frontiers FOR YOUNG MINDS

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BINGING, BOOZING, AND THE TEENAGE BRAIN

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AGES: 8-14

Why do some teenagers binge drink and what happens to their brains when they do? Many people are surprised to find out that the brain continues to develop until the mid-20s and it is particularly vulnerable during the teenage years. In this article, we talk about how the brain matures and some of the different ways that we can measure the brain and mental functions. We explain what binge drinking is. Then we summarize brain research that can give us clues about how much some teenagers will drink and what happens to the brain after teenagers start binge drinking.

What makes for a good party? For some young people, the answer is obvious: alcohol! Drinking alcohol is often glorified in teenage movies and encouraged through the party culture. But have you ever wondered what harm drinking alcohol can have on a young person's brain? Or whether brain development can affect teenagers' decisions about how much they drink?

THE TEENAGE BRAIN

For a long time, scientists thought that the brain finished developing by age five. More recently, neuroscientists who study the brain made a surprise discovery: the brain continues to grow and change until the mid-20s [1]!

The teenage years are very important for brain development. During this time, the brain reorganizes itself through processes called **myelination** and **pruning**. Myelination is the process of adding a substance called myelin around brain cells. Myelin is a layer of fat that acts like insulation around the brain cells, keeping them protected and healthy and allowing them to communicate with other brain cells faster. Pruning is the opposite. In the same way a gardener prunes a tree, the brain prunes weak connections between cells, which allows the strong connections to become even more powerful. The process of pruning helps the brain to become more efficient and productive.

The inner part of the brain, known as the **limbic system**, matures between the ages of 14–17 years [Figure 3; [1]]. The limbic system is the part of the brain that is important for emotions and feelings. It instructs us to do fun and sometimes risky activities. The **prefrontal cortex (PFC)**, which is right behind the forehead, continues to develop until the age of 21–24 years [1]. The PFC is responsible for many higher-level thinking skills and helps keep the limbic system in check. The PFC helps us complete complex tasks, such as making tough decisions by weighing up the pros and cons. Millions of brain cells must be connected in complicated patterns to complete these difficult tasks and this is why it takes a long time for the PFC to develop.

The different amounts of time it takes for certain areas of the brain to develop means that young people can have well-developed limbic systems and less-developed PFCs. This means young people are more likely to engage in activities that they find fun in the short term. This is typical of normal development. However, this imbalance in brain development can also lead to experimentation with alcohol, without considering the consequences [2]. Since their brains are still developing, young people experience greater harm to their brains from drinking than do older drinkers who drink the same amount of alcohol [3].

MYELINATION

The process of adding a layer of fat, known as myelin, around brain cells. The fat layer keeps brain cells protected and healthy, and this allows brain cells to communicate with each other faster.

PRUNING

The brain prunes weak connections between cells, which allows the strong connections to become more efficient and productive.

LIMBIC SYSTEM

The inner part of the brain that controls emotions and feelings. It is the part of the brain that encourages us to do fun, rewarding, and sometimes risky activities.

PREFRONTAL CORTEX (PFC)

Brain area responsible for many higher-level thinking skills, located right behind the forehead. It allows us to complete complex mental tasks and is the slowest part of the brain to fully develop.

BINGE DRINKING

Drinking large amounts of alcohol within a short period, which leads to a blood alcohol concentration level of at least 0.08 g per 100 g of blood.

WHAT IS BINGE DRINKING?

The term used for drinking large amounts of alcohol over a short period of time is **binge drinking**. We can measure how much alcohol a person has drunk based on the blood alcohol concentration levels in the bloodstream. The National Institute on Alcohol Abuse and Alcoholism uses this measure to define binge drinking, which is

Figure 1

Examples of one standard drink. The percent of pure alcohol varies by alcohol type.

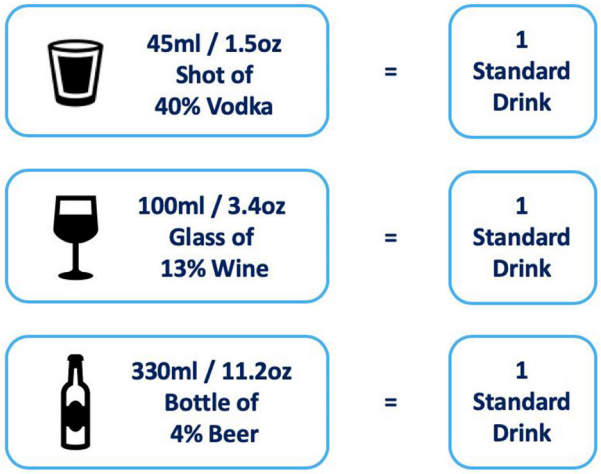

Figure 1

defined as blood concentration levels of alcohol of at least 0.08 g per 100 g of blood [4]. A female typically reaches this level after having 4+ standard drinks within 2 h, while for males it is generally 5+ standard drinks. In the US, a standard drink is any drink containing 14 g of alcohol, regardless of glass size or alcohol type (Figure 1). Other drinking patterns include light drinking (occasional 1–2 standard drinks), moderate drinking (1–2 drinks per occasion on a weekly basis) and heavy drinking (daily drinking or 3+ drinks per occasion on a weekly basis).

In the US, by the eighth grade, approximately one in 20 (5%) students report binge drinking in the past 2 weeks. By the tenth grade, this increases to approximately one in 10 students (10%), and by the last year of high school, approximately one in six students report binge drinking in the past 2 weeks (17%). By college, two in five report regular binge drinking (40%) [4]. Regular binge drinking can lead to poor mental health and participation in other risky behaviors.

HOW DO SCIENTISTS MEASURE THE BRAIN?

MAGNETIC RESONANCE IMAGING (MRI)

An imaging method using strong magnets to capture images of the structure (structural MRI) and blood flow (functional MRI) of the brain.

Scientists have investigated whether features of the brain can help predict which people may binge drink and what happens to their brains when they do. There are different ways that scientists can examine the brain and how it functions. A technique called structural **magnetic resonance imaging (MRI)** captures lots of images that can be combined to create a 3D picture of structures in the brain. These images allow us to examine the volume, thickness, and surface area of brain structures. A similar technique called functional MRI measures brain activity, by detecting changes in blood flow while a person is doing a task (like solving problems). Another less direct way to measure how the brain works is through mental task performance. For example, scientists can measure your ability to remember and change

information in your head by reading out a series of numbers to you (8-4-3-7-1) and asking you to reverse the order and say them back (1-7-3-4-8). This is called the digit span backwards task and is one task that is thought to measure how well the PFC works.

To examine how binge drinking affects the brain, scientists have conducted cross-sectional and longitudinal studies (Figure 2). Cross-sectional studies compare people who binge drink with those who do not at one timepoint. For example, scientists may test a group of college students once during spring break. Cross-sectional studies can use structural or functional MRI to tell us whether binge drinking is related to differences in brain structure, and brain functions can also be assessed using functional MRI and mental task performance at that timepoint. But cross-sectional studies represent just a single snapshot in time and this kind of study cannot tell us whether unusual features in the brain influence how much some teenagers choose to drink or whether binge drinking causes these unusual brain features, or both. This is known as the cause-effect relationship. Longitudinal studies can help us work out the cause-effect relationship between binge drinking and brain development by testing a group of children who have never drunk alcohol and then re-testing this same group throughout their teenage years, as some of them start to drink. This way, we have data on the brain before and after alcohol use, and we can determine the cause-effect relationship by comparing the results from people who have and have not started binge drinking.

BINGE DRINKING AND THE BRAIN

Using structural MRI, cross-sectional studies show that the **cerebral cortex** (outer surface of the brain) in binge drinkers is thinner than in those who do not binge drink, and thicker cerebral cortices tend to be better for development! The brains of binge drinkers tend to have less volume, particularly in the PFC, than the brains of teenagers who do not binge drink [5]. Cross-sectional functional MRI studies have shown us that when binge drinkers complete mental tasks, like the digit span backwards task, their brains have to work harder in order for them to successfully complete those tasks. Cross-sectional studies using mental task performance have shown that binge drinkers tend to make poorer decisions and find it more difficult to stop their quick, impulsive responses and use their reasoning skills to choose the correct answer.

CEREBRAL CORTEX

The outer layer of the brain, which is typically 2–3 mm thick. It is made up of neurons, which are brain cells that communicate with each other.

These cross-sectional studies show us that binge drinking is related to differences in brain structure and activity in the PFC, which is responsible for higher-level thinking. Without a well-functioning PFC, the limbic system takes over and encourages us to do fun but often risky things, in this case, binge drink. These cross-sectional studies are an important first step in uncovering how binge drinking and the brain impact each other. But it is unclear whether binge

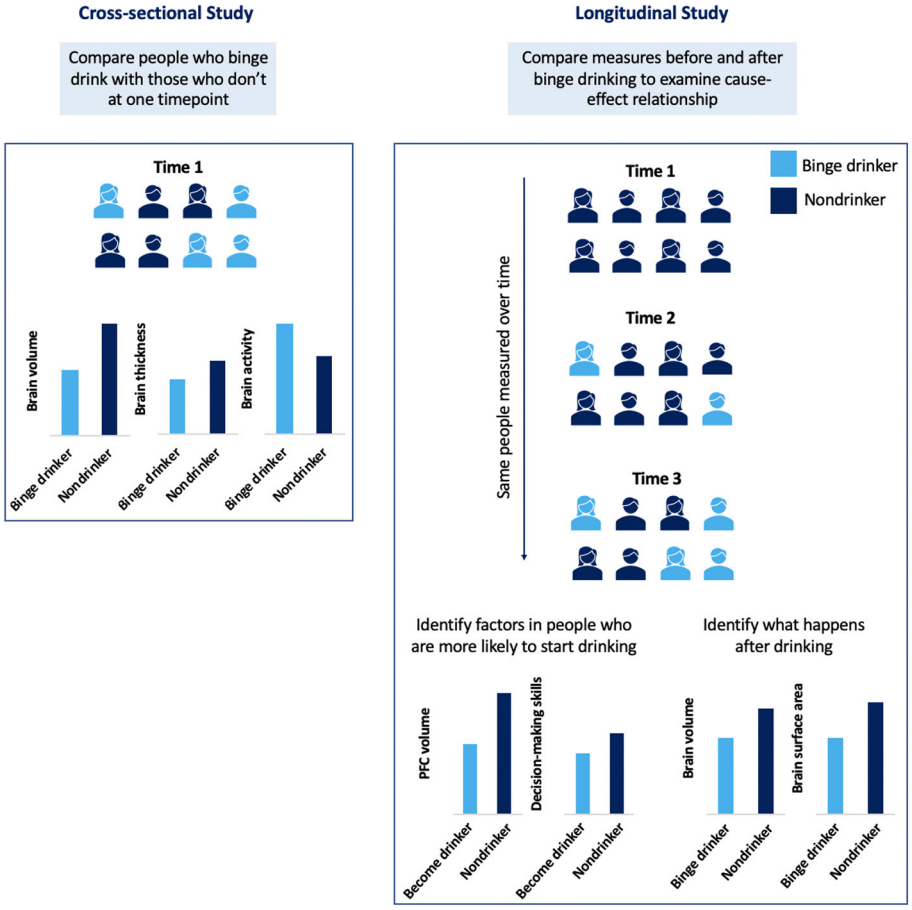

Figure 2

Figure 2

Cross-sectional and longitudinal studies. Cross-sectional studies measure participants at one timepoint, and scientists have found that teenagers who binge drink have smaller and thinner brains with greater brain activity than non-drinking students. Longitudinal studies measure the same participants multiple times. In the study shown, for example, slower PFC development and poorer decision-making skills might cause a teenager to be more likely to start binge drinking. While binge drinking might cause teenagers' brains to grow more slowly.

drinking is causing these differences in the brain, or whether the brain differences are causing binge drinking. To determine the cause-effect relationship, we need to follow people over many timepoints, using longitudinal data.

THE BRAIN CAN INFLUENCE THE CHOICES TEENAGERS MAKE ABOUT BINGE DRINKING

Longitudinal studies using both structural and functional MRI showed that teenagers with slower-developing PFCs (less brain volume and surface area, and less brain activity during performance of mental tasks) are more likely to take up binge drinking than teenagers with PFCs that are faster to develop (Figure 3). Slower PFC development makes it more difficult for teenagers to make good decisions. When scientists tested decision-making ability using mental task performance, they found that children with poorer decision-making skills were more likely to start binge drinking as teenagers [5]. Slower PFC development and poorer decision-making skills might cause a teenager to be more likely to start binge drinking (effect). This information is helpful because we can use it to help teenagers

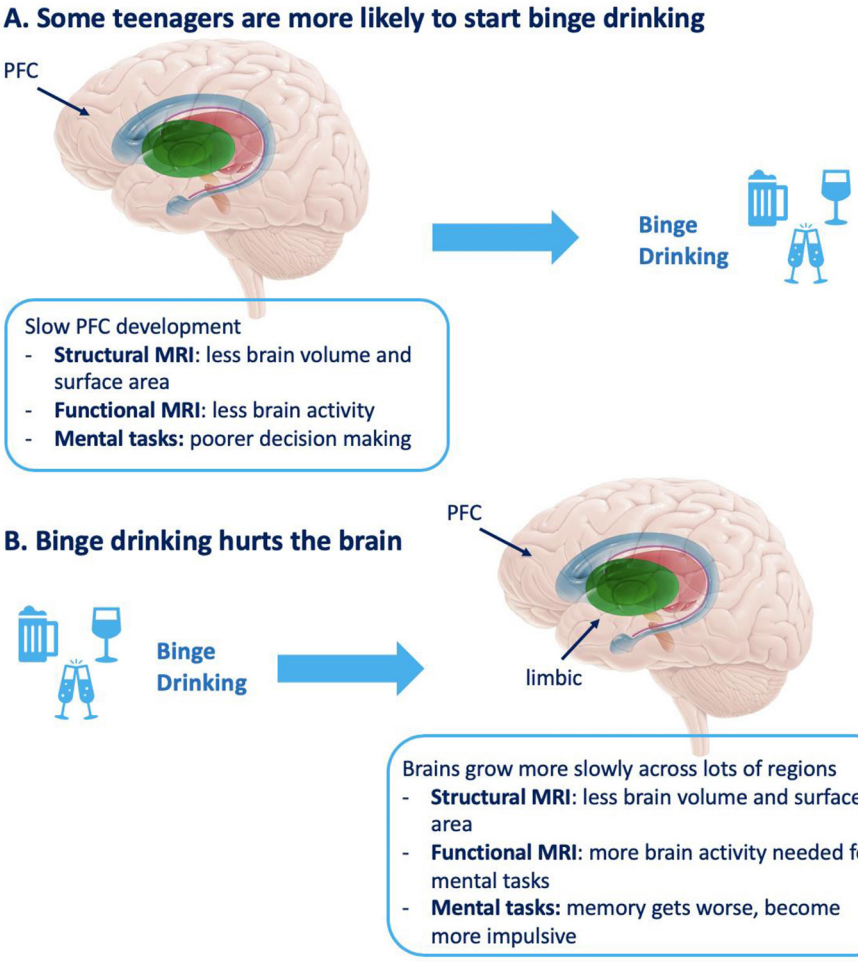

Figure 3

(A) Differences in the brain that increase the likelihood of a teenager binge drinking. In teenagers who are more likely to start binge drinking, the PFC is smaller and there is less brain activity. The PFC is responsible for many higher-level thinking skills, and these teenagers tend to perform more poorly on decision-making mental tasks. **(B)** Summary of what tends to happen to the brain after a teenager starts binge drinking. Binge drinking can cause the brain to grow more slowly and this can lead to poorer memory and impulsive actions. The limbic system (shown in blue, green, and red) is drawn to rewarding activities.

make safer choices about drinking by working to improve their decision-making skills.

WHAT HAPPENS TO THE TEENAGE BRAIN AFTER BINGE DRINKING?

Once teenagers start regular binge drinking (cause), structural MRI shows that their brains, including the PFC, tend to grow more slowly (effect) [5]. Binge drinking can cause interference with successful myelination and pruning, which are important for making the brain productive. Using functional MRI, scientists have also discovered that after teenagers take up binge drinking, their brains must work harder to perform mental tasks than do the brains of teenagers who do not binge drink. After binge drinking, teenagers tend to have more difficulty learning and get worse at remembering things. They also become more impulsive, which means they are more likely to engage in other risky activities.

There are still many unanswered questions about the teenage brain and binge drinking, such as, "*can we protect the brain from alcohol*

through brain training?" Or, *"can the brain repair itself after a young person stops binge drinking?"* At this stage, the answers to these questions remain unknown. More research still needs to be done!

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The Explora Young Minds reviewers are a group of science enthusiasts working with museum educators and mentors from the University of New Mexico. We enjoy learning about the brain through the articles. We also enjoy asking questions and making suggestions to help the scientists make their work more understandable

for everyone! We were helped by our Science Mentor, Crina Floruta, who is a M.D./Ph.D. candidate working in a neuroscience lab and who is hoping to pursue a Neurosurgical residency in the future. She loves Albuquerque, hiking, reading, and talking about the brain with people.

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