THE JOURNAL OF
GLOBAL DRUG POLICY AND PRACTICE

Adolescent Brain Development and Alcohol Abuse

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Support for this work is provided by grants from the Archie & Bertha Walker Foundation, RKMC Private Foundation and NIDA (K02 DA015347). The author thanks Jeff Lee, Jack Tonkin, Tom McLellan, and Behin Abedi for assistance with this manuscript.

New scientific discoveries have put a much different perspective on our understanding of adolescent behavior. Research now suggests that the human brain is still maturing during the adolescent years. The developing brain may help explain why adolescents sometimes make decisions that are risky and can lead to safety or health concerns, including unique vulnerabilities to alcohol abuse.

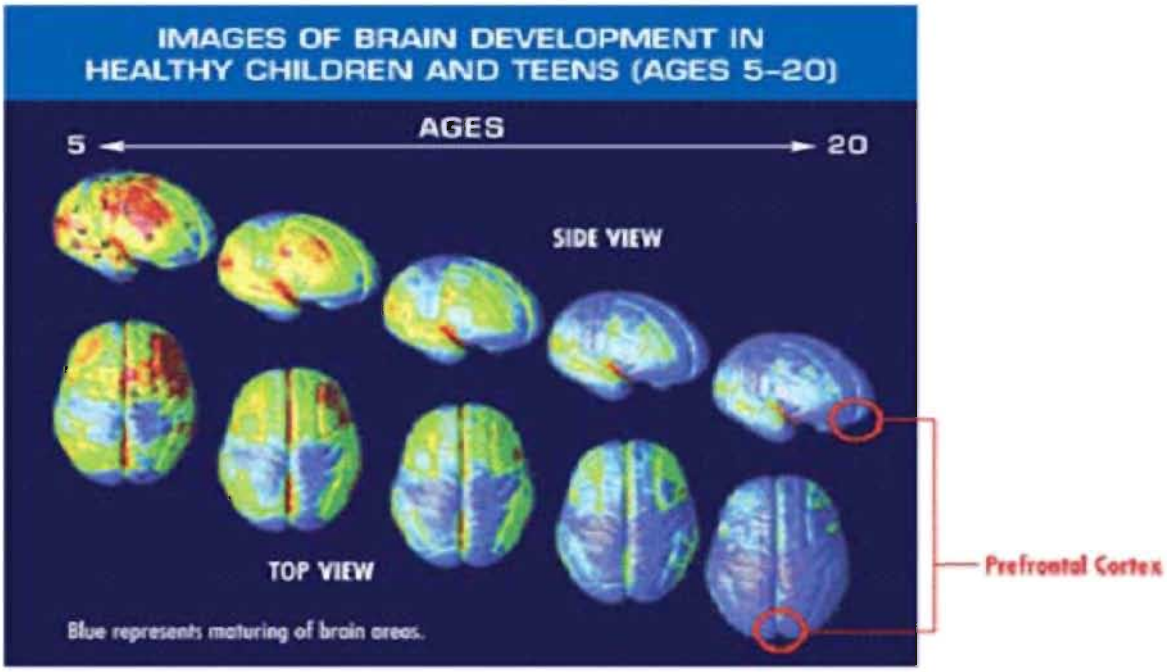
Work in Progress

Advanced technologies in brain imaging have provided windows to the developing brain. Based on the pioneering work of Jay Giedd and colleagues at the National Institute of Mental Health (1), evidence is accumulating that the brain is not fully formed at the end of childhood as earlier thought. The juvenile brain is still maturing in the teenage years, and reasoning and judgment are developing well into the early to mid 20s.

During the pre-teen years, the brain grows an excessive number of connections between brain cells. At about year 11 or 12, a young person begins to lose or "prune back" a substantial fraction of these connections. This loss is healthy in the long run and is a vital part of growing up. The pruning process clears out unneeded wiring to make way for more efficient and faster information-processing as we become adults. And it promotes building the long chains of nerve cells that are required for the more demanding problem-solving of adulthood.

The pruning process appears to be modified within each individual according to the principle of "use-it-or-lose-it," according to experts. Thus, neural connections or circuitry that gets exercised as a child grows up are retained, while the connections that are not activated or used, get pruned away. If you learned a musical instrument while growing up, the neural connections involved in music playing will be strong and resistant to pruning. Dr. Giedd refers to this process in this way: "Ineffective or weak connections are pruned in much the same way a gardener would prune a tree or bush, giving the plant the desired shape" (1).

This brain maturation tends to occur from the back of the brain to the front (see Figure 1). The front region of the brain, known as the prefrontal cortex, which is responsible for high-level reasoning and decision-making (such as having to consider multiple points of view when arriving at a decision), is the brain region that is relatively last to finish the maturation process.



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The prefrontal cortex is the part of the brain that enables a person to think clearly, to delay gratification and to control impulses. It is primarily responsible for how much priority to give incoming, highly emotional messages such as "Do this now." Because the emotion-related regions of the brain are predominantly located behind the front of the brain and have progressed more with the pruning process, it is difficult for the "control" part of the brain (the prefrontal cortex) to exert much influence. Psychologist Laurence Steinberg describes the teenager's brain as an automobile with "a well-developed accelerator but only a partly developed brake" (2).

Implications for Understanding Adolescent Behavior

Scientists caution against definitive linkages between brain development and adolescent behavior, but there is a growing sentiment among experts that when teenagers are feeling high emotion or intense peer pressure, conditions are ripe for the still-maturing circuitry in the front part of the brain to be overwhelmed, resulting in risky behaviors and decisions that lack judgment.

This does not mean that teenagers always make bad decisions and behave in ways that lead to harmful consequences. The teenage brain is capable of demonstrating sound mental ability; for example, mental capacities associated with language and spatial abilities are generally functioning at normal levels by adolescence. But the teenager, with less than optimal impulse control mechanisms, may be prone to act impulsively and with gut instinct when confronted with stressful situations, without fully appreciating the immediate consequences of his/her actions.

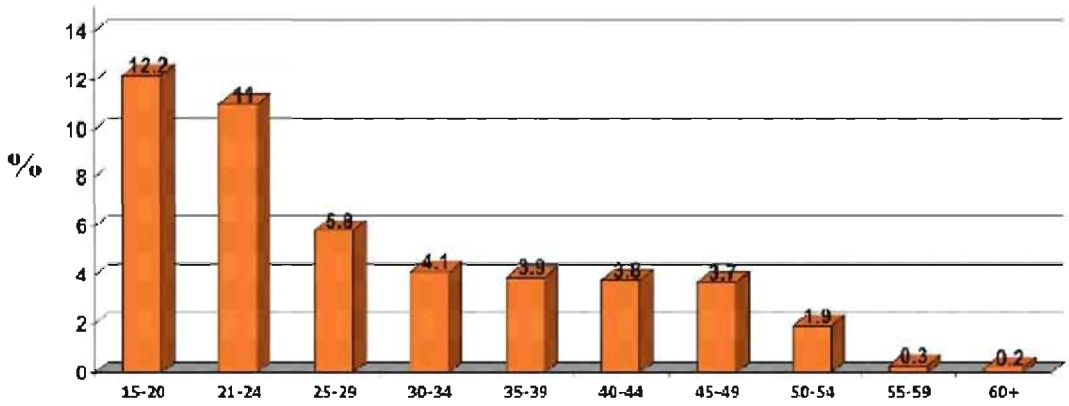
Experts say that even at ages 16 and 17, when compared to adults, adolescents on average are more impulsive, aggressive, emotionally volatile, likely to take risks, reactive to stress, vulnerable to peer pressure, prone to focus on and overestimate short-term payoffs and underplay longer-term consequences of ones' actions, and likely to overlook alternative courses of behavior (3).

The Developing Brain and Alcohol Abuse

Scientists are beginning to explore whether these new discoveries help to explain adolescent drug use and related impulsive behaviors. The adolescent, who has a tendency to take risks, is likely to be curious about alcohol. National surveys indicate that use of alcohol (as well as other drugs) is relatively common among youth (4). The majority of young people will try alcohol before the legal age of 21, and over half will try an illicit drug at least once during their teenage years. Furthermore, young people show higher rates of alcohol problems compared to older age groups. Table 1 below shows that among youth aged 15-20 years old, 12.2% met an official definition (5) of an alcohol dependence disorder within the past 12 months. This rate was much higher than the other age groups. For example, the rate of alcohol dependence was 4.1% for individuals in the 30-34 age group. A related finding from survey research is that the earlier the onset of alcohol use, the greater the likelihood that a person will develop an alcohol problem both during the teenage years as well as later in adulthood (6).

Prevalence of Past-Year DSM-IV Alcohol Dependence: United States, 2001-2002

(Grant, B.F., et al., Drug and Alcohol Dependence, 74, 223-234, 2004)

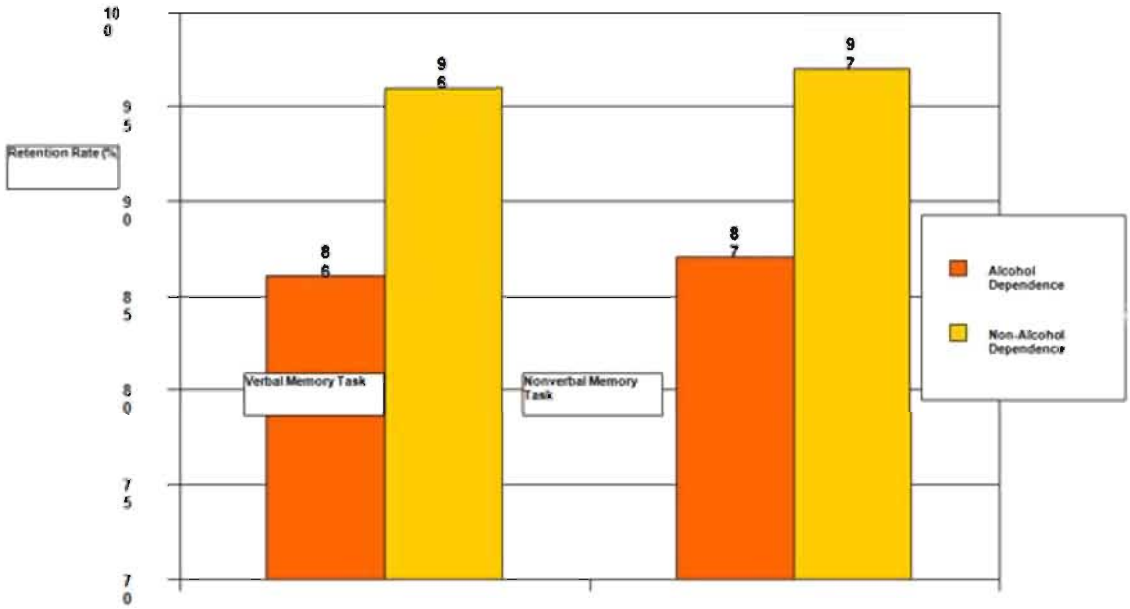


To what extent do brain development factors predispose adolescents to seek out and use and abuse alcohol? A related question is this: Are there any deleterious effects on brain development as result of alcohol abuse in adolescence? Evidence from animal and human data pertain to both of these questions.

1. Are adolescents more vulnerable than adults to the effects of alcohol? Several scientific findings provide provisional answers to this question. As already noted, a developing prefrontal cortex increases the likelihood of teenagers to act impulsively and to ignore the negative consequences of such behavior. Studies using animal models suggest that adolescents may subjectively report greater feelings of social disinhibition when drinking alcohol compared to adults (7).

This effect could create a more pleasurable social experience for the adolescent (e.g., contribute to feeling less shy) while drinking compared to adults. Also, adolescent rats are observed to be less sensitive to the effects of intoxication than adult rats. They typically consume two to three times as much alcohol for their body weight as adults (7). Adolescent humans also show this diminished sensitivity to intoxication; their higher metabolic rates allow them to consume higher amounts of alcohol (7). A lower sensitivity to alcohol's effects would be consistent with the observation that young people are capable of drinking large amounts of alcohol without feeling all that intoxicated. Hormones have a role here as well. Hormones encourage novelty seeking and promote social competitiveness. The revved-up hormonal production of adolescence may promote alcohol use to the extent that it represents a novel experience to the youth who is also seeking social approval from peers during the experience.

2. Arrested development? A limited amount of science suggests that the developing brain is prone to the deleterious effects of alcohol. Adolescent rats exposed to various amounts of alcohol have significantly more brain damage in their frontal cortex than their adult counterparts (7). They also show greater damage to their working memory. With long-term use, adolescent rats have shown massive neuronal loss in other key parts of the brain, including the cerebellum (sensory perception and motor coordination), basal forebrain (learning), and the neocortex (language) (7). In human studies, adolescents with an alcohol dependence disorder showed greater memory retrieval deficits compared to a non-dependent control group (see Table 2) (8).



Opportunities for Drug Prevention and Treatment

Where does this new science lead us? Can an understanding of adolescent brain development help us do a better job preventing and treating alcohol abuse among teenagers? While it's too early to say if this new knowledge will dramatically impact prevention, there are several things to consider.

Because many teens begin using alcohol at a young age and because of alcohol's possible deleterious effects on the developing brain, the urgency for prevention is real. Delaying the onset of alcohol use, especially if it is delayed until adulthood, is better for both brain development and for preventing escalation of use. Teenagers who abuse alcohol may avoid permanent neurological damage if they can cut down or abstain.

The possible dangers of alcohol use to the developing brain should be emphasized to both youth and parents. This concern should reinforce that underage drinking is associated with more dangers than the vague social and legal consequences often highlighted in prevention messages. Evidence now suggests deeper consequences, including possible harm to cognitive functioning.

Creating age-appropriate health curriculum to educate youth about their developing brain is a need. The emerging sciences of the neurobiology of addiction (9) and of brain development are providing new insights about how substances affect the brain and how teenagers make critical and life influencing decisions, including their decisions about substance use. Resources are needed to educate youth about this critical new knowledge in brain development. This emerging information can be harnessed to reframe and strengthen current drug prevention approaches by encouraging youth to capitalize on the assets of the developing brain, avail themselves of alternatives to potentially health-compromising risk-taking, and to promote personal growth and healthy lifestyles.

This new science also places importance on educating youth about the skill of using the "thinking breaks" when faced with having to make a decision that involves delaying or not delaying immediate gratification. Conditions under which the developing judgment region of the brain is likely to be challenged and how to engage in "second thought" mechanisms should be part of health education classes in schools.

There is also the need to educate parents about the developing teenage brain. If the seemingly irresponsible behaviors of teens are not truly willful acts but are the result of the brain still "under construction," parents will want to be more tolerant of such annoying behaviors common during adolescence. On the other hand, brain development science reinforces the importance for parents to be actively involved in their teenager's life. Rather than the message: "I need to know where you are and who you are with because I am not sure I can trust you," the more scientifically justified message is: "I need to help you anticipate risky situations and how to deal with them."

The evidence that youth are more vulnerable to effects of alcohol does not support policy arguments that our country should lower the minimum drinking age below 21 years of age. What is being learned about brain maturation serves to reinforce that a lowering of the minimum age for alcohol would have deleterious health effects on our youth.

Summary

Adolescence is a time when a young person forges a sense of self, experiments with independence, and seeks new experiences. This developmental period is also likely to be the years when we observe behaviors that reflect how social pressures and thrill-seeking can override common sense. The juvenile brain responds more quickly and more intensively to excitement, arousal, and rewards. It also may be more vulnerable to the effects of alcohol, which may place youth at an elevated risk for alcohol abuse and for early damage to their brain if alcohol is used. Channeling adolescent exuberance toward healthy and growth-enriching experiences is a vital priority for our schools and communities, as well as being among the important tasks for parents.

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