in gene-environment interaction have been accompanied by advances in the science of early childhood program evaluation to yield a better evidence-based understanding of effective intervention strategies than has previously existed. We can exploit neuroplasticity because we more fully understand what to do to improve children's welfare.

These findings are relevant to legal policy and practice to the extent that one of the responsibilities of the legal system is to advance child welfare. Certainly for several of the issues profiled here, including the experience of children in foster care and the treatment of families adjudicated for child abuse or neglect, child protection concerns are prominent in legal decisions and their consequences for children. In these and related areas of family law, recognizing the importance of brain plasticity and both brain-experience and gene-environment interactions mandates attention to evidence-based interventions that can improve the odds of promoting healthy development. More broadly, as legal policy and practice contribute to the development of public policy, advances in developmental neuroscience can contribute to policies that support preventive strategies to help ensure that fewer children are growing up in aversive family environments. This includes scientifically informed policies that both strengthen family functioning and parental competence and directly support children's healthy development.

CONCLUSION

The neuroscience that is changing our understanding of human behavior is exciting, promising, and daunting. Brain research offers fascinating insights into human behavior and development, but it is a young and technically complex science with conclusions that can easily be misunderstood. One research group found that when college students read a scientific report that included a brain-imaging picture, they judged the credibility of the article's conclusions higher by comparison with students who read the same article without the brain image.¹⁰⁹ Importantly, the evidence that was presented did not justify the conclusions in the report. This finding is consistent with what some have called "neuro-realism,"¹¹⁰ the tendency of people to uncritically view the results of brain research as "visual proof" of conventional conclusions about human functioning despite the enormous complexities of neuroscience research. Neuroscience tends to be approached uncritically because most people are unfamiliar with the technical challenges in interpreting a functional

109. David P. McCabe & Alan D. Castel, *Seeing Is Believing: The Effect of Brain Images on Judgments of Scientific Reasoning*, 107 COGNITION 343, 343-52 (2008).

110. Eric Racine et al., *fMRI in the Public Eye*, 6 NATURE REV. NEUROSCI. 159, 160 (2005).

Magnetic Resonance Imaging or electroencephalograms and because the materialism of brain imaging seems to offer more substantive evidence than the behavioral responses of children or adults in most psychological research.

This Article has proposed that misinterpretation of developmental neuroscience also arises because of the enlistment of traditional interpretive frameworks that contribute to misleading conclusions about the findings of brain research. These traditional frameworks become default interpretive frames until updated and more appropriate views—such as the complex and continuous interaction of brain maturation and experience, the emphasis from epigenetics on gene-environment interaction, and the importance of brain plasticity—become incorporated into thinking about human behavior. When this occurs, more confident and responsible applications of developmental neuroscience to legal policy and practice can emerge. Such applications are likely to require the collaboration of scientists and legal scholars, as reflected in the Symposium that is the basis for this special issue.

In this Article, I have offered several general principles concerning the applications of developmental neuroscience to the law that can help guide careful and thoughtful analysis. First is the principle that the most confident applications of developmental neuroscience to policy and practice are when the conclusions of neuroscience are consistent with those of behavioral research. This principle helps to ensure the most responsible applications of neuroscience through the convergence of brain-based research with findings derived from behavioral research. The convergence in conclusions strengthens confidence in legal applications, even though those applications require a hard-nosed analysis of what the behavioral and neuroscientific research actually shows. This is illustrated by the neuroscience and behavioral research on child-caregiver relationships that leads to shared conclusions about the importance of early experiences, the significance of the caregiving system for buffering stress, and the potentially long-term consequences of growing up in aversive caregiving conditions. Such research has significant implications for legal policy and practice concerning child welfare, especially with respect to understanding intergenerational processes of risk transmission and the future potential of using biomarkers of early vulnerability to risk for children. Both of these applications are relevant to enlisting legal policy to advance child welfare, especially the well-being of children from disadvantaged circumstances.

The second principle is that complex interactions between brain maturation and experience are likely to be typical, not exceptional, in the development of competencies relevant to legal policy and practice. This principle underscores the complex, mutual influences of developing brain systems and experience in shaping human behavior and growth. It

emphasizes that behavior is not simply a derivative of brain maturation or brain chemistry, but that brain processes are also shaped by experiences over time, and that multiple neural systems are involved in complex behavior. This is especially true of the development of complex behavior of considerable interest to legal analysis, such as the growth of “responsibility” and “competence.”

Finally, applications of developmental neuroscience to legal policy and practice must take seriously the importance of brain plasticity and its developmentally changing implications for children’s behavioral adaptation to new opportunities. Neuroplasticity and the behavioral adaptation it enables are what make humans uniquely capable of learning and changing in response to experience. This principle underscores the continuing significance of the interaction of brain and experience and its implications for interventions to improve developmental outcomes—especially those that begin early. The implications of this principle for legal policy and practice highlight the value of scientifically informed policies in child protection and of broader preventive efforts to reduce the numbers of children growing up in aversive family environments.

The effort to bridge concepts and ideas from developmental neuroscience to domains of practice, including the law, is challenging but important and worthwhile. In resisting the most self-evident, intuitive, and sometimes incorrect applications of neuroscience to complex domains of legal analysis, careful bridge-builders are likely to experience both the frustration of exciting integrations thwarted by second thoughts and the rewards of reflection, analysis, and second-order questioning.