Early brain development research review and update

by Pam Schiller

Thanks to imaging technology used in neurobiology, we have access to useful and critical information regarding the development of the human brain. This information allows us to become much more effective in helping children in their early development. In fact, when we base our practices on the findings from medical science research, we optimize learning for all children. This article will review five research findings and new areas under investigation.

Review

The first findings from the advancement of technology in the neuroscience field made their way into the early childhood profession in *Rethinking the Brain: New Insights into Early Development* published by the Families and Work Institute (1996). This publication examined five major findings and their relevance to the development of young children and to those who work with young children.

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Finding 1: The brain of a three year old is two-and-a-half times more active than an adult's.

Infants are born with a limited amount of neurological wiring. Their vision is rudimentarily wired, as are their hearing and other senses. Nothing is wired in the higher region of the brain, known as the cerebellum. The hardware is in place and ready to wire but requires 'earthly' experiences and human interactions for the cells to forge the neurological networks that will become the foundation for thinking and reasoning, language, physical movement, and social and emotional behaviors. During the first three years of life, a child builds an estimated 1,000 trillion synapses through the experiences she encounters.

Finding 2: Brain development is contingent on a complex interplay between genes and the environment.

One of the most dramatic findings from medical research was the significant role the environment plays in the structure and capacity of the brain. Daniel Goleman (2006) says, "Seventy percent of what is given to us genetically is brought to fruition by our environmental experiences." The richer the environment and the more intentional and purposeful the interactions and experiences, the greater the number of neurological connections children are able to forge.

Finding 3: Experience wires the brain. Repetition strengthens the wiring.

The primary task of the brain during early childhood is to connect brain cells (neurons). Every neuron has an axon, which sends information out to other neurons, and several dendrites, which receive information from the other cells. As axons hook up with dendrites, trillions of connections, called synapses, are formed. Everything we learn is stored in communities of neurons. Experience forges the connections and repetition strengthens them.

Finding 4: Brain development is non-linear (Families and Work Institute, 1996).

There are fertile times when the brain is able to wire specific skills at an optimum level. These fertile times are called 'windows of opportunity.' The windows are scientific; they are open from birth to puberty. The open windows of opportunity are the same for all children, no matter where on the planet they are born, and no matter the conditions under which they are born — premature, developmentally-delayed, or typically-developing. Positive experiences during open (fertile) windows result in positive outcomes. Negative experiences during open windows result in a negative outcome. (See Table 1 on next page.)

Finding 5: Early relationships affect 'wiring.'

Young children depend on adults — parents, teachers, and caregivers. They are biologically wired to speak, think, feel, interact, and to be mobile. However, they depend on human interaction to learn these skills. As early as four months of age, the cells that will wire for social inter-action and empathy (spindle cells and mirror neurons) are already positioning and preparing for their role in the child's social and emotional intelligence. According to Daniel Goleman (2006), how prolific they are depends on various factors, such as a loving atmosphere (for the better) and stress (for worse).

Update: What's new?

In the past two decades neuroscience has flourished. Many of the findings have become mainstream and the applications from these findings have shaped practices in early childhood classrooms and centers. For example, teachers have adapted their environments to be more brain compatible by reducing clutter and decorations. Infant and toddler teachers chatter constantly to help little ones develop early language skills. In some places infant and toddler caregivers move forward with children as they mature as opposed to sending them on to the next teacher — often a stranger.

Emerging research continues to provide findings that allow us to refine our practices. Here are some of the latest findings that have relevance to our work with children.

Finding 1: Music and language are partners in the brain.
Linguists, psychologists, and neuroscientists have recently changed their long held opinion about the relationship between speaking and singing. The latest data show that music and language are so intertwined that an awareness of music is critical to a baby's language development (Deutsch, 2010). As children grow, music fosters their communication skills. Our sense of song helps us learn to talk, read, and even make friends.

Brain areas governing music and language overlap. Music and language have much in common. Both are governed by rules and basic elements (word and notes). In language, words make phrases, which combine to make larger phrases and eventually sentences. In music, notes combine and grow to form a melody.

The neurological ties between music and language go both ways; a person's native tongue influences the way he perceives music. The same progression of notes may sound different depending on the language the listener learned growing up. Speakers of tonal languages (most Asian languages) are much more likely than Westerners to have perfect pitch. All languages have a melody that is unique. Infants echo the inherent melodies of their native language when they cry, long before they speak.

Speech has a natural melody called prosody. Prosody is the rhythmic and intonational aspect of language. It changes with emotions. The more excited the speaker, the faster the rhythm. It also emphasizes word boundaries. Prosody is exaggerated in the way people speak to infants. This high pitch sing-song language is referred to as 'parentese.'

Applications:
- Sing! Sing! Sing!
- Use 'parentese' with newborns.
- Include a time for music each day.

Finding 2: Learning styles differ greatly across situations.

Researchers have long been baffled by their inability to prove that matching the delivery of information to a student's learning style enhances learning. This notion has been treated as a truism in much of recent educational theory and practice. However, new findings from neuroscience point out that students display different learning styles in different situations (Scott et al., 2010). A child may exhibit one style while putting a puzzle together and a completely different style while participating in a music activity.

Applications:
- Spend less time focusing on 'matching' teaching to learning styles and more time setting high expectations for all children and providing the motivation and skills necessary to attain them.
- Continue including strategies that appeal to each learning style (visual, auditory, and kinesthetic) during group activities and instruction.

Finding 3: Touch, movement and gestures are critical to learning.

The sense of touch helps children to ground abstract ideas in concrete experiences. Hip-hip hooray for early childhood professionals! We have held this theory as truth for a long time.

Based on research assembled over the last 15 years, Cabrera and Cotosi (2010) have concluded that hands-on explorations contribute not only to the understanding of abstract concepts but also to four critical thinking skills essential to learning: making distinctions, recognizing relationships, organizing systems, and taking multiple perspectives. This higher level thinking starts with touch.

When children exercise, they are building muscle and they are boosting brainpower. Neuroscientist Henriette

Table 1. Windows of Opportunity

Window	Wiring Opportunity	Greatest Enhancement
Social Development	0-48 months	4 years to puberty
Attachment	0-12 months	
Independence	18-36 months	
Cooperation	24-48 months	
Emotional Intelligence	0-48 months	4 years to puberty
Trust	0-14 months	
Impulse Control	16-48 months	
Motor Development	0-24 months	2 years to puberty
Vision	0-24 months	2 years to puberty
Thinking Skills	0-48 months	4 years to puberty
Cause and Effect	16-48 months	
Problem-Solving	0-16 months	
Language Skills	0-24 months	2-7 years
Early Sounds	0-24 months	8 months to puberty
Vocabulary	4-8 months	2-5 years

van Praag, of the National Institute on Aging in Baltimore and her colleagues, among dozens of other teams of researchers, have discovered that exercise increases the amount of key proteins that help build the brain's infrastructure for learning and memory (2009).

We use gestures when explaining a complex topic but we also move our hands while simply talking with a friend. These spontaneous hand movements are not random — they reflect our thoughts (Goldin-Meadow, 2010). Children who are on the verge of mastering a task advertise this fact in their gestures. Sensitive teachers and caregivers can glean information from these exaggerated movements and often do so unconsciously. Teachers and parents will often change their own gestures in response to a child's. Children learn best from this customized instruction.

Applications:

- Continue hands-on learning oppor-tun-ities.
- Educate parents and others about the importance of hands-on learning for all children and most particularly preschool children.
- Include daily routines of exercise.
- Be sensitive to children's gestures. Exaggerated movements often foretell a breakthrough in understanding. This is the time to be patient while a child gains clarity.

Finding 4: Technology has both a positive and a negative impact on the brain.

We know that the brain's neural circuitry responds in every moment to sensory input. This constant reshaping of our brain is referred to as *neural plasticity*. For example, the current explosion of digital technology is profoundly altering the evolution of our brains. The current technological revolution (smart phones, computers, video games, etc.) is gradually strengthening new neural pathways in our brains and simultaneously weakening old pathways (Small & Vorgan, 2009).

On the positive side, technology is sharpening some cognitive abilities. We learn to react more quickly to visual stimuli, improve some forms of attention and become more adept at noticing images in our peripheral vision.

On the negative side, technology is creating something coined by Linda Stone in 1998 as "continuous partial attention" — keeping tabs on everything while never truly focusing on anything. Our brains are not built to sustain such extensive monitoring for long periods of time. Hours of unrelenting digital connectivity can create a unique type of brain strain, making people feel fatigued, irritable, and distracted.

Digital technology is not only influencing how we think, but also how we feel. As the brain evolves and shifts its focus toward new technological skills, it drifts away from fundamental social skills (reading facial expressions and grasping the emotional context of a subtle gesture). A Stanford study (2002) found that for every hour we spend on our computers, video games, or television, traditional face-to-face interaction time with other people is cut in half. Researchers suggest that we are losing personal touch with our real-life relationships and may be developing an artificial sense of intimacy.

Applications:

- Limit use of technology for preschool children.
- Encourage face-to-face interactions with peers.
- 'Be fully present' in the classroom. Model paying close attention and sincerely responding when children are speaking.

Finding #5: During sleep the brain engages in data analysis, from strengthening memories to solving problems.

For several decades we have known that the brain processes information during sleep, but what we didn't know was just how critical this processing time is for memory strengthening and the rehearsing of tasks. The latest research suggests that while we are asleep, our brain is actively processing the day's information. It sifts through recently formed memories, stabilizing, copying, and filing them so that they will be more useful the next day. A night of sleep can make memories resistant to interference from other information and enables us to recall them for use more effectively the next morning (Ellenbogen et al., 2007).

Researchers have found that adults who get at least six hours of sleep at night are two-and-a-half times more likely to be able to solve problems presented during a learning episode the next time they encounter the same or a similar problem than are those who get fewer hours of sleep. It needs to be pointed out that six hours of sleep is the minimum. Researchers say that eight is optimal for adults. For children, the recommended amount of sleep varies by age. A preschooler, for example, should be getting nine to ten hours of sleep each day.

Applications:

- Encourage families to make sure their children are going to bed early enough to acquire nine to ten hours of sleep each evening.
- Make sure you get your eight hours each night.

Conclusion

These are only a few of the many findings that are emerging daily in the field of brain study. There is a great deal more promising research on the horizon. For example, scientists are on the brink of providing definitive information regarding autism, maternal stress on the unborn fetus, the impact of maternal levels of testosterone in the womb on the development of the right hemisphere, and much more. There has never been a field of research more related to our work with children than this. Keep reading, studying, and applying. There are many findings in early brain research with important implications for you and the children whose lives you are shaping.

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Further reading

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Useful Web Sites

iamyourchild.org
Parents Action for Children brings leading child development experts together to help raise public awareness about the critical importance that the prenatal period through the first early years plays in a child's healthy brain development.

naeyc.org
The National Association for the Education of Young Children (NAEYC) is dedicated to improving the well-being of all young children, with particular focus on the quality of educational and developmental services for all children from birth through age 8.

nccic.org
The National Child Care Information and Technical Assistance Center (NCCIC), a service of the Child Care Bureau, is a national clearinghouse and technical assistance (TA) center that provides comprehensive child care information resources and TA services to Child Care and Development Fund (CCDF) Administrators and other key stakeholders.

zerotothree.org
ZERO TO THREE supports the healthy development and well-being of infants, toddlers and their families. It is a national nonprofit multidisciplinary organization that advances its mission by informing, educating and supporting adults who influence the lives of infants and toddlers.

(For an excellent overall review of brain development written for developmental scientists, see Nowakowski & Hayes, 2012; Stiles, 2008.) View chapter Purchase book. Read full chapter.Â Brain development begins early and continues for many years after birth, with adult neurogenesis occurring throughout life for CNS repair. Originally, the epiblast cells of the embryo differentiate into primary stem cells, some of which then become neuroectodermal cells, and subsequently, neuroepithelial cells (neural stem/progenitor cells) that generate all the cells, which the brain and CNS are composed of.9 Thus, the NSCs are also called neural progenitor cells. This article reviews five research findings and new areas under investigation. (Contains 1 table and 4 online resources.)Â Thanks to imaging technology used in neurobiology, people have access to useful and critical information regarding the development of the human brain. This information allows them to become much more effective in helping children in their early development. In fact, when people base their practices on the findings from medical science research, they optimize learning for all children. This article reviews five research findings and new areas under investigation. (Contains 1 table and 4 online resources.)