

An Overview of Brain Development and Early Intervention

Parents, the media, educators, policymakers, and others concerned with the welfare of children have focused their attention recently on early brain development research. What have researchers learned about the developing brains of children and the potential of early interventions to support brain development?

- **Brain development is a lifelong process, but the process changes over time.**

The brain develops continuously throughout life in response to new learning and new experiences. How it develops changes as an individual gets older.

Early month and years of life. The brain develops at a fantastic pace in the months before birth and in the early years of life. Neurons (nerve cells) are created and form connections with other neurons so that messages can be sent to different parts of the brain. Brain structures take shape. During these years, basic abilities – sensation, perception, motor response, memory, emotion, motivation, language, and other essential functions – develop. If we compare brain development to building a house, these early years would be like the construction of the foundation, framework, and walls of the house.

Childhood and early adolescence. Less is known about brain development during childhood and adolescence, but it is clear that the parts of the brain that control the most sophisticated forms of human thoughts and emotion (e.g., planning, abstract reasoning, self-regulation, self-motivation) are maturing. Brain development during this period is like installing the working of the house – plumbing, electricity, and heat and air conditioning – that controls its internal functioning.

Later adolescence and adulthood. Brain functioning is refined during this period and is dependent on life experience. Although changes are not as dramatic as in earlier years, it is clear that changes are clearly related to individual experiences. In the analogy of home construction, it is during this time period that the rooms are painted, decorated, and renovated to suit the individual needs and preferences of the homeowners.

- **Brain development is guided by three kinds of influences: genetics, experiences of the child, and organic influences.**

Genetic influences. The individual's genetic blueprint guides brain growth, the early production of neurons, and the development of the initial connections between neurons. Genetics also establishes the general architecture of the developing brain.

Experience. A child's everyday experiences – positive or negative, stimulating or deprived – also shape how the brain develops. Caretakers should do all that they can to ensure that children's environments are engaging and stimulating.

Organic influences (physical hazards). Physical hazards such as maternal malnutrition, maternal alcohol and drug use, maternal diseases (e.g., rubella, HIV), environmental toxins (lead, mercury, DDT), and maternal stress can seriously affect brain development of the fetus. After birth, exposure to drugs and environmental toxins, chronic stress, and malnutrition also can impair brain growth.

- **Brain development is cumulative.**

Early brain development provides a foundation for later growth. As a result, early influences on brain development can have long-term consequences. Early problems in development can contribute to later, more significant problems if not corrected. Similarly, early positive stimulation often provides a good basis for later brain development. However, more than a foundation is needed. Appropriate stimulation as children grow is essential to thinking, reasoning, and self-regulation. This means that brain development must be supported early and continuously, from infancy through adolescence. Without continuing supports and stimulation, early gains are often lost.

- **Early behavioral and cognitive problems typically have many different origins, and multiple avenues to prevent early developmental disorders exist.**

When young children enter school unprepared to learn, when they have problems getting along with their peers, or when they cannot control their behavior, to what extent are these problems linked to early brain development? Research provides clues to understanding the complexity of these difficulties. For example, some children who have problems with attention and learning may have been exposed prenatally to drugs, maternal stress, or other hazards. Others who have problems with self-control may have been exposed after birth to lead, malnutrition, or chronic stress caused by growing up in an abusive environment. Some children who have trouble concentrating on schoolwork may live in environments with overstimulating amounts of TV and may have parents who are too overwhelmed or disinterested to provide appropriate stimulation. Most of these circumstances can relate to brain development.

It is extremely difficult to identify specific causes of behavioral and cognitive problems in young children, but it is easy to identify effective broad-scale interventions to reduce the incidence of many of these problems. Good examples include:

- Good prenatal care;
 - Voluntary home visitation and parent education programs that encourage the development of a safe, healthy, and appropriately stimulating home environment;
 - Community programs designed to eliminate lead-based and other environmental toxins from residential areas, and
 - Programs providing supplemental nourishment to poor children and their families.
- **Many of the most important requirements of brain development are fulfilled through relationships with others.**

Successful early (and continuing) interventions support caregivers as well as young children. Research shows that the experiences that a child gains through relationships with parents and other caregivers are critical to brain development. Two-generation interventions, directed at children and their caregiver, are extremely beneficial. Research indicates that the quality of early nurturance by caregivers rather than the kind of nurturance (e.g. maternal care at home versus day care) is the critical factor in shaping early brain growth. Infants and young children have significantly different experience with caregivers who are positive, responsive, and supportive compared with caregivers who are stressed, disinterested, or negative. These experiences affect early brain development. Although many parents and caregivers naturally do the things that stimulate and nurture young brains, efforts to improve the quality of care that children receive - through home visitation programs, during pediatric check-ups, in childcare programs – are needed.

Promoting Brain Development

Brain growth occurs at a rapid, dramatic pace in the early years of life as basic neural abilities develop and organize. In the years following birth, the brain's growth slows and is more individualized as the developing brain builds upon the foundation provided by the early years of growth. Scientific studies of brain development have not only identified major influences on the brain's organization and functioning, but they have also highlighted important ways to promote healthy brain development.

Influences on the Developing Brain

In addition to the guidance provided by hereditary influences, the developing brain is influenced by the following factors:

- ***The stimulation provided by early experiences, especially those provided by caregivers.***

The developing brain relies on everyday experiences to stimulate developing brain structures in the early years of life. Caregivers provide a variety of experiences that help to stimulate brain development. These include:

- The animated visual, auditory, tactile, and motor experiences that occur in face-to-face play;
- The sound of language that help to prepare the growing brain for later language learning;
- The emotional security that encourages a child to explore his or her world with confidence and learn from this exploration;
- Sensitive responsiveness that reinforces a young child's developing sense of competency and effectiveness in social interaction; and
- The protection from undue stress or stimulation that might tax a young child's limited coping capacities and stress-related brain structure.

- ***The quality of nutrition, beginning prenatally.***

Because of its rapid developmental pace, the brain consumes astonishing physical resources in the early years. By one estimate, more than 65% of the baby's total metabolism is devoted to brain development in the first year of life! Consequently, the brain relies on the physical resources necessary to its rapid growth, such as oxygen and glucose. Adequate nutrition, beginning prenatally, is essential to healthy brain development, and the consequences of an inadequate diet (due either to maternal malnutrition during prenatal development or an infant's inadequate diet after birth) can have life-long consequences for brain functioning.

- ***Avoidance of environmental hazards that can harm brain growth.***

The rapidly developing brain is vulnerable to many environmental hazards that can have long-term effects on its functioning. These include: exposure to environmental toxins such as PCB, DDT, mercury and lead; exposure to drugs, including alcohol, cocaine, heroin, and other substances, which can harm brain growth prenatally (through the mother's use) as well as after birth; diseases, such as HIV, which can have very harmful consequences at any time of exposure; and chronic stress, in which the brain's functioning is affected by the long-term secretion of stress hormones within the mother's body (prenatally) or the child's body (after birth).

- ***Continuing opportunities for learning and intellectual stimulation and helping to make up for early disadvantage.***

Brain development continues throughout childhood and adolescence and into the adult years, although at a slower and more individualized manner than in infancy. This means that experiences offering continuing opportunities of the development of higher thinking and problem-solving skills, capacities for self-management and strategic planning, and abstract reasoning are important as new brain regions slowly mature. These experiences can occur in school, but they can also occur outside the classroom through thoughtful discussions with parents and other supportive adults, exposure to diverse viewpoints, and reading the newspaper and other materials.

Furthermore, brain development is promoted by later opportunities to help make up for the consequences of early disadvantage, especially when children have grown up in environments that are not optimal for brain development. This may occur through medical education and other programs specially designed for such children.

Intervening to Promote Brain Development

The following points are important to consider in efforts to promote brain development, either to prevent early disadvantages or to later counter the effects of early disadvantage:

- Early intervention is important: initial hazards to brain development build upon each other if they are not addressed early.
- The developing brain is especially vulnerable to chronic or long-lasting dangers, which pose greater risks to brain development than one-time exposure.
- The timing of brain development is as important as its pace. There are critical periods in which exposure to certain kinds of environmental stimulation (such as patterned light or sounds) must occur for the brain to develop properly. Likewise, some hazards to brain development depend on the timing of exposure. Harm may be particularly great during certain phases of early brain development, but not others.
- The greatest hazards to brain development occur when young children are exposed to multiple and overlapping hazards over time. Unfortunately, many children are currently growing up in conditions where they have an inadequate diet, are exposed to environmental hazards, have an overwhelmed or unresponsive caregiver, and have inadequate learning opportunities outside of their home.

Brain Development and School Readiness

Too many children arrive at school by age six unprepared to learn. Many of these children also have difficulties getting along with their peers, are unable to control their behavior, or are incapable of responding appropriately to the requirements of academic learning. To what extent do these difficulties arise from problems in early brain development?

Developmental scientists have identified a number of hazards to early brain development that are associated with these problems. For example, early speech and language disorders may be caused by many problems related to brain functioning, including:

- Prenatal trauma, exposure to viral infection, or exposure to alcohol, other drugs, or other toxins, or difficulties in the birth process.
- Malnutrition, beginning either prenatally or postnatally.
- Head trauma (which can occur in child abuse), infections, or brain tumors.
- Exposure to lead, pesticides, drugs, or other environmental toxins.

It is often difficult to pinpoint the specific cause of any child's speech or language problems, because the child may have been exposed to several of these hazards to brain development, and one of which contribute to later difficulties.

This does not mean, however, that it is impossible to identify potential, and preventable, hazards that may undermine school readiness. The research on early brain development indicates that children will be most likely to be ready to begin school when they:

- Have been raised in a warm, positive, and responsive caregiving environment that involves lots of age-appropriate stimulation, including animated social play, language stimulation (such as through regular reading to the child), and a sense of security.
- Have been adequately nourished both prenatally and after birth.
- Have been safeguarded from exposure to environmental toxins, drugs, diseases, and other hazardous substances, especially in the early years of life.
- Have been protected from chronic stress that may arise from inadequate or abusive caregiving, lasting problems in the home environment, or threats or difficulties in the neighborhood in which the child lives.
- Have plenty of opportunities for stimulation outside of the home, either in a developmentally appropriate early childhood education program, in a well-designed childcare program with a well-trained staff, or in informal opportunities to learn from adults and other children.

How Experiences Influence Brain Development

A person's everyday experiences shape how the brain functions, whether those experiences are stimulating or deprived, positive or negative, enriching or abusive. Although experience has a stronger influence on brain development early in life, the challenges and opportunities for new learning that occur throughout life continuously change the brain.

Early month and years of life

The initial months and years of life witness the construction of basic brain capacities. Brain development is most rapid, and the changes in brain functioning are most dramatic in this period of development. Consequently, early experiences provide critical influences on brain organization and growth.

In fact, brain growth relies on certain kinds of early experiences to prompt the interconnections among brain cells in different regions. For example, visual experiences in the early months of life are necessary to organize neurons in the parts of the brain that process visual stimulation. Likewise, the brain depends on auditory experiences of various kinds (like the sound of human speech) to organize brain areas concerned with auditory stimulation.

If a child does not encounter these kinds of typical human experiences (for instance, if a child is born blind or deaf), the brain regions normally devoted to these abilities will quickly reorganize to assume other functions. As a result, the brain's capacity to process vision or hearing will be permanently lost.

We do not yet know the range of early experiences on which the brain depends for its growth and organization. However, it is safe to assume that frequent opportunities to exercise developing sensory (e.g., vision, hearing, touch), motor, emotional, and intellectual abilities within a supportive and caring environment will promote brain development.

Childhood and early adolescence

As children mature, other brain regions begin to develop more fully. These brain areas govern higher abilities for thinking, reasoning, and problem-solving. They strengthen child's capacities for self-control and playfulness, self-monitoring, creativity, and even the growth of personality.

During childhood and adolescence, the brain becomes more interconnected. For example, the basic capacities for emotion and memory established during the early years become integrated with higher capacities for self-control. As a result, children begin to manage their emotions, and they can remember and recall more competently than they could before.

The experiences that promote brain development during this stage help children to exercise their developing skills for thinking, planning, and problem-solving. This may occur through discussions with people who have different viewpoints, the intellectual challenges of schoolwork, and the opportunities to weigh and evaluate options in decision-making. While these brain skills are developing, the support of parents and teachers can enable children to master the challenges they are capable of, while safeguarding them from problems that might be too difficult.

Later adolescence and adulthood

Brain development is refined during adulthood according to one's life experiences. This means that the experiences that may shape one person's brain to function in a particular way will be different from the experiences that affect someone else. For example, one research team found that the brain regions controlling the finger movements of experienced string musicians were more sophisticated than the same brain regions of adults who did not play string instruments! In a similar manner, the recurring, everyday experiences of each adult – whether

they are a professional musician, skilled gardener, expert mathematician, expressive artist, or surgeon – alter their brain’s organization and functioning in small but important ways.

Because experience influences brain development throughout life, each of us has a brain that is similar to everybody else’s – but is also individually tailored to our personal interests, skills, and experiences.

Physical Hazards to Early Brain Development

Influences on Brain Development

There are three major influences on the development of a child's brain:

- Genetic influences
- A child's everyday experiences
- Physical hazards (organic influences)

In the months before a child is born and in the early years after birth, a child's brain develops at a very fast pace. This rapid growth means that the developing brain structures are very vulnerable to damage from physical hazards such as poor nutrition, disease, trauma, lack of oxygen, environmental deficiencies, and toxins (such as drugs or lead). Because the developing brain is flexible, it often can recover from physical hazards. However, in many cases, there can be long-term brain damage. In recent years, scientists have learned a lot about the effects of such physical hazards on brain development.

Physical Hazards to Brain Development

There are a number of physical hazards that have been found to impair brain development both prenatally and in the early years after birth:

- **Maternal Malnutrition** – nutritional deficiencies of a mother may seriously affect the brain of her unborn child by limiting the development or maturation of neurons. For example, folic acid deficiency in early pregnancy can lead to permanent neural tube defects, and thyroid hormone deficiency can cause severe brain damage in an unborn child.
- **Malnutrition of the Child** – malnutrition during the first two or three years of life impairs brain growth. Children who suffer from general nutritional deficiencies or specific protein deficiencies during their first three years of life have smaller brains and fewer neurons. Greater brain damage occurs the earlier that malnutrition begins and the longer it persists. Fortunately, much of the damage of early malnutrition can be reversed if a comprehensive program of nutritional support is provided in early childhood, particularly with stimulation and emotional support to the child.
- **Teratogens** – Teratogens such as drugs, diseases, and environmental toxins can have lasting effects on a developing fetus or young child. The consequences of these teratogens depend upon the age of the child and the amount of exposure to the hazard.

Maternal alcohol use - chronic alcohol use by a pregnant mother can cause fetal alcohol syndrome, which may result in mental retardation and physical abnormalities.

Maternal drug use – during pregnancy, the use of drugs such as cocaine and heroine poses risks for early brain development, although scientists are still learning about their consequences.

Environmental toxins – Environmental toxins such as PCB, DDT, lead, and mercury can cause permanent damage to a developing brain (including problems with learning and memory).

Maternal diseases – exposure to the Human Immunodeficiency Virus (**HIV**) is one of several viruses that may cause neurological problems in a fetus or young child. Rubella is

another disease with the potential to cause prenatal damage to the developing nervous system.

- **Maternal stress** – Stress during pregnancy can create risks for early brain development. Newborn infants of mothers who experienced high stress during pregnancy may tend to be more jittery, more poorly coordinated and more passive.
- **Head Trauma** – Head trauma, such as the trauma that may result from shaking a child or other physical abuse, may also cause lasting damage to a young child's brain.

Multiple Hazards

The greatest hazards to brain development occur when young children are exposed to multiple and overlapping hazards over time. Unfortunately, too many children currently are growing up in conditions where exposure to environmental hazards, disease, chronic stress, prenatal exposure to alcohol or other drugs, inadequate nutrition, and physical abuse build upon each other if they are not addressed.

Attachment and Early Brain Development

For many years, parents, practitioners, and researchers have understood that a close and secure attachment to a caregiver is critical for a young child's healthy emotional growth. Now developmental scientists are recognizing the importance of attachment to early brain development.

Attachment is important to brain growth because early experiences influence the brain's developing organization and functioning. In fact, the brain relies on certain kinds of early experiences to prompt the development of brain cells and their proper connections within the growing brain. Without everyday experiences of sight, sound, and touch, for example the brain regions that process information from the eyes, ears, and skin senses do not develop properly.

Many of the early experiences that guide brain development occur in the warm and secure relationship between a young child and a caregiver.

- When they play together, caregivers provide a child with an integrated sensory experience – consisting of sight, sounds, touch, smells, and other sensations that come from the same person – that stimulate brain regions concerned with vision, hearing, and other sensations.
- Caregivers play with infants and young children in ways that also exercise developing brain regions concerned with motor coordination by helping babies to reach to them, grasp their hands or hair, or hold and manipulate toys that are part of their play. These experiences not only exercise developing motor skills, but they also promote visual-motor coordination within the child's developing brain.
- One critical part of sensitive caregiving is the adult's responsiveness to the baby's needs, intentions, and expressions. When caregivers are sensitive and responsive, young children develop an understanding of cause-and-effect relations and their own effectiveness in getting help from others.
- Caregivers talk to infants and young children in a unique manner that stimulates the developing brain to recognize and respond to the sounds of the native language. Adult speech to infants – often called “baby talk” or “parentese” – is rhythmic, animated, and repetitious. This makes it easier for the baby to comprehend speech sounds. Similar kinds of language stimulation also occur when adults regularly read to children and talk with them about each day's events. When caregivers talk to children in this manner, the developing brain becomes prepared for later learning about language.
- Adults are not only rich sources of stimulation for the developing brain, but they also provide infants and young children with clean, safe, and developmentally appropriate toys that children can grasp, look at, and handle in ways that also stimulate brain growth. Toys that are easy to manipulate, that respond to the child's actions, and that provide many sensory experiences are rich sources of early brain stimulation.
- The emotional security that young children get from their attachments to caregivers gives them a safe feeling that encourages them to explore their environment with confidence. Infants and young children who can confidently explore their surroundings are likely to learn more from everyday experiences than those who are more insecure or uncertain in their attachments to caregivers.
- Caregivers provide a sense of security in other ways also: by helping children to manage their emotions (such as when children become upset) and by restricting their exposure to situations that may be too much for their limited coping skills (such as watching violence on television). This sense of security supports the growth of slowly developing structures in the brain that control self-regulation and self-control. It also helps to ensure that the developing brain does not have to contend with the overproduction of stress hormones within the body.

- In addition to these influences, thoughtful caregivers ensure that children grow up in a safe and healthy manner. By providing children with a balanced diet, keeping them safe from environmental toxins and hazards, and ensuring that they are immunized from dangerous viruses and protected from hazardous drugs, caregivers promote brain development by keeping a child safe from some of the most important hazards to the brain's healthy growth.
- The warm, secure attachment bond between caregivers and young children clearly helps to promote early brain development. The importance of the caregiver's role in early brain development does not end with early childhood, however. Parents and other caregivers provide many forms of stimulation to the developing brain through opportunities for intellectual challenge, exposure to new learning experiences, guidance in developing self-regulatory skills, and opportunities for personal decision-making that stimulate brain growth in late childhood and early adolescence.

Caregivers in Home and Out of Home

Young children develop important attachments to the adults who regularly care for them. These include parents, of course, but also other adults who care for the child outside of the home, such as a regular babysitter, child-care provider, or grandparent. The characteristics of warm and sensitive caregiving that promote healthy brain development are not just parenting skills, but characteristics that should be true of all the adults who play an important role in a young child's life.

Two-Generation Interventions

To promote healthy brain development, therefore, it is important not only to provide experiences that directly stimulate the minds of young children, but also experiences that equip their caregivers to nurture brain growth in the children in their care. These children will benefit as caregivers learn of the significance of their role in guiding and stimulating brain development and are supported in their efforts to do so.