

The Teenage Brain: Under Construction

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ABSTRACT: Can sexual activity, alcohol and drug use, and other risky behaviors damage adolescent minds? In a word – yes. Early high-risk behaviors, including sexual encounters, are powerful influences and appear to be harmful to the brain’s development. The hormones and neural patterns triggered can lead to addictive, high-risk behaviors, social withdrawal, and depression. What’s more, these adolescent behaviors may have additional long-term negative consequences – not just for them, but also for their future children.

Shakespeare wrote, “I would there were no age between ten and three and twenty... For there is nothing in the between but getting wenches with child, wronging the ancients, stealing, fighting.” (*The Winter’s Tale*, Act III, Sc. iii) It is amazing that over 400 years later, scientists are confirming Shakespeare’s observation that the adolescent’s brain is not fully mature until approximately 23 – 25 years of age. New and ongoing scientific research, utilizing functional magnetic resonance imaging (fMRI), demonstrates that during adolescence nearly every aspect of the brain is undergoing dramatic changes—changes that are not just genetically determined, but are greatly affected by experiences and environment. The “nature versus nurture” debate is no longer relevant, as research clearly documents that both have impressive impact. Environment affects the growth and development of brain cells, impacts the wiring of these cells, and affects which cells live or die. More importantly, it is possible through epigenetics for environmental influences such as alcohol and other drugs to turn on or off genes within a person’s genome that is contrary to the usual expression of those genes.^{1,2} Thus, activities and experiences have the potential to impact the development and functioning of the brain, not just during the adolescent years, but for a lifetime.

Between 11 and 13 years of age, the adolescent’s brain experiences rapid growth of nerve cells, along with increased numbers of connections between nerves (synapses). Since the adolescent brain is undergoing rapid development, this is a time of great vulnerability. This growth is followed by a time of “pruning,” when nerve cells that are not used or needed are deprived of nutrition and die. The pruning process allows the adolescent brain to function more rapidly for tasks that are already known, but decreases the brain’s capacity to learn new tasks or acquire new skills.³

Along with changes in the number of neurons, the brain also experiences changes in its hormonal environment. It has been known for decades that adolescence is characterized by surges in sex hormones – estrogen and testosterone. Recently it has been demonstrated that receptors for these hormones exist in many organs of the body, including the brain. In addition, other hormones and neurotransmitters such as oxytocin, vasopressin, dopamine, and serotonin also influence brain development.

Dopamine, the neurotransmitter most responsible for feelings of pleasure, has a powerful impact. The early adolescent brain, with its increased number of nerve cells, has higher levels of dopamine circulating in the prefrontal cortex, but dopamine levels in the reward center of the brain (nucleus accumbens) are changing throughout adolescence. These changes in the dopamine levels in the reward center suggest that the adolescent requires more excitement and stimulation to achieve the same level of pleasure as an adult.^{4,5} So the teenager will attempt riskier behaviors to achieve elation. Dopamine is also the neurotransmitter secreted when individuals participate in various addictive behaviors. Drug use, gambling, video gaming, pornography, and sexual experiences can all become addicting as the individual strives to achieve a dopamine-mediated pleasure. As their

brain is under construction and nerve pathways are forming, adolescents become addicted more easily.⁶ This vulnerability of the developing brain may well explain why these behaviors identified in adults often have their onset during adolescence or early adulthood. For example, 40% of adult alcoholics identify onset between 15 and 19 years of age.⁷ In addition, adolescents are more likely to become addicted with even minimal exposure to a high-risk behavior. Although an adolescent may smoke fewer cigarettes than an adult, the adolescent demonstrates higher rates of addiction.⁸

Recent research has investigated the influence genes exert on an individual's willingness to take risks. Dopamine receptor DRD4 appears to play a major role in determining the risk-taking behavior of the individual. Adolescents may be viewed as either "high risk takers" or "low risk takers" depending upon their genetic propensity to seek excitement through risky behaviors. Alcohol can affect the expression of the risk-taking gene, causing adolescents who are not generally considered "high risk takers" to take risks when under the influence of alcohol.⁷ Research also demonstrates that adolescents who drink alcohol are more likely to participate in other high-risk behaviors, including sexual activity. Marijuana is another drug that can affect an adolescent's decision making, decrease inhibitions, and thereby increase risk-taking behaviors.⁹ These behaviors in turn further modify the structure and function of the brain.

Oxytocin and vasopressin function as "bonding" hormones. Oxytocin, a peptide secreted during labor, delivery, and breastfeeding, is also powerfully active in the female brain during physical touch or even intense gazing. Its release increases the likelihood that the female will trust her sexual partner but decreases the functioning of her frontal cortex, the judgment center. The hormone serves to bond the woman to her mate with repetitive touches and sexual relations increasing the likelihood of monogamy.¹⁰

Adolescents who initiate sexual activity early are more likely to have more sexual partners by early adulthood. The Centers for Disease Control and Prevention documented that 49.2% of girls and women report more than five lifetime sexual partners if their sexual debut occurred younger than 16 years of age. However, if sexual debut occurred at age 20 years or older, only 9.0% had more than five sexual partners during their lifetime.¹¹ Since sexual touching brings pleasure and raises dopamine levels, the developing adolescent brain, in its craving for repetitive elevations of dopamine, overrides the healthy bonding effects of oxytocin and vasopressin. This, in turn, makes it more difficult for the adolescent to maintain a monogamous relationship later in life, as demonstrated by studies reporting that married adults who have experienced premarital sex are more likely to suffer divorce than those who abstained.¹²

The frontal lobe, the judgment center or CEO of the brain, allows the individual to contemplate and plan actions, to evaluate consequences of behaviors, to assess risk, and to think strategically. It is also the "inhibition center" of the brain, discouraging the individual from acting impulsively. The frontal lobe ultimately develops connections to many other areas of the brain, so that experiences and emotions are processed through the judgment center. The frontal lobe does not fully mature until approximately 23 – 25 years of age.¹³ The immaturity of the adolescent's judgment center explains much of the inability of adolescents to properly interpret experiences in the environment and thus make appropriate and healthy decisions.

Many other areas of the brain likewise are not completely myelinated until the early 20s. The amygdala, which is the emotion center of the brain, is immature in adolescents and not fully connected to the frontal lobe. Adolescents, then, may have a more difficult time interpreting their emotions, as well as the emotions of others.¹³ More importantly, since the amygdala is poorly

connected to the judgment center of the brain, the adolescent is more likely to make decisions based upon the emotional impact rather than upon logic. As Pustilnik and Henry state, “Executive function and emotional responses are not just less developed or different in teens: These two capacities are also less closely linked than in the typical adult brain. As a result, a teen may intellectually understand an issue and emotionally have a response to that issue, but those two processes may occur nearly in parallel rather than in dialogue. Emotional and executive functions must work together to bring about almost any kind of decision.”¹⁴

The hippocampus, the memory center of the brain, is also immature and is very susceptible to the effects of alcohol and marijuana. Alcohol and marijuana can hinder the ability to develop memories and thereby impact learning. Adolescents who binge drink are particularly susceptible to the negative effects of alcohol on the developing hippocampus.¹⁵

Another area of the developing brain deserving of attention are the cells that compose the mirror neuron system. Mirror neurons are those cells that assist in the development of empathy and compassion as the cells are active when an individual either experiences an emotion or observes that emotion being experienced by another person. This is ‘cognitive empathy’ – the ability to take another person’s perspective – and this system is also undergoing dramatic changes during adolescence. Researchers from UCLA studied the impact of cell phone use and screen time on the ability of adolescents to interpret the emotions of others. Sixth graders who attended a science and nature camp and who went without smart phone or digital screen time for just five days improved in their ability to interpret facial expressions in photos and videos. The authors state, “The displacement of in-person social interaction by screen interaction seems to be reducing social skills.”¹⁶

It is also important to note there are many sexual differences in the developing brain as documented by brain imaging techniques.¹⁷ The amygdala, the center of emotions noted above, grows faster in adolescent boys than in girls and there are more testosterone receptors in the amygdala of males. The hippocampus, however, appears to grow faster in adolescent girls and this area has more estrogen receptors.^{18,19} Even the cerebellum, an area of the brain utilized in complicated problem solving, differs in size between males and females, being 10 - 13% larger in adolescent males.¹⁹ These sexual variations are important to understand as their onset may begin with in utero development and will contribute to the different way males and females tend to respond to learning environments, risk seeking, and even discipline; yet each human male and female is an individual with considerable variation between different areas of the brain and considerable overlap in brain features among men and women.²¹

All this research demonstrates the adolescent’s brain is immature – in virtually every area that has been studied. The adolescent’s brain is prone to seek excitement at a time when the frontal lobe is not mature enough to moderate such behavior. This is also the time when the developing brain is at greatest risk to form neuronal connections that may lead to addictions and impact future emotional well-being and decision making. Making matters worse, modern media portrays high-risk behaviors as admirable, exciting, and even safe, while discouraging parental involvement that would positively modify the behaviors.

There is a clear link between high-risk behaviors and subsequent depression and even suicide. In the National Longitudinal Study on Adolescent Health, 13,491 adolescents in grades 7 to 11 were interviewed in 1995 and again one year later. The authors differentiated the cause and effects of

depression and found that early high-risk behaviors, including sexual activity and drug use, were linked with later depression, but early depression did not cause high-risk behaviors.²²

Further analysis of the same study revealed that adolescents who had involvement in any drinking, smoking, and/or sexual activity were significantly more likely to suffer from depression, suicidal ideation, and suicide attempts.”²³

In summary, this evidence-based research on brain development must serve as an impetus for all adults who interact with and care for adolescents to reconsider the health information provided to youth. The adolescent brain is under construction and can be adversely affected by high-risk behaviors and by the environment the brain experiences. The judgment center is immature, leading to poor decision making. The dopamine pleasure system is in a state of rapid change, leading to higher potential for participation in high-risk behaviors and addictions. Oxytocin and vasopressin are present and ready to emotionally bond the teenager to any individual with whom he or she has sexual experiences, and heighten the consequences of the likely ending of the relationship.

Clearly, the adolescent years are a time of rapid brain development, a time of susceptibility. Those who care about the future of the adolescent must acknowledge that high-risk behaviors encountered during these vulnerable years can have lasting adverse consequences and should be avoided.

The good news is that parents play a pivotal and crucial role during the adolescent years, and the influence of parents can positively impact the developing brain. Since their prefrontal cortex is immature, adolescents will benefit from the wisdom and guidance of their parents in making decisions and strategizing. Limit setting, structure, and communication that help minimize exposure to high risk behaviors will protect the adolescent, not just during the adolescent years, but also long term. Parents can even take advantage of the need for excitement by seeking positive experiences for their adolescents. Parents can challenge their teens to find excitement in learning new things. For academic teens it might be learning a new language or skill. For athletic teens it might be learning how to dive or some other physical skill. These challenges produce the same sort of dopamine high that teens receive from things that are risky, dangerous and sometimes illegal.²⁴

Participating in exciting activities together will also help parent and teen to bond and connect with each other. Research from the National Longitudinal Study on Adolescent Health demonstrated that adolescents are less likely to participate in high risk behaviors when they are highly connected to their parents.²⁵ Alan Booth, a researcher at Pennsylvania State University, evaluated the role of parenting on adolescent high-risk behaviors and found that even adolescents who are more prone to them will be less likely to participate if they have a close relationship with their parents.²⁶ Researchers at the National Center on [Addiction](#) and [Substance Abuse](#) (CASA) at Columbia University demonstrated that adolescents with “hands-on” parents (those who monitored the activities of their adolescents and participated in family dinner hour together) are at one-fourth the risk of substance abuse as those with “hands-off” parents.²⁷ Parents can help shape their adolescent’s environment, affect the adolescent’s tendency to participate in high-risk behaviors, and can help them in their decision-making and critical thinking skills. An adolescent’s close relationship with his/her parent is protective despite other negative environmental factors. Research clearly shows that parents play a critical role in the healthy development of their adolescents. Health care professionals should acknowledge this, encourage parents to develop healthy relationships with their children, and support them in the parenting role. On a broader

level, public health policies that currently treat adolescents as young adults in their abilities to problem solve and make decisions should be re-evaluated and revised based on this new research and will need continued revision as new information emerges.

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See the following other College statements that have information regarding the teenage brain:

[Marijuana Use: Detrimental to Youth](#)

[The Roles, Responsibilities and Rights of Parents](#)

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