The Grim Neurology of Teenage Drinking

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Sandy Huffaker for The New York Times

Teenagers have been drinking alcohol for centuries. In pre-Revolutionary America, young apprentices were handed buckets of ale. In the 1890's, at the age of 15, the writer Jack London regularly drank grown sailors under the table.

Toren Volkmann has written a book about his problems with alcohol, which began at age 14.

For almost as long, concerned adults have tried to limit teenage alcohol consumption. In the 1830's, temperance societies administered lifelong abstinence pledges to schoolchildren. Today, public health experts regularly warn that teenage drinkers run greatly increased risks of involvement in car accidents, fights and messy scenes in Cancún.

But what was once a social and moral debate may soon become a neurobiological one.

The costs of early heavy drinking, experts say, appear to extend far beyond the time that drinking takes away from doing homework, dating, acquiring social skills, and the related tasks of growing up.

Mounting research suggests that alcohol causes more damage to the developing brains of teenagers than was previously thought, injuring them significantly more than it does adult brains. The findings, though preliminary, have demolished the assumption that people can drink heavily for years before causing themselves significant neurological injury. And the research even suggests that early heavy drinking may undermine the precise neurological capacities needed to protect oneself from alcoholism.

The new findings may help explain why people who begin drinking at an early age face enormous risks of becoming alcoholics. According to the results of a national survey of 43,093 adults, published yesterday in Archives of Pediatrics & Adolescent Medicine, 47 percent of those who begin drinking alcohol before the age of 14 become alcohol

dependent at some time in their lives, compared with 9 percent of those who wait at least until age 21. The correlation holds even when genetic risks for alcoholism are taken into account.

The most alarming evidence of physical damage comes from federally financed laboratory experiments on the brains of adolescent rats subjected to binge doses of alcohol. These studies found significant cellular damage to the forebrain and the hippocampus.

And although it is unclear how directly these findings can be applied to humans, there is some evidence to suggest that young alcoholics may suffer analogous deficits. Studies conducted over the last eight years by federally financed researchers in San Diego, for example, found that alcoholic teenagers performed poorly on tests of verbal and nonverbal memory, attention focusing and exercising spatial skills like those required to read a map or assemble a precut bookcase.

"There is no doubt about it now: there are long-term cognitive consequences to excessive drinking of alcohol in adolescence," said Aaron White, an assistant research professor in the psychiatry department at Duke University and the co-author of a recent study of extreme drinking on college campuses.

"We definitely didn't know 5 or 10 years ago that alcohol affected the teen brain differently," said Dr. White, who has also been involved in research at Duke on alcohol in adolescent rats. "Now there's a sense of urgency. It's the same place we were in when everyone realized what a bad thing it was for pregnant women to drink alcohol."

One of two brain areas known to be affected is the hippocampus, a structure crucial for learning and memory. In 1995, Dr. White and other researchers placed delicate sensors inside living brain slices from the hippocampi of adolescent rats and discovered that alcohol drastically suppressed the activity of specific chemical receptors in the region. Normally, these receptors are activated by the neurotransmitter glutamate and allow calcium to enter neurons, setting off a cascade of changes that strengthen synapses, by helping to create repeated connections between cells, aiding in the efficient formation of new memories.

But at the equivalent of one or two alcoholic drinks, the receptors' activity slowed, and at higher doses, they shut down almost entirely. The researchers, led by Scott Swartzwelder, a neuropsychologist at Duke and at the Veterans Affairs Medical Center in Durham, N.C., found that the suppressive effect was significantly stronger in

adolescent rat brain cells than in the brain cells of adult rats.
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As might be predicted, the cellular shutdown affected the ability of the younger rats to learn and remember. In other experiments, the team found that adolescent rats under the influence of alcohol had far more trouble than did tipsy adult rats when required repeatedly to locate a platform submerged in a tub of cloudy water and swim to it.

Dr. Swartzwelder said it was likely that in human teenagers, analogous neural mechanisms might explain alcohol "blackouts" — a lack of memory for events that occur during a night of heavy drinking without a loss of consciousness. Blackouts were once thought to be a symptom of advanced adult alcoholism, but researchers have recently discovered just how frequent they are among teenagers as well.

In a 2002 e-mail survey of 772 Duke undergraduates, Dr. White and Dr. Swartzwelder found that 51 percent of those who drank at all had had at least one blackout in their drinking lifetimes; they reported an average of three blackouts apiece.
These averages barely suggest the frequency of blackouts among young adults at the extreme end of the drinking scale. Toren Volkmann, 26, is a graduate of the University of San Diego who, at 14, started drinking heavily almost every weekend and at 24 checked himself into a residential alcohol treatment program.

"It was common for me to basically black out at least once or twice every weekend in late high school and definitely through college, and it wasn't a big deal to me," said Mr. Volkmann, a co-author, with his mother, Chris, of "From Binge to Blackout: A Mother and Son Struggle With Teen Drinking," to be published in August. "I wouldn't even worry about what happened, because I wouldn't know."

Blackouts are usually mercifully brief, and once they are over, the capacity to form new memories returns. But younger rats subjected to binge drinking also displayed subtler long-term problems in learning and memory, the researchers found, even after they were allowed to grow up and "dry out."

In experiments conducted by the Duke team, the reformed rat drinkers learned mazes normally when they were sober. But after the equivalent of only a couple of drinks, their performance declined significantly more than did that of rats that had never tippled before they became adults. The study was published in 2000 in the journal Alcoholism: Clinical and Experimental Research. Other research has found that while drunken adolescent rats become more sensitive to memory impairment, their

hippocampal cells become less responsive than adults' to the neurotransmitter gamma-amino butyric acid, or GABA, which helps induce calmness and sleepiness. This cellular mechanism may help explain Jack London's observation, in "John Barleycorn: Alcoholic Memoirs," that when he was a teenager he could keep drinking long after his adult companions fell asleep.

"Clearly, something is changed in the brain by early alcohol exposure," Dr. Swartzwelder said in an interview. "It's a double-edged sword and both of the edges are bad.

"Teenagers can drink far more than adults before they get sleepy enough to stop, but along the way they're impairing their cognitive functions much more powerfully." Alcohol also appears to damage more severely the frontal areas of the adolescent brain, crucial for controlling impulses and thinking through consequences of intended actions — capacities many addicts and alcoholics of all ages lack.

In 2000, Fulton Crews, a neuropharmacologist at the University of North Carolina, subjected adolescent and adult rats to the equivalent of a four-day alcoholic binge and then autopsied them, sectioning their forebrains and staining them with a silver solution to identify dead neurons.

All the rats showed some cell die-off in the forebrain, but the damage was at least twice as severe in the forebrains of the adolescent rats, and it occurred in some areas that were entirely spared in the adults.

Although human brains are far more developed and elaborate in their frontal regions, some functions are analogous across species, Dr. Crews said, including planning and impulse control. During human adolescence, these portions of the brain are heavily remolded and rewired, as teenagers learn — often excruciatingly slowly — how to exercise adult decision-making skills, like the ability to focus, to discriminate, to predict and to ponder questions of right and wrong.

"Alcohol creates disruption in parts of the brain essential for self-control, motivation and goal setting," Dr. Crews said, and can compound pre-existing genetic and psychological vulnerabilities. "Early drinking is affecting a sensitive brain in a way that promotes the progression to addiction.

"Let's say you've been arrested for driving while drunk and spent seven days in jail," Dr. Crews said. "You'd think, 'No way am I going to speed and drive drunk again,' because

you have the ability to weigh the consequences and the importance of a behavior. This is exactly what addicts don't do."

In another experiment, published this year in the journal Neuroscience, Dr. Crews found that even a single high dose of alcohol temporarily prevented the creation of new nerve cells from progenitor stem cells in the forebrain that appear to be involved in brain development.

The damage, far more serious in adolescent rats than in adult rats, began at a level equivalent to two drinks in humans and increased steadily as the dosage was increased to the equivalent of 10 beers, when it stopped the production of almost all new nerve cells.

Dr. Crews added, however, that adult alcoholics who stop drinking are known to recover cognitive function over time.

The same may hold true for hard-drinking teenagers. In 1998, Sandra Brown and Susan Tapert, clinical psychologists at the University of California, San Diego, and at the Veterans Affairs Medical Center there, found that 15-to-16-year-olds who said they had been drunk at least 100 times performed significantly more poorly than their matched nondrinking peers on tests of verbal and nonverbal memory.

The teenagers, who were sober during the testing, had been drunk an average of 750 times in the course of their young lives.

"Heavy alcohol involvement during adolescence is associated with cognitive deficits that worsen as drinking continues into late adolescence and young adulthood," Dr. Tapert said.

Two M.R.I. scan studies, one conducted by Dr. Tapert, have found that hard-drinking teenagers had significantly smaller hippocampi than their sober counterparts. But it is also possible, the researchers said, that the heavy drinkers had smaller hippocampi even before they started to drink.

Teenagers who drink heavily may also use their brains differently to make up for subtle neurological damage, Dr. Tapert said. A study using functional M.R.I. scans, published in 2004, found that alcohol-abusing teenagers who were given a spatial test showed more activation in the parietal regions of the brain, toward the back of the skull, than did nondrinking teenagers.

When female drinkers in the group were tested in their early 20's, their performance declined significantly in comparison with nondrinkers, and their brains showed less activation than normal in the frontal and parietal regions.

Dr. Tapert hypothesized that when the drinkers were younger, their brains had been able to recruit wider areas of the brain for the task.

"This is a fairly sensitive measure of early stages of subtle neuronal disruption, and it is likely to be rectifiable if the person stops drinking," Dr. Tapert said.

The good news is that the brain is remarkably plastic, she added, and future studies may show that the teenage brain, while more vulnerable to the effects of alcohol, is also more resilient.

She pointed to test results from the original group of teenagers, recruited from substance abuse treatment centers and brought into the lab when they were 15 by Dr. Brown. When Dr. Tapert 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.

On the other hand, the relative handful of teenagers and young adults in the group who stayed sober — 28 percent of the total — performed almost as well, at both the four-year and the eight-year mark, as other San Diego teenagers who had rarely, if ever, had a drink.

Mr. Volkmann, the University of San Diego graduate, was not part of Dr. Tapert's study. While in college, Mr. Volkmann said, he thought he drank for the fun of it. His moment of truth came in the Peace Corps in Paraguay, when he began waking up with sweats and tremors. He discovered he could not control his drinking even when he wanted. The son of an anesthesiologist and a former teacher in Olympia, Wash., Mr. Volkmann spent a month in a residential treatment program and six months in a halfway house.

He has since returned to San Diego.

He said in an interview that he had no way of knowing exactly how drinking affected his overall brain function. But on one point, he is clear.
"My memory is definitely better now," he said. "Every day now, I can count on the fact that when I think back to the night before, I know what happened."