What Were You Thinking?! – Understanding the Neurobiology of the Teen Brain

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What Were You Thinking?!

Have you ever found yourself uttering the age-old phrase, 'What were you thinking?!' Aside from the self-directed use of this phrase by adults, this common expression is frequently directed at teens, and seems to be somewhat of a conundrum. Adults are often of the mind that teens were not thinking at all when they made that obviously awful decision. This is, however, a myth: teens are thinking, and quite rapidly at that. In fact, if you ask your teen "what was the better choice?" they often know the right answer. However, ask them "why did you do it?" and you will likely receive the less than acceptable answer, "I don't know." 'What were you thinking?!' isn't necessarily a lack of knowing right from wrong, but rather an inability to hold back the wrong answer or behavior.

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Our lab, the Neurodevelopmental Laboratory on Addictions and Mental Health, studies this phenomenon and its neurobiological underpinnings. We use neuroimaging technology (MRI) to characterize the beautiful young brain working its way through dynamic and elegant neurobiological transformations that lead to improved decision-making skills, among many other notable abilities. Why is this important? All of us are making decisions all of the time, sometimes even below the level of conscious awareness. For better or for worse, teens are constantly gaining new experiences, learning new skills, and having to make decisions, which is a complex intertwined process intended to propel them into adulthood. Brain development is delicately unfolding as some teens begin experimenting with alcohol, marijuana, and other substances, and some teens during a whirlwind of emotional storminess, start to experience significant changes in mood and anxiety. The mission of our work is to use MRI to search for potential markers in the brain that may serve as risk factors for later addictive disorders and mental health issues, particularly given that adolescent onset of alcohol/drug use and psychiatric symptoms are predictive of more severe problems in adulthood.

Biology 101 of Brain Development

We are not alone in our search for clues to the adolescent 'brain-iverse'. A PubMed search of the phrase "adolescence and brain" reveals that research in this area has exponentially exploded over the past decade, more than doubling from 2,734 citations in 2003 to 5,885 citations in 2013. One contribution to this dramatic increase is the evolution of non-invasive neuroimaging technologies that can provide a high-resolution window into the teen brain. Such technologies do not require exposure to potentially harmful x-rays or substances, making MRI particularly appealing for studying the development of the young brain. Indeed, work from our lab, and several others, document that adolescence is a critical period for brain development. For instance, overall brain size has been found to plateau around age five, followed by significant and rapid reorganization beginning around age eight and lasting into the early twenties. Thus, a bigger brain is not necessary a smarter brain. On the contrary, improved cognitive ability associated with the teen years (i.e., getting smarter) is related to rewiring that occurs via two major processes: myelination and pruning.

Myelin insulates connections between brain cells, leading to faster processing speed and improved efficiency, whereas pruning involves removal of inefficient brain cells and connections, keeping the best of the best to get the job done. Together these events significantly improve "cell service," so to speak. While myelination and pruning occur across the brain, the most notable rewiring during adolescence occurs in the frontal lobe, the brain region responsible for organization, planning, decision-making, working memory, and impulse control, among other executive functions. Thus, some of the behaviors we dismayingly observe in adolescents such as messy rooms, lack of planning ahead for an upcoming test, an inability to abstractly imagine 'what if' after an impulsive or risky behavior, can be developmentally appropriate given the maturing status of the brain. Teens constantly attempt to make good choices despite having to access an area of the brain that has is not yet fully developed.

More is Not Better – Different Matters

Structural rewiring, resulting from myelination and pruning, leads to changes in how the brain functions. In studies using functional MRI, differences are observed between teens and adults in which areas of the brain light up (or don't) while they perform a cognitive task. For instance, on a "Go No Go" task, an executive functioning task requiring cognitive control (a computerized version of 'Simon Says Do This'), participants are instructed to press a button every time they see a shape, except if it is a small square, which occurs less frequently than all other shapes. Stimuli are presented at a very rapid pace, requiring fast responding; all the while, signals are being recorded from the brain. The main difference observed between the adult brain and the adolescent brain is that activation is more wide spread (or diffuse) in the teen brain, with more brain areas recruited to perform that task than are needed by an adult. In adults, activation is more specific (or focal) to the region of the frontal lobe that mediates task performance. On a behavioral level, we observe teens performing at lightning fast speeds compared to adults. Although adults perform a bit slower, their accuracy is significantly better. This is the speed versus accuracy trade off, observed behaviorally, which likely reflects improved neuronal efficiency of the adult brain.

Our laboratory also uses magnetic resonance spectroscopy, a type of brain scan that measures brain chemicals necessary for good cellular health and neurotransmission. Among the neurochemicals we can measure is gamma amino butyric acid (GABA), the major neurotransmitter in the brain that serves to inhibit or halt responding (i.e., helps put on the brakes). We were the first to report low frontal lobe brain GABA levels in healthy teens compared to young adults, which also predicted worse cognitive control and greater levels of impulsiveness (Silveri et al., 2013). Importantly, low frontal lobe GABA has been observed in individuals with depression, anxiety, sleep disorders, and addictions. Therefore, developmentally low GABA could be a key contributor to risk for addiction, as well as mental health issues.

Why Proceed with Caution: Adolescent Brain Under Construction

Adulthood has conventionally been accepted as age 18. Evidence from neuroimaging is redefining our view. I have presented our work locally and nationally to throngs of students, parents, teachers, faculty, mental health workers, enforcement officers, policy makers and more, all eager to better understand the development of the teen brain and its vulnerabilities. The answer to the million-dollar question everyone wants to know – okay, so when will I/my teen be an adult? Based on neuroscience, individuals reach 'neurobiological' adulthood during the mid-twenties, within emerging adulthood (18-24 years), a time characterized as having greater functional independence and competence than adolescence, but less so than adulthood. Until then, the second decade of life, while a time of great opportunity, is a time of notable vulnerability. I often joke with my audiences that the next time teens are asked "what were you thinking?," they are not allowed to claim "immature frontal lobe," because if they knew to say that, then they should have known better, and perhaps should have engaged their frontal lobe more before acting.

An important context of this lesson is that brain development is an energy-intensive process. Initiation of alcohol or substance use can derail this important process and can have long-term consequences for the efficiency of the brain, and associated behaviors that could place individuals in harm's way if they do not make good decisions. Neuroimaging has demonstrated consequences of teen alcohol use ranging from altered cognitive abilities to altered brain structure and function. The lesson seems simple, it is better to tell teens that drinking is a choice to be made when they turn 21, when their brain is neurobiologically adult and less vulnerable to alcohol's effects. Until then, youth should be the only thing impairing judgment. Similarly important is that decreased perceptions of risk and increased availability and potency of marijuana also has serious consequences for brain development. Taken together, uniquely important brain changes occur in the second decade of life, ten years that could very well influence one's entire life. With increasing longevity and well-established interventions available for fixing one's body along the aging process, we have been less successful in the pursuit of means to keep the mind young. Our best effort to keep the mind in step with the body may be to arm teens and their parents with the science on the delicate nature of brain development and the increased vulnerability of the teen brain to alcohol and marijuana use, in an effort to ensure achieving the best possible brain that will be with us for the long haul.

Further Reading

The Community of Concern: A Parent's Guide for the Prevention of Alcohol, Tobacco and Other Drug Use

National Institute of Mental Health: The Teen Brain: Still Under Construction

National Institute on Alcohol Abuse and Alcoholism: Publications & Multimedia

National Institute on Drug Abuse: NIDA for Teens Drug Facts

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