



THE BRAIN AND DEVELOPMENT: WHAT THE NEW BRAIN RESEARCH SAYS TO PARENTS AND CHILD PROFESSIONALS

Special Report

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A national media campaign in the Spring of 1997 announced that new research on the development of the human brain reveals the contribution of stimulation to infants and young children in the development of adult characteristics that define success and fulfillment.

Some scientists and journalists claim brain development occurs through a sequence of critical periods, each offering a “window of opportunity” for environmental stimulation to support and enhance development, and that without such stimulation, important potential capabilities for learning, thinking, feeling, and loving may be lost forever.

But some of the claims and conclusions seem contradictory. Parents, for example, are admonished to stimulate their infants and children before these windows of opportunity close, but then they are advised not to feel guilty if they have not provided enough stimulation to their infants because it is never too late to encourage child development. Also, if early experience is so crucial, why is it that a dose of early stimulation often fails to produce permanent benefits?

This report provides the basic facts and attempts to clarify questions about brain development and what the new research demonstrates.

The Basics of Brain Development

Two Fundamental Principles

There are two fundamental principles that are important for understanding brain development:

1. Except for minor reflexes, essentially all human behavior --- looking, listening, speaking, thinking, loving, worshiping, imagining, and socializing -- is largely governed by the brain. Persistent changes in the behavior of an infant, child, or adult are accompanied by changes in the brain of that individual.

For example, providing rats with toys to play with instead of keeping them in barren cages produces bigger and better brains. The brains of severely neglected children are smaller than those of advantaged children. So, just because certain experiences are found to produce changes in the brain does not make those experiences more important. All persistent behavior changes are located in the brain – scientists just need to locate them.

The latest brain research, for the most part, simply shows that experience which produces changes in behavior produces changes in the brain. Most of the research *illustrates* what child development psychologists, child care professionals, and many parents and grandparents already knew, and *confirms* the nature of good parenting and child care.

2. Much of the brain research shows the terrible consequences of extremely poor and atypical stimulation and environments on the brain development of animals and humans. No research, however, shows that extreme amounts of stimulation or super-rich environments produce a superior brain and human being.

This research confirms that abusive and neglectful treatment of infants and young children produce serious and sometimes permanent deficits in the brains and behaviors of these victims. But it does not show that bombarding infants and young children with sights,

sounds, language, social interaction, music, games, and other experiences will produce a super child. In fact, too much stimulation and experiences that are not developmentally appropriate may hinder infant development and turn a child off to learning and other opportunities for growth.

The Developmental Task

The neurological process of brain development is an incredible phenomenon. The brain of every human, for example, has approximately one billion nerves, each formed between the sixth week and the fifth month of prenatal life. These nerves are wired in ways that enable us to learn, imagine, and love. The new brain research is beginning to reveal the secrets of how that takes place.

Neural Proliferation

Brain development occurs in overlapping stages. The first stage is **neural proliferation**, during which those one billion nerve cells, called neurons, are created by the end of the fifth prenatal month. Barring extremely unfavorable conditions, these neurons are produced in every infant according to biological instructions.

Neural Migration

The second stage, **neural migration**, is largely completed during prenatal life. By a process not yet fully understood, nerves literally grow and send long arms through the brain to different areas and make contact with one another. This migration is like the laying of telephone “trunk lines” that allow calls to be made between cities and to any specific phone.

Synaptogenesis and Differentiation

During and after neural migration, **neural synaptogenesis and differentiation** occurs. Synaptogenesis is the connecting of different nerve cells (at places called synapses) to form a network of linkages. As a result of these connections, neurons that start

out essentially the same become differentiated to perform one function instead of another --- hearing, for example, rather than seeing.

Neural synaptogenesis and differentiation does not occur at the same time in every area of the brain, so different functions develop at different times. The peak activity of such development occurs in the region associated with hearing during the first postnatal months, in the region associated with vision during the first 3-4 months of postnatal life, and in areas responsible for cognition and intelligence at age one year through adolescence.

This sequencing is part of the neurological basis for “developmentally appropriate practices,” or providing stimulation and pertinent experiences for different skills and functions at appropriate times in a child’s life.

Neural Overproduction

In the process of making all of these connections, the brain **overproduces connections**, making more than it needs. An infant in the first few months of life, for example, is capable of distinguishing between every pair of sounds that occurs in any language in the world.

Selective Elimination and Degeneration

Most of brain growth is governed by biology. But experience, or “stimulation,” is needed. Experience enhances **both connections between neurons** and **selective elimination and degeneration** of connections, in what is sometimes called a “use or lose it” developmental process. The connections in the brain that help the infant distinguish the sounds (phonemes) of various languages are used when an infant hears those sounds. But if infants are not exposed to sounds unique to a specific language, those neural connections that distinguish them wither and die. For example, all infants are born with the ability to distinguish “r” and “l” sounds. But within the first six months of life, infants in Japan can no longer distinguish between “r” and “l” sounds, because those sounds do not exist in the Japanese language. This is one of the reasons parents are advised to talk to their infants, even if their infants cannot understand words.

Selective elimination may be the first, if not most crucial, component of the ability of human beings to adapt to their environments. It makes us exceedingly flexible.

But the fact that nerve connections die if not used is often invoked as the basis for the claim that if certain capabilities are not nurtured at particular times in early development, they are lost and cannot be developed later. This is only partly true.

But, not every set of connections and every capability is permanently lost if not stimulated early. *In fact, very few human functions are lost forever from lack of stimulation.* For most abilities, connections that once degenerated can be recreated when the environment changes.

Myelination

Another late stage of brain development is **myelination**, the process by which nerve cells become coated with a layer of fatty cells (myelin) that insulates them and speeds neural conduction. Myelination contributes speed and efficiency to the functioning of the brain.

The Role of Experience

While much of this brain development is biologically programmed, stimulation and experience is nevertheless necessary. How much stimulation is necessary? Is more stimulation better? When is it necessary? When, if ever, is it too late? Is earlier better? How do we know we are doing the right things to promote the development of our children? The answers depend on particular functions and capabilities.

Basic Functions

Brain development occurs in stages that are arranged in a hierarchical order.

Functions that are necessary for survival, which essentially every human being acquires in basic form, tend to develop first. These functions require some

experience at particular times to develop normally. But the necessary experience is fairly minimal and is very common in the typical environments of human infants and children. Therefore, almost every human infant and child receives the minimum amount of experience necessary, and more of such experience does not improve the development of these capabilities.

For example, unless an infant sees light during the first six months of life, the nerves leading from the eye to the visual cortex of the brain that process those signals will degenerate and die. An infant born with total cataracts that are not removed for several months will be blind for the rest of his or her life. But for the elderly, cataracts developed in their later years typically do not cause blindness. When the cataracts are removed, the elderly person can see, because the nerves of the visual system had developed at an appropriate time. Although infants are given a relatively narrow window of opportunity during which to experience light, nearly all are exposed to light during development. A minimum amount of light is needed, but more than the minimum does not improve vision.

More complex visual behavior such as distinguishing shapes, geometric forms, and people's faces, requires stimulation and experience as well. But for these slightly higher visual functions, the window of opportunity is longer and more forgiving. Take, for example, monkeys that have been deprived of opportunities to use pattern vision abilities during the first 6 months of life (i.e., they are allowed to see light, but not forms). When normal visual experiences are finally allowed, their abilities to distinguish between objects and to reach for them are similar to those of newborn monkeys. Their pattern vision abilities have been delayed, but not lost. From then on, the monkeys develop at the same rate as monkeys that had been given normal visual experiences from birth.

With humans, having a warm, caring, stable relationship with another human being, usually a parent, is a crucial early experience, without which the ability to care, love, socialize, empathize, and so on may not develop normally. Attachment starts very early and should be nurtured from the beginning. But the window of opportunity is wide. Children probably must have such a relationship before the age of four years, otherwise long-lasting problems will occur because of timing alone.

Higher Functions

In contrast to the functions described above that essentially every human acquires, "higher functions" are those that some people are better at than others. They include most of the social, emotional, and mental characteristics we cherish --- language fluency and intelligence, social relations and loving, and so forth.

Higher functions require certain stimulation and experience to occur, but the necessary experiences are more likely to be unique to the individual and not shared with all other people. In addition, the "window of opportunity" is much longer and may even be lifelong, and the necessary experiences may not need to be tied to the particular period in which the brain that governs that function is developing most rapidly.

Language development, for example, consists of a combination of basic and higher processes. It is probably the case that humans, who are biologically disposed to developing language, need to experience a responsive language environment before they will develop basic language. Consequently, a child kept in a closet for the first six years of life, for example, will not walk out of the closet speaking a language. But with the exception of unusual situations, every child experiences *a responsive language environment* and develops basic language.

When does a child need to experience a responsive language environment "before it's too late?" Parents are often advised to talk and sing to their infants (even fetuses) during the first three years of life. Fetuses and newborns can come to recognize their parents' voices and, by selective degeneration, infants will focus on the sounds of the particular language spoken to them. But will infants fail to develop normal language or the ability to sing or appreciate music if special efforts are not made to talk and sing to them in the first months or year of life? The answer is, no.

Experience with a responsive language environment probably needs to occur during the *first 8-12 years of life* before permanent dysfunction in developing a language is likely to occur. A girl who had been locked in a closet until age 6 had essentially three guttural "words" when discovered. But after 18 months of tutoring, she

developed a vocabulary, language fluency, and IQ within the normal range.

However, children differ in their ability to use language, their ability to think and conceptualize abstractly, their ability to solve problems, and so forth. Such higher skills, important for success in school and in the development of "intelligence," also require experience. But not every child receives the same type and amount of the needed experience, so children differ in these abilities. Further, such experience does not necessarily have to occur at specific periods of time in development. Even rats that were given special toys as pups and grew to have larger brains did not necessarily have to experience those toys as pups. Rats deprived of such experience until adulthood and then given toys to play with also developed larger brains.

Consequently, higher skills do not require highly specific experiences at particular ages for their development. They do require a great deal of and a great variety of stimulation that is most efficiently delivered both early and over a prolonged period of time. Concern should not be focused so much on how early we give stimulation or how much of it is provided lest the brain die and its functions lost forever. Concern should center on providing a variety of developmentally appropriate experiences both early and throughout childhood, adolescence, and beyond.

Is Earlier Better?

The answer is, sometimes.

Earlier is essential for *basic functions*. It is better, but not so essential, for *higher functions*. That is, the developmental window of opportunity for basic functions is shorter than for higher functions.

Light is essential early; pattern vision can occur a little bit later. A caring, stable relationship with another human is needed in the first years of life. Exposure to a responsive language environment is needed in the first 8-12 years of life. But exposure to more complicated language, thought processes, problem-solving strategies, and abstract reasoning can probably occur over a very long period, perhaps decades in length.

But even if windows of opportunity are quite long, there is something very compelling about the idea that "earlier is better." In fact, earlier can be better even for higher functions.

Developmentally-appropriate stimulation should probably begin when a window of opportunity opens, even if it may be many years before that window closes.

Just because the window of opportunity to experience a caring, stable human relationship is four years does not mean we deliberately wait until then to start such a relationship. It is best to start at the beginning of that window --- at birth if not sooner.

Does such early stimulation produce better social relationships, language, and intelligence later? Yes, a little. Children who learn a second language earlier in their lives, for example, do somewhat better at that language than those who wait until adolescence or adulthood to learn it. But adolescents and adults can learn a second language, albeit with somewhat greater difficulty.

Is More Stimulation Better?

Again the answer is, sometimes.

For basic functions, a modest amount of stimulation is often all that is required and more is not necessarily better. For progressively higher functions, however, a good deal of varied stimulation over a prolonged period of time will produce corresponding results --- that is, more is better.

More stimulation is not always beneficial and sometimes can be harmful. In terms of raw stimulation necessary to keep the eyes and ears operating, low-income children get more things to look at and sounds to hear because they live in close quarters with many other people than do infants from upper-income homes, who tend to have their own bedrooms and fewer people in the house. But the sensory skills of low-income infants are no better than those of high-income infants. The appropriate stimulation of an infant is one that is distinctive --- that stands out from a quiet background --- and is delivered up close and personal to the baby, followed

by a long pause of no stimulation, which allows the infant to absorb the experience and respond to it.

But, for higher functions, more developmentally-appropriate stimulation is better. Abilities such as fluid language, abstract thinking, higher mathematics, and exceptional social skills need a great deal of nurturing with progressively more complex developmentally-appropriate stimulation over a fairly long period of time --- decades, in some cases. That is why *quality education* is so important, and why schooling takes 12, 16, or 20-plus years.

How Much Is Enough?

The answer again depends on the function.

For basic functions, relatively little stimulation at the right time in development is often enough to produce permanent benefits. But for higher functions, relatively more stimulation over much longer periods of time is often required to develop and maintain the ability.

A little light early in life will keep the visual neurons functioning for the rest of one's life, even if light is not available later. But for fluid language and intelligence, much more is needed over a longer period of time, and early stimulation may not produce permanent benefits without continued stimulation.

This principle is important for public policy. It says that for many higher functions, including school and life success, **the inoculation model of early experience is not true.** In other words, giving children a dose of language and mental stimulation at age 4, such as Head Start, will not immunize them against the subsequent effects of poor environments, including the poor-quality schools they might attend after leaving Head Start. Brain development for higher abilities is a lifelong process and continuous environmental support of higher functions is probably necessary.

So What Should Be Done?

1. Basic and higher functions and capabilities will

develop normally if a child is reared in a typical, normal environment. Being neglected or abused or having a dysfunctional parent because of alcohol, drug abuse, or psychopathology, for example, is not a normal environment. Such families need help to provide a typical environment, and some of these children may need out-of-home experiences or care to develop normally.

2. For infants living in normal environments, to a great extent, “Grandma knows best.” She will tell us that having a good time with your infant by talking, responding, listening, or just plain “loving your infant where he or she is at” is what a good parent does. Be sensitive to how your infant communicates that he or she is having a good time or, conversely, is overloaded. Provide infant-only time. Be on call to your infant’s or children’s needs. Be caring, responsible, and devoted, and you will provide the necessary ingredients for normal development.

3. Even for higher functions, there are some advantages to beginning earlier. But earlier is certainly only better if it is matched in a developmentally-appropriate manner to the infant’s and child’s capabilities and interests at the moment. Charting out ages and stages and matching experiences to those skills and interests is the appropriate curriculum for early childhood education. These experiences should be delivered at “teachable moments,” naturally occurring instances in which the child needs to know something and is ready to learn. To match experience to an infant’s or young child’s ability and motivations, parents and caregivers are better advised to *respond* to a child rather than to stimulate him or her. One of the best ways to respond appropriately is to imitate the child’s action, perhaps with slight variations. Then the adult is doing something the child understands. The simple advice is that if the child is relaxed, attentive, responsive, and you both are having a good time together, chances are those activities are developmentally appropriate.

4. Many of the most important skills and human characteristics need long-term and varied nurturing from parents, caregivers, teachers, and friends. The United States invests disproportionately in education beginning at approximately age 6. But evening out the commitment and investing more in quality early childhood education and family programs is important. Parents need these programs; some crucial child functions, such as attachment, have early windows, and other functions, such as language, can be advanced more easily and efficiently when encouraged beginning early.

5. We should not expect to inoculate children with a shot of early quality education before age 6 and then send low-income children to inferior schools for the remainder of their educational lives and expect them to perform at national average. The most crucial human characteristics benefit from both early and continued nurturing paced and tailored to the changing developmental and motivational needs of children and adolescents.

The new brain research highlights the incredible development of the human mind, and while that mind needs certain environmental food early on, it also requires sustenance throughout its existence to produce the intellectual, social, and emotional fruit we all want for our children and our nation.

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