The Science of Infant Brain Development: Insights on the Nature/Nurture Debate

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Introduction

My purpose in this paper is to raise awareness of recent developments in the field of neurobiology that have implications for the development of children; it is not to offer detailed recommendations for policy. However, since this research sheds light on the importance of an infant's early environment in laying the foundation of his or her physical, intellectual, and emotional development, some philosophical and practical implications should become obvious. Although only a brief overview of this subject is offered, my hope is that the information will be compelling enough to leaders and policy makers to instill a desire to pursue this study for insights into possible implementation of specific policies and practices. Several of the references cited at the end of the paper contain policy suggestions (*see* especially National Research Council; Shore).

The Nature/Nurture Debate

For decades, child development scholars have debated about which of two primary influences on a child most impact his or her development. The two main influences considered are commonly known as *nature* and *nurture*, and thus the debate is known as the nature/nurture debate. The nature part of the issue focuses on that which we inherit through genetics—our biological endowment. For example, Sigmund Freud emphasized biologically-based drives, and posited that a child's personality was basically set by the time he or she was five years old. Today, sociobiologists theorize that not only intelligence and physical characteristics, but, also, emotions and social behavior are functions of the evolutionary biological drive to survive and reproduce. Author Judith Harris stated this case strongly in her recent book, *The Nurture Assumption*:

> After parents contribute an egg or a sperm filled with DNA, virtually nothing they do or say—no kind words or hugs, slaps or tirades; neither permissiveness nor authoritarianism; neither encouragement nor scorn—makes a smidgen of difference to what kind of adult the child becomes. Nothing parents do will affect his [or her] behavior, mental health, ability to form relationships, sense of self-worth, intelligence or personality (Begley, p. 53, 55).

This type of thinking persuaded some scholars to coin the phrase "biology is destiny" to indicate how powerful they feel genetic influence is in the lives of developing children.

On the other hand, there are those who have argued that nurture, or environmental influences, are the most salient influences in a child's development. Here the issue centers not only on the impact of parenting behavior, but also that of peers, educational experiences, and ethnic and cultural practices. Behaviorists and social learning theorists are examples of scientists who come down strongly on the nurture side of the debate. This position holds that children can be molded and shaped significantly by their environment through behavior modification, rewards and punishments, etc. In fact, in the early part of this century, behaviorist John Watson claimed that if you gave him a child at birth, he could turn it into any sort of person he decided upon. These theories have tended to emphasize the unidirectionality of parent-child interaction—parents were felt to be shapers of the child, and not vice versa. Many of today's popular parenting books and seminars, knowingly or unknowingly, advocate this approach. In fact, one lecturer claims that it's not that hard to change the misbehavior of children, noting that scientists have been doing this with rats for years (Jones).

Infant Brain Development

In recent years, the nature/nurture debate has been impacted by the science of neurobiology, specifically the study of infant brain development. New technology has allowed scientists to get a better understanding of how the brain develops, both before and after birth. PET scans, MRIs, EEGs, and measurement of various levels of chemicals secreted by the brain are some of the tools used to study brain development. Studies of children who have suffered localized brain damage, or who have been exposed to harmful substances before birth, and/or who have been in abusive or neglectful environments have also informed this issue. More detailed description of the biology of brain development can be found in nearly all of the references listed in the reference section at the end of this paper.

Neuroscientists as recently as the 1960s believed that the brain was designed and crafted essentially by nature, by genetics, and was unaffected by the environment, except in the case of extreme physical trauma before or after birth. But an intriguing discovery involving lab rats opened up a whole new understanding of brain development. In the experiments, infant rat pups were divided into two groups. The rats in one group were raised as solitary individuals, in empty cages. The members of the other group were raised in small colonies, in cages filled with a variety of toys. The rats raised in the stimulating environment were found to

be able to run mazes much better than the rats raised in the impoverished environment. What was even more astonishing to these early scientists was that they found, upon autopsy, that the brains of the rats raised in the enriched environments had grown thicker and heavier than those raised in a sterile environment (For a detailed discussion of these experiments, see Diamond and Hopson.).

Since this early research in the 1960s, there has been an explosion in brain research. We now know that infants are born with almost all of the neurons (brain cells) that they will ever have. However, in order to function, neurons must be connected to other neurons by a system of axons and dendrites. In a newborn infant, only those neurons necessary for survival outside the womb, such as for breathing, sucking, etc., are already "wired" or connected—about 17 percent of the brain. The vast majority of the neurons remain unconnected until exposed to environmental stimulation. Exposure to light wires the neurons allocated to sight, exposure to sound wires the neurons allocated to hearing, etc. Those areas of the brain that do not receive the appropriate stimulation remain unconnected; eventually the underused, and therefore underconnected, neurons are "pruned," or eliminated. In other words, the old adage "use it or lose it" has some application to brain development.

Some rather ingenious experiments have shown how this works in practice. Kittens who were blindfolded at birth for the first two to three months are unable to see when the blindfolds are removed. There are no physical abnormalities within the structure of the eye or the optic nerve. The problem is that the neurons dedicated to sight were not connected during the sensitive period for visual development. Baby songbirds kept in a perfectly quiet environment never learn to sing. And very young children kept, by nature or abuse, from the sounds of human speech, never learn to speak articulately.

The brain produces many more connections, or synapses, than are needed. Each of the approximately 100 billion neurons has ten thousand dendrites, so the possible number of connections that can be made is over 1,000 trillion. Synaptic production, or connection of the neurons, begins to rise just prior to birth, and reaches a peak at about three years old. This high level of connective activity continues until about ten years of age, when it begins to decline and eventually tapers off to the adult level in later adolescence. Connection and pruning both occur during this time, but by the late teenage years, nearly half of the synapses formed at age three will have been discarded. The key point here is that it is environmental stimulation that determines which neural connections are strengthened, and lack of stimulation that determines which connections are pruned.

Insights on the Nature/Nurture Debate

While this introduction and overview of brain development is intentionally brief and, therefore, simplistic, it should be clear that genetics and experience, biology and environment, and nature and nurture interact in significant ways to shape the development of a child's brain. To put these new research findings in perspective, I will now summarize the key points of a report based on the proceedings of a national conference on early brain development held in June 1996 (Shore). Statements in italics are taken directly from this report.

1. Human development hinges on the interplay between nature and nurture

This interplay has been variously characterized as a dance, as a programming and reprogramming of a computer, as branching and pruning, and as sculpting, but most neuroscientists and developmental scholars now would probably agree that:

> The roles of nature and nurture in determining intelligence and emotional resilience should not be weighted quantitatively; genetic and environmental factors have a more dynamic, qualitative interplay that cannot be reduced to a simple equation. Both factors are crucial. New knowledge about brain development should end the "nature or nurture" debate once and for all (Shore, p. 27).

2. Early care and nurture have a decisive, long-lasting impact on how [children] develop, their ability to learn, and their capacity to regulate their own emotions.

Numerous studies have documented the importance of consistent, sensitive, responsive caregiving to the physical, cognitive, and socio-emotional development of children. Children who are seriously abused have been found to exhibit actual physical changes in their brain structure and secretions. Stress hormones such as cortisol, which are produced in situations of fear and stress, over time act like acid on the brain, resulting in a 20–30 percent reduction in brain mass. Some of these children seem to have "hair-trigger" responses to stress, including aggression, anxiety, and/or hyperactivity (Begley). In studies of children raised in Romanian orphanages, where little physical stimulation or tender care were proffered, areas of the children's brains were found, in PET scans, to be dark, indicating there was very little mental activity in the regions related to emotions. Upon adoption, even into loving homes, these children often had difficulty giving and accepting love. In summary, "a child's capacity to control emotions appears to hinge, to a significant extent, on biological systems shaped by [his or] her early experiences" (Shore, p. 29).

3. The human brain has a remarkable capacity to change, but timing is crucial.

Neuroscientists refer to the brain's capacity to grow and change as "plasticity." As noted above, the brain changes rapidly in the early years of a child's development and only slows down in late adolescence. This feature of brain development is both a source of vulnerability and a source

of adaptability. Many children who suffer brain trauma at a young age have been able to regain mental and physical functions at a remarkable rate. However, if the trauma occurs in later childhood—after the age of about ten years old—the recovery is more difficult and less likely to be complete. Young children exposed to more than one language have the capacity to learn to speak both languages fluently. Adults learning a new language have a much more difficult time. In fact, studies show that young children learning two languages at the same time process them both in the same area of the brain, whereas adults learning a second language use a different part of their brain to learn a second language.

Even though we often equate brain development with intellectual development, it is important to remember that parts of the brain are also devoted to emotional development and attachment behaviors. In fact:

> The parts of the brain that process emotion grow and mature relatively early in a child and are very sensitive to parental feedback and handling. . . . Proper nurturing at this stage is a priceless form of mental enrichment that lasts a lifetime, whereas inappropriate or inconsistent treatment, neglect, or outright abuse are forms of mental impoverishment that can also take a lifelong toll. . . . A child raised without sufficient love, attachment, or attention, given little encouragement for exploring and learning and punished frequently or severely . . . will suffer an abnormal process of synapse formation and pruning, leaving [him or] her without normal circuitry in emotional brain regions, and without the normal range of emotional responses or their control (Diamond and Hopson, p. 124–26).

"The bottom line is that the brain's plasticity presents us with immense opportunities and weighty responsibilities" (Shore, p. 37).

4. The brain's plasticity also means that there are times when negative experiences or the absence of appropriate stimulation are more likely to have serious and sustained effects.

Numerous studies over many years have documented negative effects on brain development from environmental sources, both before and after birth. The most well known of these studies deal with prenatal exposure to teratogens, substances that compromise brain development, such as maternal smoking, drinking, or drug use during pregnancy. Less publicized is the impact of maternal depression and poverty post-natally. Long-term (beyond six months), untreated postpartum depression has been shown to have negative cognitive and emotional effects on infants. This is probably because information embedded in an emotional context stimulates neural circuitry more powerfully than information alone (Begley, 1997). An infant with a depressed, unresponsive mother soon learns that his or her overtures for attention or comforting go unheaded, thus giving the child a view of the world as untrustworthy. Effects of poverty on a child include problems with:

> nutrition, access to medical care, the safety and predictability of their physical environment, the level of stress experienced by their parents and other caregivers, and the quality and continuity of their day-to-day care. Poverty also affects children's in-home and out-of-home stimulation, and their exposure to extreme stress and violence (Shore, p. 48).

Certainly we know how devastating early abuse, neglect, and/or trauma can be on children physically, mentally, and emotionally, but new brain development research has shown us the actual physical roots of the damage:

> [Trauma and neglect] can interfere with development of the subcortical and limbic areas of the brain, resulting in extreme anxiety, depression, and/or the inability to form healthy attachments to others. Adverse experiences throughout childhood can also impair cognitive abilities, resulting in processing and problem-solving styles that predispose an individual to respond with aggression or violence to stressful or frustrating situations (Shore, p. 40).

In fact, one researcher states that "prolonged periods of intense stress may actually alter DNA," and another concludes that in the case of violence, "It's not the finger that pulls the trigger, it's the brain" (Karr-Morse and Wiley, p. 10, 11). Dr. Bruce Perry, an expert on how emotional trauma and child abuse alter the developing brain, notes that "one of the hardest things to communicate to people in our culture . . . is not just that hitting kids and screaming and yelling at them leads to injuries, but that the absence of touch, the absence of eye contact, leads to [the frontal cortex] not growing" (Diamond and Hobson, p. 129). Periods of profound neglect or abuse have produced children who are "unattached, emotionally empty . . . likely to be violent . . . [with] less inhibitory capacity . . . more aggressive . . . [and] more reactive" (Diamond and Hopson, p. 130).

Dr. Allan Schore believes that the orbitofrontal cortex is critically involved in both infant attachment and emotional regulation, and that "an early relationship with an emotionally attuned primary caregiver who regulates the baby's physical and emotional states provides a growth-promoting environment for the infant's developing orbitofrontal cortex" (Karr-Morse and Wiley, p. 38). Ramey and Ramey believe that "if children don't learn how to trust at least one other person by the time they are three or four, chances are slim that they can ever gain this essential ability" (p. 14). This seems to be the case with many emotionally deprived orphans and other neglected children.

Implications of Brain Development Research for Families

The implications of brain development research are many and varied. We know much about prevention of teratogenic

effects, including how important prenatal care and maternal nutrition is in preventing brain deficiencies. We know that impoverished environments for children, not just for rats, lead to diminished physical, intellectual, and/or emotional functioning. And we know much more.

However, while the new knowledge being generated tells us much about the impact of insults and deprivations on infant brains, it tells us little about the effects of enrichment in normal environments, and therefore is subject to over-interpretion and/or misinterpretation. For example, the knowledge that babies can hear and even "learn" in the womb has generated so-called "prenatal university" programs, where parents are taught how to engage in a regimen of auditory and physical stimulation of their unborn babies. For other parents, books and programs to "raise a brighter child" have parents using flash cards to teach their infant to read at an extraordinarily young age.

Although there are many successful programs with measurable positive effects for early enrichment of underprivileged, "at risk" children, to date "there are no long-term studies of the effects of systematic enrichment for normal infants from families that already provide a stimulating and responsive environment on a daily basis" (Ramey and Ramey, p. 13). Indeed, Dr. Heidelise Als worries that "early sensory stimulation may present unexpected challenges to brain development and may distort it by triggering sensitive periods at a time when the brain can't incorporate visual, touch, or other kinds of stimulation" (Diamond and Hopson, p. 94).

In addition, new research on the way brains are wired by experience from a very early age has led to a worry among some parents that they might have missed critical opportunities to give their children advantages at young ages, and, failing to do so, they feel it is too late. Let's return for a moment to the lab rats to allay these worries. Remember that the rats with the smaller brains lived in absolutely sterile environments. These constituted environmental deprivation. However, the rats that lived in the "enriched" or stimulating environments were actually living in circumstances that would more closely approximate their natural habitat, had they been raised in the wild. So these experiments should not be seen as "normal versus enriched." Rather, they should be seen as "deprived versus normal." And while there was some cortical thickening of the rats in the "enriched" environment, the impact of boredom on the brains of the deprived rats was even more profound. "Reduced environmental stimuli had a more powerful effect on cortex-thinning than enhanced stimuli had on cortex thickening" (Diamond and Hopson, p. 150).

Additionally, these same deprivation studies on adult lab rats showed that those in "enriched" environments continued to produce weighter brains, although not as dramatic as in the young rats. In other words, although early brain development is crucial to a child's normal growth, brain development does not cease in childhood but continues throughout adulthood.

Today many child development scholars feel that a typical home environment, with books, blocks, and simple toys, and parents (or other loving caregivers) who provide emotional warmth and responsiveness and meet the child's basic physical needs is "good enough" stimulation for the developing brain. While "elaborate and expensive equipment" is not required:

> A loving adult is indispensable as an interpreter, or "mediator" between the child and the confusing demands of the environment. . . . In our zest for stimulating children's minds, we shouldn't forget that a loving and safe home is always the first order of business (Healy, p. 29, 43).

Ramey and Ramey have been designing and implementing programs for child enrichment for over thirty years.

> They have distilled the "essential daily ingredients" for improving a young child's everyday life. . . . Adults must encourage children to explore; show them basic skills; praise their accomplishments; help them practice and expand their skills; protect them from disapproval, teasing, or punishment; and surround them with a rich and responsive language environment (Diamond and Hopson, p. 160).

Ramey and Ramey conclude that "the most profound teaching [a] child receives is the aggregate experience of everyday life with family and friends, at home and outside, receiving and giving to the world" (p. 62).

Implications of Brain Development Research for Policy Makers

What can governments and policy makers glean from this information? First and foremost is that, while the brain is very resilient and can respond favorably to intervention after physical and emotional traumas to young children, many problems can be reduced or eliminated with early prevention and intervention measures. Local, regional, and national governments can use new research and proven methods to protect at-risk children and families, both before and after the birth of infants.

Second, we now know that environment matters very much. And that, except in extreme cases, families are the best environment to provide the experience that sculpts a child's brain for optimum physical, intellectual, and emotional growth. Unfortunately, in modern industrialized societies:

> [Children] have suffered a grievous decline in just the goods that are most important to them: adult time, energy, and company. . . . The scientific moral [of the brain research story] is not that we need experts to tell us what to do with our children. What we need are the time and

> space and opportunity to do what we would do anyway. . . . Being in the company of caring adults is school for babies (Gopnik, Meltzoff, and Kuhl, p. 204–05).

Ramey and Ramey conclude that "Ideally, every baby should receive lots of love, care, and stimulation from at least two caring and knowledgeable adults who are part of the child's everyday experience" (p. 130).

With the understanding of the importance of nurturing environments in shaping neurological outcomes in a baby's brain, and knowing that loving parents are most likely to provide the warm, responsive environments conducive to infant brain development, officers of governments could promote measures in their villages, cities, and nations that will help parents give the needed stimulation and care to their children. Programs to educate and policies that allow parents to give children "time, energy, and company" should be promoted. Although this effort may come at a financial cost to governments, failure to provide these measures may come at a far greater social cost.

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