



# Buzz Kill

How does alcohol affect the teenage brain?

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**T**oren Volkmann of Portland, OR, drank his first beer when he was 15 years old. Like many teenagers, he turned to alcohol out of boredom. It was a way for him to experiment, take risks, and look “cool” in front of his friends.

“What started out as a weekend thing eventually took over my social life,” says Volkmann, a co-author with his mother, Chris, of *From Binge to Blackout: A Mother and Son Struggle with Drinking* (NAL Trade, 2006). “Alcohol is just so alluring, particularly during a time when fitting in is more important than ever before and you’re seeking pleasure.”

Volkmann’s experience with alcohol isn’t unique. According to the Centers for Disease Control and Prevention (CDC), one in four high school students engage in binge drinking every month, meaning they consume four or five drinks over the span of a few hours. The problem: Binge drinking not only increases the risk of fatal car accidents, irresponsible sexual behavior, and acute alcohol poisoning, but it can also have long-term—perhaps irrevers-

ible—effects on the teenage brain, according to recent research.

“While teenagers may physically look similar to adults, their brains are still developing,” says Lindsay Squeglia, M.S., a graduate researcher in the San Diego State University/University of California San Diego Joint Doctoral Program in Clinical Psychology. Squeglia recently defended her doctoral dissertation on brain differences associated with alcohol use during adolescence and has worked on several published studies on the subject with Susan Tapert, Ph.D., a leading researcher in the field. “Overall brain volume doesn’t change much during adolescence, but there are significant decreases in gray matter (the parts of the brain involved in thoughts and emotions) and increases in white matter (the super highways of the brain that connect different gray matter brain regions),” Squeglia says.

The problem for teens is that white matter doesn’t reach its full density in the prefrontal cortex—the area responsible for judgment, decision-making, and impulse control—until age 25 or

By the end of high school, Volkmann was drinking 10 to 12 beers a night—and **engaging in greater risks**, such as getting behind the wheel of a car, unsafe sex, and initiating drunken brawls.

30. And that lack of white matter is one reason teenagers are more likely to engage in risky behaviors.

### THE TEENAGE BRAIN EXPLAINED

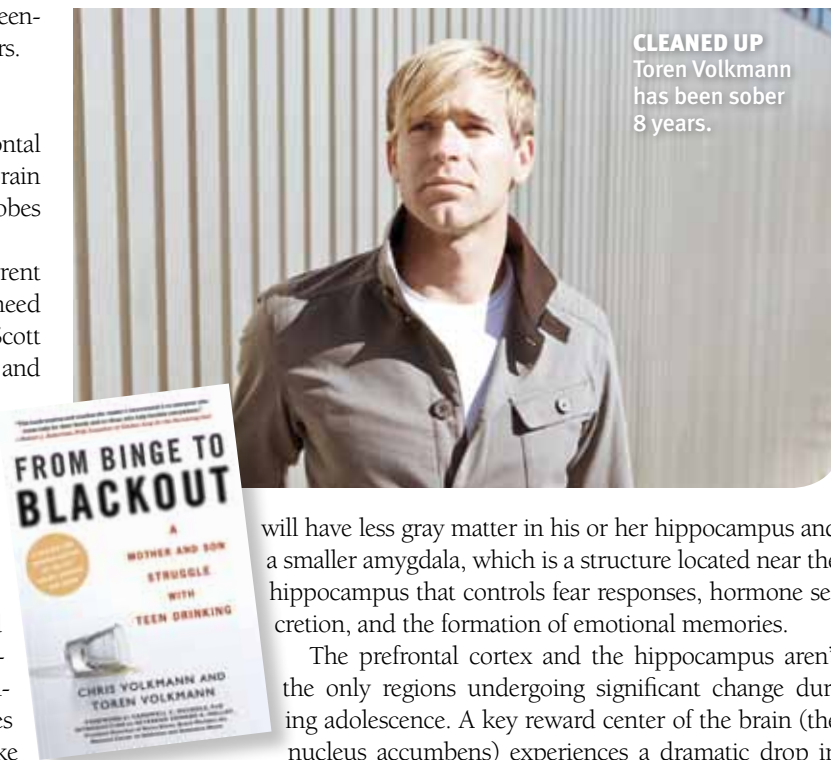
The frontal lobes, which include the prefrontal cortex, control what most of the rest of the brain does. Like a master switchboard, the frontal lobes keep things running smoothly.

“In order for the brain to work well, different regions involved with different functions need to not only work, but work together,” says Scott Swartzwelder, Ph.D., professor of psychiatry and behavioral sciences at Duke University in Durham, NC. “The frontal lobes have a lot to do with organizing the activity of the brain and making sure that the flutes are playing well with the percussion section, so to speak. They organize and orchestrate the interactions of the rest of the brain.”

That’s why the prefrontal cortex—located behind the eyes—is often referred to as the executive control center. It is essential for weighing risks and rewards and for putting the brakes on the pursuit of immediate gratification (like drugs and alcohol) in favor of longer-term goals (like next week’s chemistry test). Unfortunately, these prefrontal regions also undergo major reorganization during adolescence, which may explain why adolescents—who have underdeveloped frontal regions—are more likely to engage in risky behaviors than adults. Without mature frontal lobes, young people are less able to weigh negative consequences and inhibit impulsive behavior like binge drinking, which then directly impacts the developing frontal lobes.

“It’s a cyclical effect,” says Squeglia. “Less developed frontal regions leave teens more likely to engage in dangerous drinking, while drinking further interferes with frontal brain development.” Any insult to the developing adolescent brain during this critical maturation period could interfere with teens’ ability to perform in school and retain new information.

Another vulnerable part of the brain during adolescence is the hippocampus, a structure involved with memory and learning. It’s not part of the frontal lobes, but it is a critical region for transforming new information into lasting memory. The hippocampus is also very sensitive to the effects of alcohol. In fact, studies show that early drinking translates to poor performance on tests of memory, attention, and spatial skills. Some experts believe that a person who drinks excessively during adolescence



**CLEANED UP**  
Toren Volkmann  
has been sober  
8 years.

will have less gray matter in his or her hippocampus and a smaller amygdala, which is a structure located near the hippocampus that controls fear responses, hormone secretion, and the formation of emotional memories.

The prefrontal cortex and the hippocampus aren’t the only regions undergoing significant change during adolescence. A key reward center of the brain (the nucleus accumbens) experiences a dramatic drop in dopamine during that time. That drop may increase teens’ tendency to engage in risky and sensation-seeking behaviors, explains Squeglia.

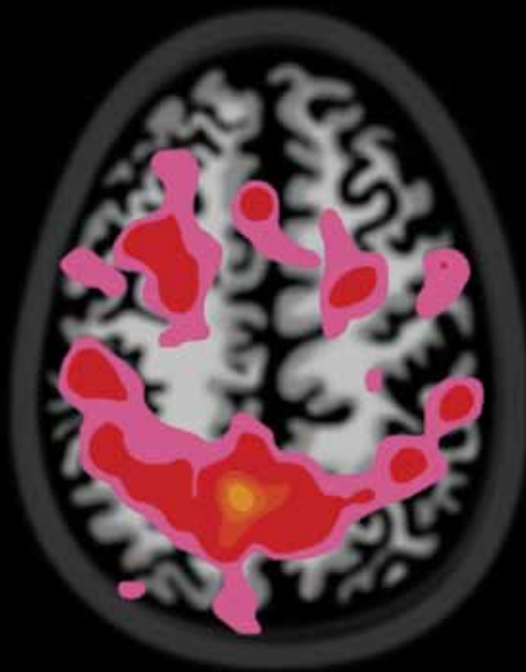
A deficit of dopamine causes the parts of the adolescent brain that are tied to emotions to crave immediate rewards. But because the prefrontal cortex, which helps control such impulses, is not fully developed, it may be more difficult for teenagers to resist a chance for pleasure, experts say. And sensitivity to dopamine encourages teens to reach for more booze because alcohol floods the brain’s reward circuits with the chemical.

### THE TEENAGE BRAIN BUZZED

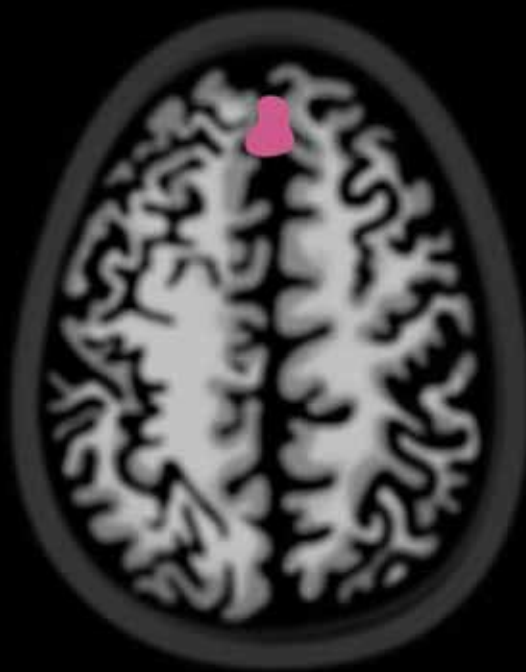
During most of his high school years, Volkmann used to stop drinking after three or four beers. But by the end of high school, his tolerance increased. He began drinking 10 to 12 beers a night—and still wasn’t satisfying his pleasure center. After his judgment was already impaired by alcohol, he would often engage in even greater risks, such as getting behind the wheel of a car, unsafe sex, and initiating drunken brawls.

“I was never concerned about how much I drank,” says Volkmann. “I was drinking to get drunk. I blacked out a lot, and even though I knew what a hangover was and got sick from time to time, I didn’t really suffer.”

## The Effects of Heavy Drinking on the Teen Brain



15 Year-old Non-Drinker



15 Year-old Heavy Drinker

Functional MRI scans of two teens while they took a working memory test. The images show that the heavy drinker isn't using those brain areas normally used to complete a memory test, while the non-drinker is. Researchers suggest that in school, heavy drinkers may not be activating those regions of the brain required to remember a lesson.

According to Squeglia, that type of drinking behavior isn't unusual for teenagers. "They tend to drink less frequently than adults, but when they do drink, they tend to drink in much larger quantities," she says.

Several studies show that binge drinking is particularly harmful to adolescent brain development. So at the same time Volkmann thought he was enjoying a relatively harmless buzz, he was also dramatically altering his brain chemistry.

"Alcohol is a pretty 'dirty' drug in that it doesn't do just one thing," says Dr. Swartzwelder. "It's not like an antidepressant or an anti-anxiety medication that binds with one type of receptor and leaves other receptors alone." Instead, alcohol interacts with and changes the functions of just about every type of chemical receptor in the brain—even at a level of just two drinks. Some of these effects are significantly stronger in adolescent brain cells than in adult brain cells.

Unlike adult drinkers, who might start slurring their words, losing their balance, and generally feeling "woozy" after a few drinks, the teenage brain seems to be less reactive to alcohol's short-term effects. Social impairment and sedation often serve as cues to limit intake, explains Gary M. Reisfield, M.D., assistant professor in the Division of Addiction Medicine at University of Florida College of Medicine in Gainesville. However, adolescents can drink far more than adults before they get sleepy enough to stop. They are also less sensitive to certain post-intoxication "hangover" effects, which often help curb drinking in adults.

In one study published in 1998 in *Alcoholism: Clinical and Ex-*

*perimental Research*, researchers gave boys between the ages of eight and 15 a dose of 0.5 mL/kg pure ethanol, which induced peak blood alcohol levels that were well within the intoxicating range for adults. Yet, the researchers found no behavioral signs of intoxication in the adolescents.

In several studies comparing adults aged 21 to 24 with adults aged 25 to 29, researchers found that alcohol impaired the younger group much more. With doses of alcohol that brought their blood-alcohol content just under the legal limit of impairment, which is .08, those in the 21 to 24 age bracket were far more impaired in terms of their ability to learn and process new material than those who were just a few years older but were out of that brain-development window. (The prefrontal cortex and hippocampus are usually fully developed by the time a person reaches their mid-twenties.)

This combination—of minimal signs of intoxication with maximal impairment—may help explain why teens tend to experience alcoholic "blackouts," in which they fail to remember events that occurred during a night of heavy drinking without a loss of consciousness. Blackouts were once thought to be a symptom only of advanced adult alcoholism, but researchers have recently discovered just how frequent they are among teenagers as well. The memory deficits from a night of heavy drinking may last longer than just the morning after, especially in teens.

Volkmann found that in the three to four days following a weekend of binge drinking and blacking out, his short-term memory was shot. "That first day back, I couldn't remem-

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ber things very well. My attention span was really short, and I couldn't concentrate on anything," he says. "I couldn't even read through a paragraph and remember what I'd read."

And while Volkmann would eventually regain his brain function through the course of the week, no one is clear on whether his drinking behavior in his teens and twenties impacted his long-term cognitive function.

### THE TEENAGE BRAIN TRACKED

Blackouts are usually mercifully brief, and, once they are over, the capacity to form new memories returns. But subtler long-term problems in learning and memory may persist even years after young minds have a chance to develop and dry out.

"Research from our lab has shown that adolescents who drink heavily show worse attention, memory, and visual-spatial functioning over a month after abstaining from alcohol," says Squeglia. Her lab's study subjects were "average" teenagers: They had relatively limited experience with alcohol, were drinking at levels that are common for kids their age (almost a quarter of all seniors admit to binge drinking in the past two weeks), had no diagnosable alcohol or drug disorders, did not use other drugs, and did not have any mental health disorders. So it seems that even "normal," healthy teenagers who engage in occasional heavy drinking (for example, having four to five drinks at a party on the weekend but not using for weeks after) show differences in the way their brains work compared to teens who don't drink at all.

Other studies show reductions in the volume of the prefrontal cortex and hippocampus in adolescents after only a few years of heavy alcohol use—changes that likely compromise learning and memory functions even years down the line.

"Repeated exposure to alcohol in adolescence might lock in a pattern of hypersensitivity to alcohol in terms of its effects on learning and memory even later in life," says Dr. Swartzwelder. "A related thing occurs if you give an animal repeated doses of alcohol during adolescence and then you let it mature: The animal remains less sensitive to the sedative effects of alcohol." Combined, the two effects may set an adolescent up for later alcohol addiction.

Indeed, studies show that the earlier a person starts to drink in an unsupervised way (at a keg party with friends, for example, instead of having a glass of wine at dinner with mom and dad), the more likely he or she is to have alcohol abuse problems later in life. According to the results of a national survey published in *Archives of Pediatrics & Adolescent Medicine* in 2006, nearly half of 43,093 adults who began drinking alcohol before the age of 14 became alcohol-dependent at some

point during their lives, compared with only nine percent of those who waited to drink until they were 21. And the correlation holds even when genetic predispositions are taken out of the equation.

That was certainly the case for Volkmann, who realized at the age of 24 that he was an alcoholic. "I couldn't control how much I drank, and I stopped caring about what was going to

## Teen Drinking, Shot by Shot

### ▶ AFTER ONE DRINK

Alcohol is a depressant, meaning it slows the function of the central nervous system. So after one drink, because stress hormones such as adrenaline and cortisol drop, teens may feel more relaxed or less anxious. Since alcohol blocks some of the messages trying to get to the brain, it may also alter perceptions, emotions, movement, and hearing. Still, adolescents are much less sensitive than their adult counterparts to many of the undesired effects of alcohol, which normally serve as cues to moderate intake. So they can drink twice as much alcohol (and certainly more than one drink) before feeling anything.

### ▶ AFTER THREE DRINKS

More alcohol causes greater changes in the brain, reducing hand-eye coordination and often resulting in blurred vision and slurred speech and increasing the chances of a teen engaging in risky behavior. Driving accidents are common at this stage since the person is mobile, awake, and may think they're "okay" to drive.

### ▶ AFTER FIVE OR MORE DRINKS

At this level of intake, most people stagger, lose their coordination, and become confused or disoriented. They may become overly friendly and talkative or very aggressive and angry. Heavy alcohol intake impedes the body's ability to warm itself and can cause blackouts (memory loss without losing consciousness). Excessive drinking can sometimes even result in low blood-sugar levels, convulsions, coma, and even death. Several studies have shown that binge drinking can interfere with the normal maturation of brain regions—especially the prefrontal cortex and hippocampus—that could lead to chronic cognitive and behavioral problems.

Theoretically, someone like Volkmann, who was a heavy drinker as a teen, **may fully recover brain function** if they stop drinking.

happen the next day or the day after,” he says. “What mattered more was when I was getting my next drink.”

Volkmann’s moment of truth came after a weekend of binge drinking when he was in Paraguay with the Peace Corps. He went to the health center and explained he was having issues with alcohol use; within three days he was on a plane back to the States. He enrolled in a 30-day residential treatment program and then spent six months in a halfway house.

It has been more than eight years since Volkmann took his last drink. And while there’s no telling whether his drinking habits during his teens and early twenties impacted his brain function over the long term, experts claim that the incompletely developed brain is remarkably resilient. So theoretically, someone like Volkmann, who was a heavy drinker as a teen, may fully recover brain function if they stop drinking.

Squeglia points to test results from a group of teenagers recruited from substance abuse treatment centers when they were 15. When researchers retested the teenagers eight years later, those who had relapsed and who continued to get drunk frequently performed the worst on tests requiring focused attention, while those who reported the most hangovers performed the worst on spatial tasks. However, the relative handful of teenagers and young adults in the group who stayed sober after treatment—28 percent of the total—showed negligible differences in their performance, at both the four-year and the eight-year mark, as other teenagers who had rarely if ever had a drink.

If you ask Volkmann, now 32 and sober, some of the cognitive effects of excessive alcohol consumption continue over the long haul. While research in this area is still ongoing, some studies suggest that heavy drinking during adolescence compromises the brain’s ability to learn and form new memories, experts say.

According to Dr. Swartzwelder, there are two ways of looking at the long-term effects of adolescent drinking. One is, “The adolescent brain gets damaged more easily by alcohol than the adult brain does.” The second is, “Maybe the adolescent brain is not damaged more easily, in the sense of killing brain cells. Maybe the adolescent brain is changing so much that drinking alcohol alters the trajectory of that development in a way that causes circuits to go awry.”

Either way, Volkmann claims his memory isn’t where he’d like it to be. “I can’t say I know my memory is bad because of alcohol,” Volkmann says. “But I blacked out so many times when I was drinking, and that affects the way your memory works, so it would also be foolish of me to believe that my memory hasn’t been impacted in some way.”

## Underage Drinking, Pumped Up

Since the introduction of Red Bull in the United States in 1997, the energy drink market has exploded. Hundreds of different brands now appear on convenience store shelves, with caffeine content ranging from a modest 50 mg to a hair-raising 505 mg per can or bottle. Despite efforts to curb teens from drinking a combination of alcohol with energy drinks, the trend continues.

Mixing alcohol with other mind-altering substances is never a good idea, and pairing it with energy drinks may be especially hazardous. “The combination of caffeine and alcohol is very dangerous in terms of what it allows people to do,” says Scott Swartzwelder, Ph.D., professor of psychiatry and behavioral sciences at Duke University in Durham, NC. Not only does caffeine counteract the sedative effects of alcohol (enabling teens to stay up longer and drink more alcohol), but it also effectively removes any built-in checks the body has for overindulging, according to a study published in 2011 in *Alcoholism: Clinical & Experimental Research*.

“Recent work here at the University of Florida demonstrated that, compared with bar patrons who consumed only alcohol, those who reported consuming alcohol and energy drinks were more than three times as likely to leave the bar highly intoxicated (that is, with a blood-alcohol content of more than 0.08), and more than four times as likely to report the intention to drive a motor vehicle home from the bar,” says Gary M. Reisfield, M.D., assistant professor in the Division of Addiction Medicine at the University of Florida College of Medicine in Gainesville.

These studies and others have prompted several states to introduce legislation banning the sale of caffeinated alcoholic beverages. And the US Food & Drug Administration has issued warning letters to companies that manufacture caffeinated alcoholic beverages, claiming there is evidence that the combinations of caffeine and alcohol in these products pose a public health concern. Until research teases out the real impact of this dangerous mix, it makes sense to avoid caffeine-containing alcoholic drinks. Of course, that’s true whether you’re in your teen years or not.