The Teenage Brain

Getting Inside a Teen Brain

Sharon Begley

You probably recognize the species: it's known for making stupid decisions... barely able to plan beyond the next minute... clueless when it comes to reading parents' facial expressions... exhibits poor self-control... seems to think with its hormones more than its brain... all thumbs when juggling several tasks.

Such is *Homo teenageris*.

But while the adolescent mind has been well documented, the reason kids passing through and just beyond puberty seem to be members of a different species has been a puzzle, though raging hormones and simple rebellion are handy scapegoats. It turns out there's a good reason adolescent brains seem different: they are. Contrary to the notion that the brain has fully matured by the age of 8 or 12, with the truly crucial wiring complete as early as 3, it turns out that the brain is an ongoing construction site. "Maturation does not stop at age 10, but continues into the teen years and even the 20s," says Jay Giedd of the National Institute of Mental Health. "What is most surprising is that you get a second wave of overproduction of gray matter, something that was thought to happen only in the first 18 months of life."

The brain reaches about 95 percent of its adult volume by the age of 5 or so. To get beyond such crude measures, in the early 1990s Giedd and colleagues began snapping images of the brains of healthy kids with magnetic resonance imaging (MRI) every two years. The first surprise came last May, with the discovery that the corpus callosum, the cable of nerves that connects the right half of the brain to the left, "continues growing into your 20s," says Giedd. Although the effect of an immature corpus callosum is not crystal clear, let us simply note that this structure has been implicated in intelligence, consciousness and self-awareness.

Until now, studies of the brains of children and adolescents have shown that their gray matter decreases with age. The rule seems to be "use it or lose it": connections among neurons that are not used wither away, a process called pruning. But neuroscientists led by Elizabeth Sowell of UCLA's Lab of Neuro Imaging found that the story is not so simple. They used MRI to compare the brains of 12- to 16-year-olds to those of twentysomethings. What they found will surprise no one who has a teen or is a teen or just remembers being a teen: the frontal lobes, responsible for such "executive" functions as self-control, judgment, emotional regulation, organization and planning, undergo the greatest change between puberty and young adulthood. They grow measurably between 10 and 12 (with girls' growth spurt generally coming a little earlier than boys'), then shrink into the 20s as extraneous branchings are pruned back into efficient, well-organized circuitry. Giedd's team, using MRI to scan the brains of 145 healthy 4- to 21-year-olds, also "found that the grey matter in the frontal lobes increased through age 11 or 12," as they reported in the journal Nature Neuroscience. "Then there is a noticeable decline. It looks like there is a second wave of creation of gray matter at puberty, probably related to new connections and branches, followed by pruning." Neuronal connections that underlie cognitive and other abilities stick around if they're used, but wither if they're not.

Toddlers are pretty much at the mercy of their parents when it comes to the kind and amount of environmental stimulation they get, and thus which connections remain. Teenagers, however, create their own world. "Teens thus have the power to determine their own brain development, to determine which connections survive and which don't," says Giedd. "Whether they do art, or music, or sports, or videogames, the brain is figuring out what it needs to survive and adapting accordingly."

Things get even more interesting once neuroscientists look beyond the frontal lobes. When the UCLA team scanned the brains of 19 normal children and adolescents, ages 7 and 16, they found that the parietal lobes (which integrate information from far-flung neighborhoods of the brain, such as auditory, tactile and visual signals) are still maturing through the midteens. The long nerve fibers called white matter are probably still being sheathed in myelin, a fatty substance that lets nerves transmit signals faster and more efficiently. As a result, circuits that make sense of disparate information are works in progress through age 16 or so. The parietal lobes reach their gray-matter peak at 10 (girls) or 12 (boys), and are then pruned. But the seats of language, as well as emotional control, called the temporal lobes, do not reach their gray-matter maximum until age 16, Giedd finds. Only then do they undergo pruning. If teens are hardly models of emotional maturity, at least they have a good excuse.

Studies at McLean Hospital outside Boston find that many teenagers are unable to read emotions in people's faces. Brain regions that light up with activity when adults read "fear" in faces are nearly dark in these teens. Their brains' emotional centers light up. But the thinking regions stay dark, as if they are unable to integrate visual, emotional and cognitive information. No wonder looking daggers at a teen hardly gets a rise out of him.

Might hormones be responsible for the changes the brain undergoes during and after adolescence? Research into this question is only in its infancy. But in one suggestive finding, Giedd reports that in girls the hippocampus, which responds to estrogen, grows faster than in boys. The hippocampus forms memories. In boys, the amygdala, which responds to androgen, grows faster than in girls. The amygdala is in charge of emotions like fear and anger.

Together, the experiments suggest that the teen brain reprises one of its most momentous acts of infancy, the overproduction and then pruning of neuronal branches. "The brain," says Sowell, "undergoes dynamic changes much later than we originally thought." Maturity is not simply a matter of slipping software (learning) into existing equipment. Instead, the hardware changes. Those changes partly reflect signals from the world outside, and seem to be a peculiarly human adaptation. Think of it as nature's way of giving us a second chance.

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Mind Expansion:

Inside the Teenage Brain

And all this time they thought it was raging hormones. Or existential angst. Or resentment of authority. But the more fundamental explanation for much of what goes on in the heads of teenagers lies ... in their heads. No sooner have teens made their peace (sort of) with the changes that puberty has inflicted on their body than their brain changes on them, too, reprising a dance of the neurons very much like the one that restructured the brain during infancy. "Brain maturation continues into the teen years and even the 20s," says Jay Giedd of the National Institute of Mental Health. As a result, although today's teens mature physically at younger ages than their parents, and although they take on many of the behavioral trappings of adulthood, "that does not mean that they understand the full implications of their behavior," says psychologist Deborah Yurgelun-Todd of McLean Hospital outside Boston. "The regions of their brain responsible for judgment, insight and planning are still immature."

Both the pattern of brain use and the structure of brain regions change through the teen years. The good news is that, around puberty, the brain blossoms with new brain cells and neural connections, something that was thought to happen only in the first 18 months of life. Then, between puberty and young adulthood the frontal lobes□ responsible for such "executive" functions as self-control, judgment, emotional regulation, organization and planning□ undergo wholesale renovation. They shrink. The reason seems to be that extraneous neuronal branchings get pruned back. Pruning also occurs in infancy, creating efficient, well-organized circuitry. The teen years are, then, a second chance to consolidate circuits that are used and prune back those that are not□ to hard-wire an ability to hit a curve ball, juggle numbers mentally or turn musical notation into finger movements almost unconsciously.

"Teens have the power to determine their own brain development, to determine which connections survive and which don't, [by] whether they do art, or music, or sports, or videogames," says Giedd.

The immaturity of the frontal lobes during the teen years may explain why the brain regions that teens use for several tasks differ from the regions adults use. McLean's Yurgelun-Todd and colleagues showed pictures of people wearing fearful expressions to teenagers between 11 and 17. Compared to adults, she finds, the teens' rational, thoughtful frontal lobes light up less and their amygdala, which registers emotions such as fear, light up more. Yet the teens often misread facial expressions, seeing sadness or anger or confusion where there was fear. The results, says Yurgelun-Todd, suggest that "in teens, the judgment, insight and reasoning power of the frontal cortex is not being brought to bear on the task as it is in adults. Teens just process information differently from adults."

Developing the ability to plan, to organize, to manage emotions, to understand others, to exhibit judgment and even to master logic and algebra requires more than slipping software into existing hardware. That's what learning is. Instead, it requires changing the very hardware of the brain. The brain you have when you enter your teen years is not the one you have when you grow out of them. Thank goodness.

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