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Commentary

Commentary: Implications from Brain Research for Early Development and Education

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Received: January 13, 2018; **Published:** February 19, 2018

One of the most important areas of human development research in the past 30 years has been research on early brain development and effects of negative environmental factors on that development [1]. Research on nutritional deficits, smoking, drug use (marijuana, cocaine) and other teratogens clearly show the "building" of the prenatal brain is harmed by such influences [2-4]. Research also has demonstrated that impoverished, unhealthy, and abusive environments negatively affect infant, toddler, and preschooler brain development [5-7]. Similarly, although evidence that young children, especially those from economically and emotionally deprived backgrounds, benefit greatly from early education is well documented [8], universally funded preschool education is not provided in the United States, although such policies are in effect in many European countries [9].

In the United Stated, information about the extreme importance of early child brain development has not resulted in comprehensive public policies that support optimal brain development and thus many young children are not starting their lives with their highest potential levels of brain functioning. Three areas of public policy that should address this concern are: 1) commitment to provision of excellent prenatal care for all pregnant women; 2: support for policies insuring excellent infant care and parental engagement, and 3) support for universal highest quality preschool education. Such policies would draw upon the present knowledge of how pre- and post-natal environments can best foster children's excellent brain development during these crucial periods. Some of that knowledge is briefly described below.

Prenatal Brain Development

The importance of optimum brain development during the fetal period cannot be overemphasized because during this period the basic structures of the brain and the neuronal network are formed. The brain develops from the initial neural tube beginning with the brainstem and ending with the cortex. In humans, about 60% of all genes are dedicated to brain development [10]. Early fetal brain development involves neuronal division, multiplication, and forming of axons that initiate synaptic connections. Motor and sensory brain activity appears about 7 weeks after gestation, with the somatosensory system (touch, pain, and temperature sensitivity), the vestibular system (balance and motion), and the visual, auditory, olfactory and gustatory senses all beginning to form at this early time. The second trimester (12 - 20 weeks) is a critical period for higher brain center formation and involves neuronal migration from the lateral ventricle toward the skull to form the layers of the cortex and the engagement of genes that define their purpose and final location. During the mid-gestation period the process of migrating cells forming higher cortical level is especially important [11]. Brain capacity for understanding language also develops and memory processes show basic brain configurations during the fetal period. At birth the well-developing infant brain contains about 100 billion neurons. Thus, the prenatal period is a primary time for assuring optimum neuronal structural growth in the brain.

Although genetic factors also influence brain development, many prenatal environmental factors (malnourishment, exposure to teratogens, maternal illness or stress) can negatively affect prenatal brain development, depending on when they occur. For example, if teratogenic substances such as cocaine, marijuana, or alcohol are absorbed at the time cell migration is occurring, some of these cells may die and others may not reach the location for which they were destined. Illnesses such as influenza or Zika also may interfere with the migration process and result in brains with deficient higher cortical levels [12,13]. Nutritional deficiencies can be crucial because at early stages the neural tube closure may be affected and at later stages low birth weight and small head size may occur. Also, maternal behaviors such as smoking can result in low birth weight infants who may have neurological or mental impairments [14,15].

Because so much of the brain's potential abilities are related to healthy development in prenatal environments, it is vitally important that pregnant women have the care and resources needed to promote optimum fetal development. All citizens, including those from groups who oppose abortion or who favor legalization of marijuana and other drugs, should be advocating for highest levels of prenatal care and safe pregnancy practices. They also should be supporting funding to assure that all pregnant women are able to gain excellent prenatal care so that their infants can be born with brains that will foster their optimum development.

Neonatal and Infant Brain Development

Although most of the neurons that the child will ever have are already present at birth, the synaptic connections among the neurons are not extensive. Eliot has stated that "fully three-quarters of the human brain develops outside the womb, in direct relationship with an external environment" [14]. Neuronal connectivity is extremely active, with brain size and weight increasing due to growth in neuronal size, more dendritic connections, myelination of axons, and increases in glial cell size and number. The two- to four-month infant period is an important time for synaptic growth, with increases in the sensorimotor areas of the cortex, parietal, temporal, and primary visual cortex, basal ganglia, and cerebellar hemispheres [16]. The frontal cortex areas become more active by 6 - 8 months and by about 9 months greater infant motor control enables infants to interact meaningfully with objects and people in their environment, begin to understand language and express sounds used in language, and to learn through imitating the actions of others. Although young infants can express emotion because the amygdala, part of the limbic system, is well formed at birth, during the 6 to 18-month period the limbic cortex, where emotions are recognized, becomes more mature. Also, activation of "mirror neurons" located in the parietal and frontal lobe [17] help the child both imitate and understand the actions of others. The brain's weight at age one is about twice its birth weight.

Because infant experiences with people and with the physical environment are so important for the development of extensive synaptic connections, parents and other caregivers should be aware of what early interactive practices facilitate infant brain development. Activities enjoyed by infants, such as being touched, looking, tasting, and manipulating objects, and being bounced, swung, or lifted all contribute to infant's ability to coordinate voluntary movement. Later activities, such as play with objects and with people in games like 'peek-a-boo' as well as a rich language and play environment, enhance the development of higher infant brain centers. Other conditions that affect how richly infant brain growth include having their basic needs met, such as sufficient food, shelter, and safety.

Toddler/Preschool Brain Development

The rapid growth of the brain continues during this age period and it is a time of environmental vulnerability, especially in relation to language and cognitive development. During the ages 3 to 6, synaptogenesis continues rapidly; by age 4 cerebral metabolic rates of glucose utilization are two times normal adult levels [18]; and refinements in fine motor, sensory-motor, memory, and language are active. There also is evidence of significant and consistent correlations between amygdala size and language abilities [19]. The 3 - 6 age period shows the fastest growth rates in the frontal networks that regulate planning of new actions [20]. Sensorimotor organization, stages of observation and perception, age, and language contexts all affect young children's language development [21].

During these years it is also clear that the impact of poor environmental conditions, especially abusive conditions, show particularly deleterious effects on children. Abused children often show a different pattern of electrical activity in the frontal and temporal lobes (in the site of limbic system functions). Hart and Rubia [22] in a review of neuroimaging studies of child abuse indicate that deficits in IQ, memory, working memory, attention, response inhibition and emotion discrimination are all associated with evidence of abuse. The hippocampus may be atrophied in children who endure abusive situations, resulting in long term memory deficits [23]. In studies of children who had been sexually abused in early childhood [24], the researchers found that at school age these children had smaller brain volume and larger lateral ventricles, and there was less development of the corpus callosum.

While evidence of harm to various brain areas is not always consistent, both ERP and fMRI studies have shown that maltreated children often are hyper-vigilant regarding potential social threats, which may "be at the cost of other developmental processes" [6]. Although critical periods for optimum brain development vary, "all critical periods probably begin within the first four years of life, when the synaptic tide turns from waxing to waning in all brain areas" [14].

Summary

Because the evidence from brain development research is now so clear, it is imperative that public policy efforts to ensure that society's youngest members have every opportunity to develop to their highest potential should include greater emphasis on the fact that optimum brain development during the prenatal, infant, and toddler/preschool age levels is of utmost importance. Many societal problems that occur at later ages might be ameliorated if every young person had optimum brain development opportunities. A national effort should be made to 1) prevent negative prenatal influences and support good prenatal care for all pregnant women, 2) provide resources needed to support families of infants and make them aware of good practices, and 3) work to gain funding to provide all preschool children with excellent educational opportunities so that they will be effective learners throughout life. Often funding is provided to address human societal problems at later ages while funding for important early experiences are not seen as essential. The body of research on early brain development is now robust enough to make the case for needed intervention at these earliest times of life.

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Volume 10 Issue 3 March 2018
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