http://www.pbs.org/wgbh/pages/frontline/shows/teenbrain/work/onereason.html

One Reason Teens Respond Differently to the World: Immature Brain Circuitry

By FRONTLINE producer Sarah Spinks

We used to think that teens respond differently to the world because of hormones, or attitude, or because they simply need independence. But when adolescents' brains are studied through magnetic resonance imaging (MRI), we see that they actually work differently than adult brains.

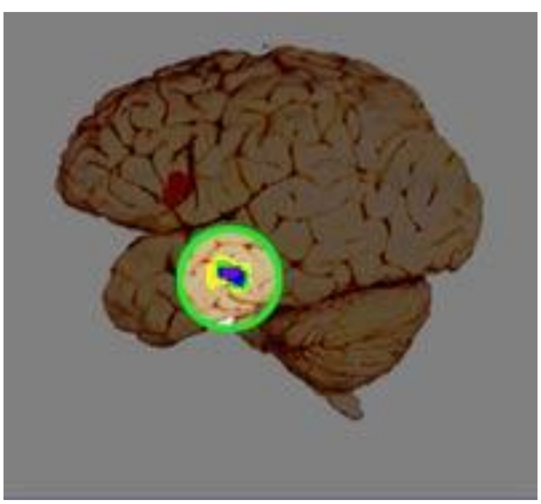
Many teen subjects failed to interpret the emotion in faces like this one as fear.

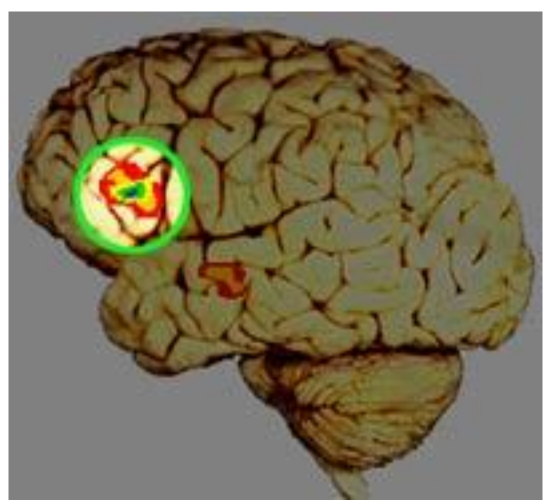
At the McLean Hospital in Belmont, Mass., Deborah Yurgelun-Todd and a group of researchers have studied how adolescents perceive emotion as compared to adults. The scientists looked at the brains of 18 children between the ages of 10 and 18 and compared them to 16 adults using functional magnetic resonance imaging (fMRI). Both groups were shown pictures of adult faces and asked to identify the emotion on the faces. Using fMRI, the researchers could trace what part of the brain responded as subjects were asked to identify the expression depicted in the picture.

The results surprised the researchers. The adults correctly identified the expression as fear. Yet the teens answered "shocked, surprised, angry." And the teens and adults used different parts of their brains to process what they were feeling. The teens mostly used the amygdala, a small almond shaped region that guides instinctual or "gut" reactions, while the adults relied on the frontal cortex, which governs reason and planning.

As the teens got older, the center of activity shifted more toward the frontal cortex and away from the cruder response of the amygdala.

Yurgelun-Todd, director of neuropsychology and cognitive neuroimaging at McLean Hospital believes the study goes partway to understanding why the teenage years seem so emotionally turbulent. The teens seemed not only to be misreading the feelings on the adult's face, but they reacted strongly from an area deep inside the brain. The frontal cortex helped the adults distinguish fear from shock or surprise. Often called the executive or CEO of the brain, the frontal cortex gives adults the ability to distinguish a subtlety of expression: "Was this really fear or was it surprise or shock?" For the teens, this area wasn't fully operating.





When reading emotion, teens **(left)** rely more on the amygdala, while adults **(right)** rely more on the frontal cortex.

Reactions, rather than rational thought, come more from the amygdala, deep in the brain, than the frontal cortex, which led Yurgelun-Todd and other neuroscientists to suggest that an immature brain leads to impulsivity, or what researchers dub "risk-taking behavior." Although it was known from animal studies and brain-injured people that the frontal cortex matures more slowly than other brain strucures, it has only been with the advent of functional MRI that researchers have been able to study brain activity in normal children.

The brain scans used in these studies are a valuable tool for researchers. Never before have scientists been able to develop data banks of normal, healthy children. Outlining the changes in normal function and development will help researchers determine the causes of psychiatric disorders that afflict children and adolescents.

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.

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http://www.pbs.org/wgbh/pages/frontline/shows/teenbrain/work/adolescent.html

Adolescent Brains are Works in Progress

By Frontline Producer Sarah Spinks

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.

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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.

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.

http://www.help4teachers.com/prefrontalcortex.htm

How the Adolescent Brain Challenges the Adult Brain

By Dr. Kathie F. Nunley

What makes the adolescent brain so challenging to the adult brain? Anyone who has ever tried to parent, teach or mentor the adolescent brain knows it can create some frustrating moments. A lot of this frustration can be blamed on some of the biology unique to the adolescent brain.

In any aged brain, the region responsible for basic survival needs (eat, flight/fight, sex) are handled by a region known as the hypothalamus. For obvious reason, the hypothalamus is powerful, influential and ready to function right from birth. Biologically speaking, if this area was not given top priority, the animal may not survive for long.

One of the frustrations with adolescents is due to the fact that hormones, environment, and learning make this survival region of the brain a "hot area" in adolescent brains.

In addition, the basic survival drives of the hypothalamus don't always agree with the social structure, morals and safety of society. For the more "civilized" human behaviors we need to involve higher regions of the brain. Higher brain regions, in the cortex, can over-ride the hypothalamus. Although these regions are not given biological priority, they are the "logical" parts of the brain and are responsible for deciding when basic hypothalamus drives may not be in our best long-term interest.

A region called the prefrontal cortex plays the role of arbitrator in making these critical decisions. It quickly sizes up the situation and makes a determination, which then drives our behavior. It is the prefrontal cortex then that tells us when to act on our anger, or curtail it, eat that second piece of dessert, or go without, seek immediate gratification or hold off for the long term.

Unfortunately some people have a poorly developed or poorly functioning prefrontal cortex. These people have a hard time controlling impulsive behaviors. Head trauma, alcohol and drug abuse as well as possible genetic predispositions can all lead to a dysfunctional prefrontal cortex. Maturity also plays a big role as this area takes about 20 years to fully develop. Hence, adolescents may have problems quickly sizing up risks and making good long-term decisions.

Other biological factors make adolescent brains even more hypothalamus driven. Children learn what to do with anger by watching other people in their sphere of influence and what they do when they are angry. Peer-influence peaks during the teen-age years, which means that key role models for an adolescent are other adolescents.

The hormone, oxytocin, found in the brain during romantic relationships, tends to settle and stimulate the hypothalamus during the beginning stages of the relationship. Anyone working with adolescents knows that they are always in the midst of "new love", which only further hampers logical decision-making.

So adolescents appear to have at least 3 strikes against them when it comes to using logic to weigh the risks in dangerous or sometimes even everyday types of decisions. The more primitive regions of their brains are strong and tend to drive behaviors. The immature region responsible for the logic of long-term benefits does not always override the impulsive, survival-oriented hypothalamus. Add any additional trauma to the mix such as abusive households or drug and alcohol use and the issue becomes even more severe.

The biology of brain shows that adolescents still need strong adult guidance and help with decision making throughout the teen-age years. Time and good role models will fortunately allow the brain to eventually mature to match the body.

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