

Alcohol & The Adolescent Brain: Immediate Impairment, Long-Term Consequences

The future of North Carolina depends on its young people. We want to protect and nurture them as they grow and develop. As parents and responsible adults, we stay alert and vigilant to keep children out of harm's way. All too often, however, we don't even consider potential dangers to their most important organ: the brain.

We rarely stop to ask the critical questions: How does the brain develop? What can interfere with that process? And what do kids' developing brains need to make the most of their education and become productive adults?

Adolescent Brains Aren't Broken. They're A Work In Progress.

The human brain continues to mature from birth into the mid-20s. The back parts (pons and medulla)—which regulate essential processes such as breathing and heart rate—function properly at birth. The front parts (frontal cortex)—responsible for sophisticated thinking like prioritizing, planning and self-reflection—are the last to mature. By the time a child is about 10, he or she has most of his or her neurons, which have been actively making connections with each other since before birth.

The last phase of brain development, however, occurs during adolescence, when bodies and brains change in remarkable ways. This phase is critical for adolescents' future success in just about all facets of life.

Adolescent Brains Are Not The Same As Adult Brains.

As the body matures, the hormonal changes of puberty affect mood, social interests and interaction with peers. At the same time, children's brains are changing in important ways.

Two national programs studying exactly how alcohol changes the adolescent brain include groups from North Carolina.

- The NCANDA (National Consortium on Alcohol and Neurodevelopment in Adolescence) includes scientists at Duke and UNC.
- The NADIA (Neurobiology of Adolescent Drinking in Adulthood) Consortium includes scientists at the Bowles Center for Alcohol Studies at UNC and at Duke.

Additional studies on alcohol and the developing brain are conducted in individual laboratories at Duke, UNC-Chapel Hill, UNC-Charlotte and Wake Forest University.

The emotional areas of the brain mature before the frontal cortex—evident in the thrill-seeking, risky decision-making, and impulsiveness that define adolescence. The process of maturation that allows the "executive area" in the frontal cortex to take control over the rest of the brain isn't complete until age 22-25.

Until this happens, adolescent brains respond more to both the promise of rewards and to threats (especially social threats) than adult brains, and they weigh immediate rewards as more valuable than future rewards. This different "brain balance" is why adolescents pay lots of attention to their peers, and why they are more likely to do something without considering the consequences.

It becomes the job of responsible adults in kids' lives to help provide the restraint that their own brains often can't.

Four Factors Can Impact Brain Development And Learning.

Young brains need the right conditions to learn and develop optimally — conditions that are directly affected by four critical elements. The first three:

- **SLEEP:** The average adolescent needs more than an adult (8–9 hours/night). Sleep helps the brain recover from the day and consolidate what was learned, and it is critical for maturation of body and brain.
- **EXERCISE:** Exercise helps attention, memory and other cognitive functions. It can actually promote the formation of new neurons in the part of the brain associated with some forms of memory (hippocampus) and improve the memories laid down in this area.
- **STRESS:** Excessive stress changes brain structure and function as much as exercise — in the wrong direction. Chronic stress makes the amygdala (the area that signals “threat”) more sensitive to threat because of changes in the neurons there.

Alcohol: The Fourth Factor — And Often Enemy #1.

Just as many parents aren’t aware of the dramatic changes occurring in the brains of their growing children, most don’t realize how significantly alcohol can interfere with normal development.


This is not just an academic concern: At least one fifth of North Carolina students start drinking alcohol by age 14. Various surveys of alcohol use in adolescents ask questions a little differently, but most national surveys report that the average age that kids begin drinking alcohol is 15–16. By the end of high school, 72 percent of high school students have consumed alcohol at least once, and about 40 percent of kids have used alcohol in the last 30 days.

So let’s take a careful look at what can actually happen to the brain when a child drinks — both the effects that are felt right away, and changes that can last a lifetime.

Short-Term Impairment.

Intoxicated brains do not function well, even for some time after the buzz is gone. It’s also important to keep in mind that adolescents are not just “young adults” when it comes to alcohol — kids process alcohol differently and experience different consequences.


- *Adolescents are less sedated by alcohol than adults.* This allows them to keep drinking past the point at which older people would have stopped.
- *Alcohol reduces “social anxiety” even better in adolescents than adults.* Kids are more likely to drink alcohol to “fit in” and feel comfortable in social situations. Peer approval is incredibly important at a young age; kids who hang out with others who are drinking experience a great deal of social pressure to participate.
- *Together, these factors make adolescents more likely to binge drink (four to five or more drinks at a time) than adults.*

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- *Binge drinking in adolescents leads to more negative consequences than in adults, such as blackouts (loss of memory from the event), unplanned and unwanted sexual activity, fights, accidents and driving while intoxicated.*
 - *Alcohol affects learning more in adolescents, and also interferes with other “brain health” behaviors, undoing the benefits of good health habits. It interferes with sleep, and slows recovery from intense exercise in athletes. There is a particularly toxic interaction of stress and alcohol use: Adolescents with a history of remote or recent stress are likely to drink more alcohol, and heavy alcohol use increases their reactions to stress.*

Long-Term Consequences.

Drinking during adolescence doesn't just affect a child while he or she is drinking — it has outcomes that may be lifelong.

- *The brains of adolescent alcohol drinkers differ from those of nondrinkers.* Certain parts of the brain are actually smaller in the brains of people who started heavy alcohol drinking as children or adolescents.
- *The hippocampus is particularly vulnerable.* Although most areas of the brain reach their peak size and number of cells during early adolescence, the hippocampus — a part of the brain critical for learning and memory — continues to form new cells throughout life. These new cells are crucial for the memory tasks supported by the hippocampus. Adolescent alcohol exposure causes a dramatic shutdown of this process, one that can continue into adult life. This may be one reason that aspects of learning that require the hippocampus are impaired into adulthood. In addition, adolescent alcohol exposure reduces the number of neurons in the brain that make the neurotransmitter acetylcholine. While the behavioral effects of this loss are not yet known for sure, some of these neurons are also thought to be critical for learning.
- *Adolescent alcohol use sets up a persistent increase in activation of brain signals that contribute to inflammation.* The consequences of this are unclear, but similar changes have been associated with depression in adults, and suggest that early alcohol use may set kids up for mood problems in adulthood.
- *Binge levels of alcohol in adolescence can cause changes in brain development and brain function.* In laboratory studies, rodents exposed to “binge” levels of alcohol during adolescence can be more uninhibited and impulsive as adults than unexposed animals, and make riskier decisions. While they can learn to perform a specific action to earn a reward, or learn to navigate a maze, they do worse than unexposed rats when the rules change. These differences point to a reduction in “behavioral flexibility,” the ability to change behavior when the occasion calls for it — a critical component of decision making required for life in the adult world.
- *The younger someone starts, the greater the chances he or she will have alcohol use problems in their lifetime.* It is hard to know whether this is due to the alcohol exposure and/or to genetics, family environment, or a predisposing personality. We do know that about 50 percent of the risk for alcoholism is inherited, but many factors may contribute to this genetic vulnerability in adolescents, including availability of drugs, peer groups and whether a parent is using drugs.

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- *Alcohol can cause specific changes in the brain that could increase risk for alcohol-use problems.* The biggest concern is that the way adolescents often drink (binging with many drinks at a time) likely causes the most long-term damage to the brain. Research in laboratory rats and mice has shown that adolescents who binge a lot can eventually develop withdrawal symptoms, including increased anxiety and (in extreme cases) seizures more severe than typically occur in adults with a similar binging history. Postmortem studies show that the brains of alcoholics who began drinking in adolescence show changes similar to adolescent binge drinkers.

Ongoing Research. Mounting Costs.

A key question facing researchers is whether alcohol itself is causing these brain and behavior changes in humans, or whether other factors like environment, parental behavior and genetics create an adolescent brain that is “primed” for alcohol. Unraveling this “chicken-or-egg” question is crucial to providing effective treatments for youth affected by drinking.

As this work continues in earnest, we all must grapple with a sobering reality: In addition to the violence, accidents, unplanned pregnancies and injuries that can occur with underage drinking, the research suggests that there will be long-term impacts on public health.

The Power Of Parents.

All of this information is a lot to absorb. The most important takeaway is that parents and responsible adults have a responsibility to act.

The facts laid out here should empower parents to express opinions about alcohol use and to provide limits on their children’s access to alcohol. Studies show over and over that parental behavior and communication can delay the initiation of alcohol consumption. Both words and deeds matter.

Starting The Conversation.

- Parents need to tell their kids what their family values are about drinking.
- They need to “walk the walk” as well as “talk the talk” — which means being mindful of their own behavior in front of their kids.
- They need to remember a few critical facts, such as:
 - *Because of their unique response to alcohol, particularly a much less pronounced “sedative” response than in adults, adolescents are prone to drinking in “binges.”*
 - *Excessive drinking has short-term consequences such as risky behavior, blackouts and accidents, and problems with memory and learning.*
 - *Binge drinking has long-term consequences that can persist into adulthood, even if drinking stops. These include changes in key brain systems and behaviors that affect health.*
 - *Preventing underage drinking in the first place is the only way to make sure your brain is protected.*
 - ***Binge drinking during adolescence can permanently change your life trajectory.***



Stopping Underage Drinking.

The adolescent brain is still developing and is uniquely sensitive to alcohol. When a child drinks, judgment, memory, learning and recovery can all be compromised. While multiple factors impact brain development, current science suggests lifelong changes in the brain are induced by binge drinking in adolescence. Parental efforts to prevent access to alcohol will increase the chances of North Carolina's children optimizing their abilities and talents.

The Authors

Dr. Cynthia Kuhn

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Dr. Kuhn studies the effects of drugs including alcohol on developing adolescents in animal models, with a focus on how males and females may respond differently. She has shown that sex differences in dopamine function emerge during puberty, and contribute to the emergence of sex-specific responses to addictive drugs. She has collaborated with Drs. Wilson and Swartzwelder in studying the effects of ethanol on the developing brain for many years.

Dr. Wilkie Wilson

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Dr. Wilson is a neuroscientist who has made seminal findings about how the hippocampus functions in its normal state, during epilepsy and after exposure to alcohol during adolescence. He and Dr. Kuhn have worked with North Carolina educators to develop and pilot a healthful living curriculum that emphasizes brain health for high school students.

Drs. Kuhn and Wilson, along with Dr. Scott Swartzwelder, wrote “Buzzed, The Straight Facts about the Effects of Drugs from Alcohol to Ecstasy,” which is now in its 4th edition. They lecture widely to professional and lay audiences about adolescence and the effects of recreational drugs on the adolescent brain.

Dr. Fulton Crews

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Dr. Crews has discovered mechanisms of alcohol-induced brain damage using rodents and postmortem human alcoholic brains. These led to a focus on adolescent brain development, which he discovered is uniquely sensitive to alcohol-induced damage. His lab found that adolescent alcohol use changes aspects of brain health and signaling, such as the loss of formation of new neurons and increases in neuroimmune signals, changes that can persist for life. He leads the national NADIA Consortium of scientists studying the consequences of underage alcohol on the adolescent brain, funded by the National Institute of Health.

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Dr. Robinson studies behavioral and motivational brain circuits and how they are altered by drugs such as alcohol and nicotine. The Robinson lab found that binge levels of alcohol during adolescence can disrupt the effects of alcohol on dopamine later in adulthood in ways that may make alcohol more rewarding. In collaboration with others, her lab also found that binge levels of alcohol during adolescence can dampen connections between the prefrontal cortex — the decision-making area of the brain that is still developing during adolescence — and parts of the brain that control motivation and reward-learning. Dr. Robinson is also head of the Education Core of the UNC limb of the NADIA, and organizes public outreach activities of the NADIA in North Carolina.

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