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That teenage feeling

Harvard researchers may have found biological clues to quirky adolescent behavior.

By Erika Packard
***Monitor* Staff**
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Parents of teenagers don't have it easy. Door-slamming fights over phone use and friend choice, late nights spent lying awake envisioning benders or high-speed car chases, the futile feeling that everything you says goes in one ear and out the other. And as much as parents struggle, teens will attest that adolescence is no cakewalk for them either.

What's happening during adolescence that turns many once-sweet kids into unruly rabble-rousers? At least part of the reason may be that adolescent brains process information differently than adult brains, according to research led by neuropsychologist Deborah Yurgelun-Todd, PhD, of Harvard University's McLean Hospital Cognitive Neuroimaging and Neuropsychology Laboratory. She and her team are using neuroimaging to investigate the neural underpinnings of the emotional turmoil many teens experience. And those imaging technologies are revealing brain differences that could explain teen traits that exasperate adults, including impulsivity, poor judgment and social anxiety.

Rebellious teen behavior could stem more from biology than stubbornness, says Yurgelun-Todd.

"Don't assume that because you've laid out the argument or presented the idea that teenagers are interpreting it in the same way you've presented it," she advises. "The frontal cortex is continuing to develop, and if you don't have the neural structure in place, the adolescent cannot really think things through at the same level as an adult."

White matter and impulsivity

A teenager drives too fast around a curve and plants his car into a tree. Though he saw posted speed limits, heard parental admonitions and suffered through hours of driver's ed training, in that moment behind the wheel, he acted seemingly without thinking.

The seat of such poor judgment might be found in the white matter microstructure in the brain's prefrontal cortex, says Marisa Silveri, PhD, a psychologist in Yurgelun-Todd's lab. The frontal cortex is associated with decision-making, insight, judgment and inhibitory control. Silveri, Yurgelun-Todd and colleagues use diffusion tensor imaging (DTI) to examine white matter microstructure, the part of the brain that's responsible for relaying signals between neurons in the gray matter. During adolescence, particularly in the frontal cortex, unneeded gray matter is pruned away and white matter, made up of axons covered by a lipid membrane known as myelin, increases.

"Similar to the concept of electrical wiring, adding insulation around a bare wire improves connectivity,

and the thicker the insulation, the better the transmission of a signal from point A to point B," says Silveri. "Myelination, or the insulating of axons, allows more rapid and efficient communication between neurons."

The researchers used DTI to examine the integrity of white matter, with more coherent organization meaning that messages are relayed between neurons more effectively. In a 2006 study by Silveri, Yurgelun-Todd and colleagues in *Magnetic Resonance Imaging* (Vol. 24, No. 7, pages 833-841), the researchers found an association between white matter organization and impulse control in both boys and girls. Interestingly, white matter integrity in boys showed a stronger relationship with self-report of impulse control, a behavioral measure, whereas girls' white matter integrity showed a stronger relationship with the ability to inhibit an incorrect answer, which is a cognitive measure. The study both underscored the role of white matter in impulse control and corroborated emerging research pointing to sex differences in the developing brain, says Silveri.

"We're not saying we have found the reason kids make bad judgments, but we do think this is one of the mechanisms that contributes to why they aren't processing information as efficiently as they should be," says Yurgelun-Todd.

Social anxiety

As if struggling to make good judgments and rein in impulsive behavior isn't challenging enough, many adolescents also wrangle with social anxiety. For some, seemingly inconsequential triggers, such as being asked to work an algebra problem in front of the class or hearing a collective snicker from the cool girls in the locker room can cause sickening unease. Now, Yurgelun-Todd has found evidence tying adolescent social anxiety to brain development. In a 2005 study, in *Developmental Neuroscience* (Vol. 16, No. 15, pages 1,671-675) she examined the amygdala, which is associated with emotions, particularly fear. Yurgelun-Todd and her team showed 16 adolescents fearful or happy faces while scanning their brains in a functional magnetic resonance imaging (fMRI) machine. They found that increased amygdala activity during the presentation of fearful faces related to higher social anxiety scores, but not with other aspects of anxiety. This finding suggests that adolescents and adults tend to attribute anxiety to different causes, says Yurgelun-Todd.

"A lot of teenage behavior is about avoiding this anxiety of feeling left out and not being a part of things," she says.

For further clues between the link between adolescent emotions and brain development, Yurgelun-Todd examines the prefrontal cortex, and a process she calls increased frontalization. As the brain matures in adolescence, the prefrontal cortex assumes responsibility for many of the cognitive processes, such as reasoning, planning and behavior control, that are initially performed in the more primitive subcortical and limbic structures, she says. The development of the prefrontal cortex parallels improvements in cognitive control and behavioral inhibition as an adolescent transitions to an adult. Frontalization may underlie adolescents' growing ability to think abstractly outside of themselves, and see themselves in the way others see them, which could contribute to the feeling of being constantly on stage and judged that many teens experience.

Isabelle Rosso, PhD, who also works in Yurgelun-Todd's lab, and colleagues reported that as adolescents' abstract reasoning skills increased, so did their levels of social anxiety. Part of abstract reasoning includes being able to take an observer perspective on one's self and to make inferences about other people's thoughts and feelings. Although the emergence of abstract reasoning is ultimately a useful tool that allows adults to self regulate, in adolescence, it might contribute to higher vulnerability to social anxiety and other emotional disorders, says Rosso. "In adolescence, you start to become more self aware, and more able to think abstractly or hypothetically about other people's thoughts and feelings," says Rosso. "But that may also allow you to have more social self consciousness, and worry more about what other people are thinking about you. It may open up new vulnerabilities in some

adolescents."

Implications and applications

Parents and school officials hungry for explanations of unpredictable teen behavior might find solace in the Harvard lab's findings. However, Yurgelun-Todd cautions that just because there are neurobiological components to teen behavior doesn't discount the effect of environmental or social factors, nor does it absolve teenagers of accountability.

"I am always asked, Is there some maturational threshold that you can identify neurobiologically," she says. "We are certainly nowhere near that scientifically."

However, the recent research on teen brains has caught the attention of educators and the justice system, and Yurgelun-Todd has spoken widely to legal personnel on her findings.

"The juvenile justice system is very concerned with how to best help its adolescents," she says. "My role is to educate the system to understand that many of our adolescents are not fully mature, and they do need help with learning how to make good decisions."

Lab members also see their work as helping to identify adolescents at risk for substance abuse, depression, schizophrenia and other psychological conditions. "If we are able to identify high-risk kids early or before the onset of illness, we could become more of a preventative field, which could lead to changes in treatment strategies, an improvement in people's quality of life, and, ultimately, reduced cost of psychiatric illness for society," says Rosso.

The popularity of neuroimaging, particularly in healthy adolescents, has exploded in the last 10 years, says Linda Spear, PhD, distinguished professor of psychology at the State University of New York at Binghamton. However, as helpful as imaging technologies are for allowing a noninvasive glimpse into healthy, living tissues, the old standby, animal research, continues to provide important insights, says Spear.

"Imaging tells us which brain areas are more active at a particular time, but by and large, it doesn't tell us the mechanism underlying the change, and we don't know causally what is going on," says Spear, who studies brain development in adolescent animals. "There is a lot you can do with fMRI and MRI, but with animal studies, you can start trying to dissect down and ask about causal changes."

A combination of imaging studies and animal research will provide the most comprehensive view, says Spear. "I think the data Dr. Yurgelun-Todd came out with is very provocative," she says. "Right now it's a little bit early to understand the whole picture, but these new findings are very tantalizing."

Further reading

1.Rosso, I.M., Young, A.D., Femia, L.A. & Yurgelun-Todd, D.A. (2004). Cognitive and emotional components of frontal lobe functioning in childhood and adolescence. *Annals of the New York Academy of Sciences, 1021*, 355-362.

2.Yurgelun-Todd, D.A. & Killgore, W.D.S. (2006) Fear-related activity in the prefrontal cortex increases with age during adolescence: A preliminary fMRI study. *Neuroscience Letters, 406*, 194-199.