

FRONTLINE

Interview with Dr. Jay Giedd

Inside the Teenage Brain



What has surprised you about looking at the adolescent brain?

The most surprising thing has been how much the teen brain is changing. By age six, the brain is already 95 percent of its adult size. But the gray matter, or thinking part of the brain, continues to thicken throughout childhood as the brain cells get extra connections, much like a tree growing extra branches, twigs and roots. In the frontal part of the brain, the part of the brain involved in judgment, organization, planning, strategizing -- those very skills that teens get better and better at -- this process of thickening of the gray matter peaks at about age 11 in girls and age 12 in boys, roughly about the same time as puberty.

After that peak, the gray matter thins as the excess connections are eliminated or pruned. So much of our research is focusing on trying to understand what influences or guides the building-up stage when the gray matter is growing extra branches and connections and what guides the thinning or pruning phase when the excess connections are eliminated.

And what do you think this might mean, this exuberant growth of those early adolescent years?

I think the exuberant growth during the pre-puberty years gives the brain enormous potential. The capacity to be skilled in many different areas is building up during those times. What the influences are of parenting or teachers, society, nutrition, bacterial and viral infections -- all these factors -- on this building-up phase, we're just beginning to try to understand. But the pruning-down phase is perhaps even more interesting, because our leading hypothesis for that is the "Use it or lose it" principle. Those cells and connections that are used will survive and flourish. Those cells and connections that are not used will wither and die.

So if a teen is doing music or sports or academics, those are the cells and connections that will be hard-wired. If they're lying on the couch or playing video games or MTV, those are the cells and connections that are going [to] survive.

Right around the time of puberty and on into the adult years is a particularly critical time for the brain sculpting to take place. Much like Michelangelo's David, you start out with a huge block of granite at the peak at the puberty years. Then the art is created by removing pieces of the granite, and that is the way the brain also sculpts itself. Bigger isn't necessarily better, or else the peak in brain function would occur at age 11 or 12. ... The advances come from actually taking away and pruning down of certain connections themselves.

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The frontal lobe is often called the CEO, or the executive of the brain. It's involved in things like planning and strategizing and organizing, initiating attention and stopping and starting and shifting attention. It's a part of the brain that most separates man from beast, if you will. That is the part of the brain that has changed most in our human evolution, and a part of the brain that allows us to conduct philosophy and to think about thinking and to think about our place in the universe.

I think that [in the teen years, this] part of the brain that is helping organization, planning and strategizing is not done being built yet ... [It's] not that the teens are stupid or incapable of [things]. It's sort of unfair to expect them to have adult levels of organizational skills or decision making before their brain is finished being built. ...

It's also a particularly cruel irony of nature, I think, that right at this time when the brain is most vulnerable is also the time when teens are most likely to experiment with drugs or alcohol. Sometimes when I'm working with teens, I actually show them these brain development curves, how they peak at puberty and then prune down and try to reason with them that if they're doing drugs or alcohol that evening, it may not just be affecting their brains for that night or even for that weekend, but for the next 80 years of their life. ...

Tell me a little bit about how the brain develops.

How does the brain -- arguably the most complicated three-pound mass of matter in the known universe -- how does the brain become the brain? It does so through two simple but powerful processes.

The first one is over-production. The brain produces way more cells and connections than can possibly survive. There's only so many nutrients, there's only so many growth factors, there's only so much room in the skull. After this vast over-production, there is a fierce, competitive elimination, in which the brain cells and connections fight it out for survival. Only a small percentage of the cells and connections make it.

This is a process that we knew happened in the womb, maybe even the first 18 months of life. But it was only when we started following the same children by scanning their brains at two-year intervals that we detected a second wave of over-production. This second wave of over-production is manifest by an actual thickening in the gray matter, or the thinking part, in the front part of the brain.

As this second wave of over-production is occurring, it prepares the adolescent brain for the challenges of entering the next stage of life, the adult years. There's enormous potential at that time. People can take many different life directions. But about around that time of puberty, people start specializing, so to speak. They start deciding, "This is what I'm going to be good at, whether it be sports or academics or art or music." All the life choices, even though they are still there, start getting whittled away, and we have to start sort of focusing in on what makes us unique and special. ...

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Do you have particular concerns about that period, too, though?

Yes. It's a time of enormous opportunity and of enormous risk. And how the teens spend their time seems to be particularly crucial. If the "Lose it or use it" principle holds true, then the activities of the teen may help guide the hard-wiring, actual physical connections in their brain.

Can you describe to me what people used to believe about the brain, actually, very recently?

One of the most exciting discoveries from recent neuroscience research is how incredibly plastic the human brain is. For a long time, we used to think that the brain, because it's already 95 percent of adult size by age six, things were largely set in place early in life. ... [There was the] saying. "Give me your child, and by the age of five, I can make him a priest or a thief or a scholar."

[There was] this notion that things were largely set at fairly early ages. And now we realize that isn't true; that even throughout childhood and even the teen years, there's enormous capacity for change. We think that this capacity for change is very empowering for teens. ...

This is an area of neuroscience that's receiving a great deal of attention ... the forces that can guide this plasticity. How do we optimize the brain's ability to learn? Are schools doing a good job? Are we as parents doing a good job? And the challenge now is to ... bridging the gap between neuroscience and practical advice for parents, teachers and society. We're not there yet, but we're closer than ever, and it's really an exciting time in neuroscience. ... The next step will be, what can you do about it, what can we do to help people? What can we do to help the teen optimize the development of their own brain? ...

There has been a great deal of attention on the early years, and particularly on stimulating the early brain. What do you think of that work and that popularization of that brain science?

There's been a great deal of emphasis in the 1990s on the critical importance of the first three years. I certainly applaud those efforts. But what happens sometimes when an area is emphasized so much, is other areas are forgotten. And even though the first 3 years are important, so are the next 16. And the ages between 3 and 16, there's still enormous dynamic activity happening in brain biology. I think that that might have been somewhat overlooked with the emphasis on the early years. ...

Not so long ago, people were emphasizing teaching little children through flashcards, through particular kinds of mobiles with black-and-white checks on them, playing Mozart. In fact, some states have sent CDs back with new

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mothers. What do you think of that? Has that been a misinterpretation of brain science?

... We all want to do the best for our children. And what I fear is happening is that we're leaping too far from the neuroscience to such things. I don't think there is any established videotape or CD or computer program or type of music to play that we've shown with any scientific backing to actually help our children.

The more technical and more advanced the science becomes, often the more it leads us back to some very basic tenets of spending loving, quality time with our children. The brain is largely wired for social interaction and for bonding with caretakers. And sometimes it's even disappointing to people that, with all the science and all the advances the best advice we can give is things that our grandmother could have told us generations ago: to spend loving, quality time with our children. ... I think [it] probably does more harm than good for parents to be confronted with so many of these conflicting reports in the media without any scientific basis. ...

What directions is the research taking to explore how we can optimize brain development?

Now that we've been able to detect the developmental path of different parts of the brain, the next phase of our research is to try to understand what influences these brain development paths. Is it nutrient or parenting or video games or the activity of the [child]? Or is it genes? By studying twins, we can begin to address some of these very basic nature/nurture-type of questions.

For instance, when twins are in the first grade, their parents often dress them in the same clothes. They get the same haircut. It's sort of cute how alike they are. But that's not as cool in high school anymore. And so a lot of the twins as teens in high school start doing different things. The one who was a little bit better in sports may become an athlete. The one who was a little bit better at academics may become a scholar. Or one may turn to music and one to art. But they often have different daily activities.

So we can scan the brains when the twins are young and doing everything very much alike; then we can scan them as teenagers, when they start having different daily activities. This gives us a sense of which parts of the brain are influenced by behavior and which parts by the genes themselves.

We've already got some interesting early data on this. One part of the brain is called the corpus callosum. It's a thick cable of nerves that connects that two halves of the brain and is involved in creativity and higher type of thinking. It's very popular for imaging studies because it leaps out of the picture. It's very easy to measure and quantify.

It's also interesting because it changes a lot throughout childhood and adolescence. It's been reported to be different in size and shape in many different illnesses that happen during

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childhood ... many higher cognitive thought [processes] like creativity and ability to solve problems. So it's been of great interest, especially to child psychiatrists. And what we find is that the size and shape of the corpus callosum is remarkably similar amongst twins ... and [so] seems to be surprisingly under the control of the genes.

But another part of the brain -- the cerebellum, in the back of the brain -- is not very genetically controlled. Identical twins' cerebellum are no more alike than non-identical twins. So we think this part of the brain is very susceptible to the environment. And interestingly, it's a part of the brain that changes most during the teen years. This part of the brain has not finished growing well into the early 20s, even. The cerebellum used to be thought to be involved in the coordination of our muscles. So if your cerebellum is working well, you were graceful, a good dancer, a good athlete.

But we now know it's also involved in coordination of our cognitive processes, our thinking processes. Just like one can be physically clumsy, one can be kind of mentally clumsy. And this ability to smooth out all the different intellectual processes to navigate the complicated social life of the teen and to get through these things smoothly and gracefully instead of lurching ... seems to be a function of the cerebellum.

And so we think it's intriguing that we see all these dynamic changes in the cerebellum taking place during the teen years, along with the changes in the behaviors that the cerebellum subserves.

What would influence the development of the cerebellum?

Traditionally it was thought that physical activity would most influence the cerebellum, and that's still one of the leading thoughts. It actually raises thoughts about, as a society, we're less active than we ever have been in the history of humanity. We're good with our thumbs and video games and such. But as far as actual physical activity, running, jumping, playing, children are doing less and less of that, and we wonder, long term, whether that may have an effect on the development of the cerebellum.

The recess and play seems to be the first thing that is cut out of school curriculums in tight times. But those actually may be as important, or maybe even more important, than some of the academic subjects that the children are doing. ... We think that the "Use it or lose it" principle holds for the cerebellum as well. If the cerebellum is exercised and used, both for physical activity but also for cognitive activities, that it will enhance its development.

... One analogy that computer people use is that [the cerebellum is] like a math co-processor. It's not essential for any activity. People can get by quite well without large chunks of it. But it makes many activities better. The more complicated the activity, the more we call upon the cerebellum to help us solve the problem. And so almost anything that one can think of as higher thought -- mathematics, music, philosophy, decision making, social skills -- seems to draw upon the cerebellum. ...

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The relationship between the findings that we have in the cerebellum and sort of practical advice or the links between behavior are not well worked out yet. That's going to be one of the great challenges of neuroscience -- to go from these neuroscience facts to useful information for parents, for teachers or for society. But it's just so recently that we've been able to capture the cerebellum that no work has yet been done on the forces that will shape the cerebellum or the link between the cerebellum shape or size and function.

When you look at the recent work that you've done in terms of the frontal cortex, do you see a difference between girls and boys?

Yes. One of the things that we're particularly interested in as child psychiatrists is the difference between boys' brains and girls' brains, because nearly everything that we look at as child psychiatrists is different between boys and girls -- different ages of onset, different symptoms, different prevalences and outcomes. Almost everything in childhood is more common in boys -- autism, dyslexia, learning disabilities, ADHD, Tourette's syndrome -- are all more common in boys. Only anorexia nervosa is more common in girls. So we wonder if the differences between boys' and girls' brains might help explain some of these clinical differences.

The male brain is about 10 percent larger than the female brain across all the stages of ... 3 to 20; not to imply that the increased size implies any sort of advantage, because it doesn't. The IQs are very similar. But there are differences between the boy and girl brains, both in the size of certain structures and in their developmental path. The basal ganglia which are a part of the brain that help the frontal lobe do executive functioning are larger in females, and this is a part of the brain that is often smaller in the childhood illnesses. I mentioned, such as ADD and Tourette's syndrome.

So girls, by virtue of having larger basal ganglia, may be afforded some protection against these illnesses. But in the general trend for brain maturation, it's that girls' brains mature earlier than boys' brains. ...

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