

Adolescent Brain Development and Drug Abuse

New findings indicate that brain development still in progress during adolescence; immature brain structures may place teenagers at elevated risk of substance abuse and arrested brain development.

Ken C. Winters, Ph.D.
Professor, Department of Psychiatry, University of Minnesota

A Special Report Commissioned by the Treatment Research Institute
Philadelphia, PA
A. Thomas McLellan, Executive Director

New scientific discoveries have put a much different perspective on the understanding of adolescent behavior. Research now suggests that the human brain is still maturing during the adolescent years, with changes continuing into the early 20s. The immature brain of the teenage years may not only explain why adolescents are prone to make poor decisions, but it may also place teenagers at an elevated risk to the harmful effects of drugs.

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, evidence is accumulating that the brain is not fully formed at puberty as earlier thought, but continues important maturation that is not complete until about age 24.

Three brain structures that undergo maturation during youth – nucleus accumbens, amygdala and prefrontal cortex – are noteworthy in terms of their implications for understanding adolescent behavior. While scientists caution about suggesting definitive linkages between

neurodevelopmental findings and behavior, the discovery that brain construction is still in progress during adolescence offers several suggestive hypotheses.

The nucleus accumbens, which directs motivated behavior, is responsible for how much effort the organism will expend in order to seek rewards. In teenagers, an immature nucleus accumbens is believed to result in preferences for activities that require low effort yet produce high excitement. Real-world observations bear this out: most teenagers tend to favor activities such as playing video-games, skate boarding and, unfortunately, substance use.

The amygdala is the structure responsible for integrating emotional reactions to pleasurable and aversive experiences. It is believed that a developing amygdala contributes to two behavioral effects: the tendency for adolescents to react explosively to situations rather than with more controlled responses, and the propensity for youth to mis-read neutral or inquisitive facial expressions of others as a sign of anger.

And one of the last areas to mature is the prefrontal cortex, located just behind the forehead. Sometimes referred to as “the seat of sober second thought,” it is the area of the brain responsible for the complex processing of information, ranging from making judgments, to controlling impulses, foreseeing consequences, and setting goals and plans. An immature prefrontal cortex is thought to be the neurobiological explanation for why teenagers show poor judgment and too often act before they think.

The Developing Brain and Drug Use

Scientists are now beginning to explore whether these new discoveries may help explain adolescent drug use and related impulsive behaviors. This is an important issue given that adolescence is a time of experimentation and novelty seeking. The 2003 Monitoring the Future study found that 70.1% of high school seniors had used alcohol in the past year and 34.9% had

used marijuana. Over half had tried an illicit drug at least once in their lifetime. Even among 8th graders, 45.6% had already tried alcohol and 22.8% reported illicit drug use in their lifetime (Johnston et al., 2003). And we know that most adult regular smokers begin using in adolescence, as do a majority of adults who meet alcohol abuse or dependence criteria (Clark et al., 1998). Youth who report first using alcohol before age 15 are more than five times as likely to report being an alcoholic compared to persons who first used alcohol at age 21 or older (Substance Abuse and Mental Health Administration, 2004).

From a neurodevelopment standpoint, two central questions merit scientific attention: Do neurodevelopmental factors predispose adolescents to seek out and abuse alcohol and drugs? And, are there any deleterious effects on brain development as result of drug use in adolescence? Evidence from both animal and human data pertain to each question.

Are adolescents more vulnerable than adults to abuse drugs? Several neurodevelopmental findings provide provisional answers to this question. As already noted, an immature prefrontal cortex increases the propensity of teenagers to act impulsively and to ignore the negative consequences of such behavior. In addition, an immature nucleus accumbens increases the adolescent's tendency to seek out activities that are exciting but require little effort. And there is growing evidence that one direct result of a developing amygdala is that adolescents subjectively report greater feelings of social disinhibition when drinking alcohol compared to adults (Spear, 2002). This effect would create a more pleasurable social experience (e.g., feeling less shy) while drinking compared to adults. All these effects of the developing brain – poor impulse control, favoring low-effort yet thrilling experiences, and heightened sensitivity to the social benefits of intoxication – may contribute to an initial decision to use drugs and make the experience rewarding enough to repeat it.

There are other considerations. In studies of adolescent rats, they 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 (Spear, 2002). Adolescent humans also show this diminished sensitivity to intoxication; their higher metabolic rates allow them to consume higher amounts of alcohol (Spear, 2002). 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 as well. Hormones encourage novelty seeking and promote social competitiveness. Increased hormonal production during adolescence may promote drug use to the extent that drug involvement represents a novel experience to the youth who is also seeking social approval from peers during the experience.

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 (Spear, 2002). They also show greater damage to their working memory. With long-term use, adolescent rats have shown massive neuronal loss in their cerebellum, basal forebrain, and neocortex (Spear, 2002). In human brain scanning studies, adolescents with alcohol use disorders had significantly smaller volume in the hippocampus (the primary structure for memory), which led to greater memory retrieval deficits, compared to non-alcohol abusing controls (Brown et al., 2000).

Implications

It is too early to say whether this new understanding of neurodevelopment will lead to revolutionary tools in the treatment of substance abuse, such as new pharmacotherapies or even a “vaccine” against addiction.

Even as researchers explore these questions, the field must examine existing policies and psychosocial treatment approaches in light of the new findings. Creating age-appropriate curriculum to educate youth about their developing brain is one possibility. Another is to incorporate neurodevelopmental information into the educational materials used by prevention specialists and educators.

A third approach is to communicate findings to treatment specialists, helping them adjust therapeutic goals and expectations based on brain maturity. To some degree, older adolescents can engage in more complex cognitive tasks, such as weighing the pros and cons of unhealthy behaviors and considering more sophisticated approaches for resistance and relapse prevention. But younger teenagers will need to be taught relatively concrete strategies.

Finally, there are the public advocates whose role in treatment and prevention cannot be underestimated. An educational effort with these groups could yield empirically derived public service messages and campaigns, ones emphasizing delaying the onset of drug and alcohol use, preferably until adulthood, and/or avoiding permanent neurological damage by abstaining or reducing use during adolescence.

For More Information about Adolescent Brain Development and Substance Abuse Contact Ken Winters, Ph.D. at winte001@umn.edu

References

- Brown, S.A., Tapert, S.F., Granholm, E., & Delis, D.C. (2000). Neurocognitive functioning of adolescents: Effects of protracted alcohol use. *Alcoholism: Clinical and Experimental Research, 24*(2), 164-171.
- Clark, D. B., Kirisci, L., & Tarter, R. E. (1998). Adolescent versus adult onset and the development of substance use disorders in males. *Drug and Alcohol Dependence, 49*, 115-121.
- Johnston, L. D., O'Malley, P. M., & Bachman, J. G. (2003). *Monitoring the Future national survey results on drug use, 1975-2002. Volume 1: Secondary School Students (NIH Publication No. 03-5375)*. Bethesda, MD: National Institute on Drug Abuse.
- Spear, L. P. (2002). Alcohol's effects on adolescents. *Alcohol Health and Research World, 26*(4), 287-291.

Suggested Readings

- Dubuc, B. (n.d.) *The brain from top to bottom*. Retrieved September 1, 2004, from McGill University Web site: http://www.thebrain.mcgill.ca/flash/index_d.html#
- Nestler, E. J., & Malenka, R. C. (2004, March). The addicted brain. *Scientific American, 290*(3), 78-85.
- Wallis, C. (2004, May 10). What makes teens tick? *Time, 163*, 57-65.