Adolescent Brains are Works in Progress

Here's Why

by FRONTLINE producer Sarah Spinks

Sarah Spinks is an independent director and producer. She was with the Canadian Broadcasting Corporation for 17 years, where her documentaries won many awards. Spinks' last FRONTLINE documentary, "Making Babies," reported on state-of-the-art infertility treatments.

Over the past 25 years, neuroscientists have discovered a great deal about the architecture and function of the brain. Their discoveries have led to huge strides in medicine, from pinpointing the timing at which children should be operated on for vision problems to shedding light on the mechanisms that cause such diseases as schizophrenia. Much of the early focus of the research was on the early years of development or on diseased brains. Now, with the advent of new imaging techniques, researchers are able to examine normal brains and brains of people throughout their lives.

More Information

See more about MRI's and fMRI's from PBS's "Secret Life of the Brain" web site.

Before the advent of magnetic resonance imaging (MRI), scientists already knew a lot about how the brain functioned. When people suffered brain damage or injury to particular parts of the brain, scientists could see what functions were impaired, and infer that the injured areas governed those functions. For example, people who had strokes in the area of the brain affecting speech lost the ability to speak.

Autopsies showed when particular parts of the brain matured, the connections were wrapped in white matter, or myelin.

With functional MRIs, researchers can see how the brain actually functions -- what parts of the brain use energy when performing certain tasks. They know, for instance, the particular part of the brain that "lights up" when performing a visual task. Those images in which brain activity is measured are called "functional" because they measure how the brain performs tasks rather than simply mapping out the structure of the brain.

FRONTLINE's "Inside the Teenage Brain" focuses on work done by Dr. Jay Giedd at the National Institute of Mental Health in Bethesda, Md., together with colleagues at McGill University in Montreal. In a particularly interesting study, Dr. Giedd looked at the brains of 145 normal children by scanning them at two-year intervals. This was work Giedd was only able to do with magnetic resonance imaging, because it requires neither harmful dyes nor radiation, making the study of normal children, as opposed to sick ones, ethically tenable.

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What the researchers have found has shed light on how the brain grows and when it grows. It was thought at one time that the foundation of the brain's architecture was laid down by the time a child is five or six. Indeed, 95 percent of the structure of the brain has been formed by then. But these researchers have discovered changes in the structure of the brain that appear relatively late in child development.

- Changes in the Prefrontal Cortex

Giedd and his colleagues found that in an area of the brain called the prefrontal cortex, the brain appeared to be growing again just before puberty. The prefrontal cortex sits just behind the forehead. It is particularly interesting to scientists because it acts as the CEO of the brain, controlling planning, working memory, organization, and modulating mood. As the prefrontal cortex matures, teenagers can reason better, develop more control over impulses and make judgments better. In fact, this part of the brain has been dubbed "the area of sober second thought."

The fact that this area was still growing surprised the scientists. Although they knew that the brain of a baby grew by over-producing synapses, or connections, they had not known that there was a second period of over-production. In a baby, the brain over-produces brain cells (neurons) and connections between brain cells (synapses) and then starts pruning them back around the age of three. The process is much like the pruning of a tree. By cutting back weak branches, others flourish. The second wave of synapse formation described by Giedd showed a spurt of growth in the frontal cortex just before puberty (age 11 in girls, 12 in boys) and then a pruning back in adolescence.

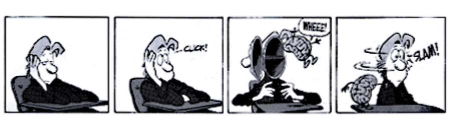
Even though it may seem that having a lot of synapses is a particularly good thing, the brain actually consolidates learning by pruning away synapses and wrapping white matter (myelin) around other connections to stabilize and strengthen them. The period of pruning, in which the brain actually loses gray matter, is as important for brain development as is the period of growth. For instance, even though the brain of a teenager between 13 and

18 is maturing, they are losing 1 percent of their gray matter every year.

Giedd hypothesizes that the growth in gray matter followed by the pruning of connections is a particularly important stage of brain development in which what teens do or do not do can affect them for the rest of their lives. He calls this the "use it or lose it principle," and tells FRONTLINE, "If a teen is doing music or sports or academics, those are the cells and connections that will be hardwired. If they're lying on the couch or playing video games or MTV, those are the cells and connections that are going to survive."

- **Corpus Callosum and Cerebellum**

In another study of growth patterns of the developing brain, Paul Thompson of the University of California at Los Angeles, along with Jay Giedd and colleagues from McGill University, found waves of growth in the corpus callosum, a fiber system that relays information between the hemispheres of the brain. Of particular interest to educators and parents is their finding that the fiber systems influencing language learning and associative thinking grew more rapidly than surrounding regions before and during puberty (a similar period to the growth of the frontal cortex), but fell off shortly after. These findings reinforce studies on language acquisition that show that the ability to learn new languages declines after the age of 12. [1]



These studies of the corpus callosum are part of a large multi-centered research study on twins. Researchers are hopeful that twin studies will also shed light on the age-old question of nature or nurture -- which traits and characteristics are due to genetics and which can be affected by the environment. For instance, the studies have shown that the corpus callosi of twins are so similar that one can put 10 twin brain MRIs on view and even a novice can spot the pairs. The researchers therefore hypothesize that this part of the brain is largely controlled by genes. However, another piece of neuroanatomy, the cerebellum, at the back of the head just above the neck, is not very similar in twins, leading Giedd to hypothesize that the cerebellum is not genetically controlled and is thus susceptible to the environment.

Interestingly, the cerebellum is a part of the brain that changes well into adolescence. Scientists think the cerebellum helps in physical coordination. But looking at functional imaging studies of the brain, researchers also see activity in the cerebellum when the brain is processing mental tasks. Giedd thinks it works like this: "It's like a math co-processor. It's not essential for any activity ... but it makes any activity better. Anything we can think of as higher thought, mathematics, music, philosophy, decision-making, social skill, draws upon the cerebellum. ... To navigate the complicated social life of the teen and to get through these things instead of lurching seems to be a function of the cerebellum."

- **Cautionary Words**

Jay Giedd and his colleagues have given us a new window into understanding how the pre-adolescent brain develops. It confirms what other neuroscientists have outlined over the past 25 years -- that different parts of the brain mature at different times. In particular, it corroborates the work of neuroscientists like Peter Huttenlocher who have shown that the frontal cortex of human beings matures relatively late in a child's life.

However, knowing more about the *structure* of the brain does not necessarily tell us more about the *function* of the brain. It is a good hypothesis that if a particular structure is still immature, the functions it governs will show immaturity. Thus, there is fairly widespread agreement that adolescents take more risks at least partly because they have an immature frontal cortex, because this is the area of the brain that takes a second look at something and reasons about a particular behavior. However, moving from structure to function, deciding what *behavior* is caused by what part of the brain is much more complicated.

Jack Shonkoff, professor of child development at Brandeis University and author of *From Neurons to Neighborhoods*, warns policymakers to be careful about interpreting the findings of neuroscientists too simplistically. In his interview with FRONTLINE, Shonkoff says, "The caution is really to be careful about what's not quite ready for prime time yet in terms of application."

John Bruer, the author of *The Myth of the First Three Years* and the president of the James S. McDonnell Foundation, is more blunt. Says Bruer: "This simple, popular, newsweekly-magazine idea that adolescents are difficult because their frontal lobes aren't mature is one we should be very cautious of. Yes, there are adolescents that are hard to get along with. There are adults that are hard to get along with for the same reason. Presumably, the adults have mature frontal areas. There are very young children who seem to have no problem with this. Very immature brain structure, yet results in very sophisticated behavior. So this notion there's going to be some easy connection between counting synapses or measuring white matter and the kinds of behaviors people display or we want them to display is one we're going to have to do a lot more work on before it's science."

Despite the caveats about how much we can know about brain function and how readily any of this work can be translated into policy, it is clear from the research that the brain is a good deal more plastic or changeable than we once thought. Important structural changes are taking place well into adolescence and beyond. Except for a few well-defined sensitive periods for certain types of vision, hearing, and first-language learning, the brain is capable of growth well beyond the first few years of life. An important part of the growth is happening just before puberty and well into adolescence. The brain research adds new dimensions to our understanding of adolescence -- a time of both heightened opportunity and risk.