

How Is the ADHD Brain Different?

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An in-depth look at the underlying causes of ADHD symptoms in children.

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Ever since it was first diagnosed in the 1960s, *ADHD*

(attention-deficit hyperactivity disorder) has been a controversial topic. Even experts often debate over how the disorder should be defined and what causes it.

While we don't completely understand what causes ADHD symptoms — difficulty regulating attention and emotions, hyperactivity, impulsivity — we do know that it's a neurodevelopmental disorder. That means that the brains of kids with ADHD develop differently from those of other kids. Researchers have started to identify the structural and chemical differences in the brain that may cause the symptoms associated with ADHD.

Differences in Brain Structure

Many of the characteristics of ADHD are related to executive functioning. This refers to a set of mental skills that include working memory, emotional control, and complex problem-solving. Essentially, executive functions are the skills we all use to manage day-to-day tasks, such as time management, staying organized, and planning. While there are several different parts of the brain that contribute to executive functioning, the prefrontal cortex is especially important in regulating these skills.

Research has shown that in children with ADHD, the prefrontal cortex matures more slowly than typically developing kids. It is also slightly smaller in size. Similarly, the cerebellum, hippocampus, and amygdala are also thought to be smaller in volume in kids with ADHD.

Like every part of the brain, the cerebellum is involved in many different functions, but its role in the regulation of movement may be especially relevant to ADHD symptoms. A smaller cerebellum could contribute to difficulty with what's called "motor response inhibition," which refers to the ability to suppress actions that interfere with a current task, such as staying seated during a class lesson. Smaller hippocampus and amygdala sizes can cause impairment in the regulation of memory, emotion, and behavior, which is a common symptom of kids with ADHD.

While these regions of the brain may remain smaller in people with ADHD, studies have shown that they do continue to grow and mature as children get older. By adulthood, the difference in size when compared to individuals without the disorder has appeared to be less significant.

Differences in Brain Connectivity

Another way to measure functionality in the brain is through activity and connectivity. Scientists use functional magnetic resonance imaging (fMRI) to measure changes in brain activity through blood flow. When an area of the brain is active, the level of blood flow to that region increases. In people with ADHD, studies using *fMRI*

technology have shown irregular activity in several regions of the brain involved in motor, *cognitive*, and emotional regulation.

There is a collective network of structures in the brain that is unusually active in children with ADHD. This is called the default mode network (DMN), and it was first discovered by accident when researchers noticed

high levels of brain activity while their study participants were simply resting.

The DMN is a relatively new concept and there is still some debate over which parts of the brain may be involved. It is thought to be the most active when we let our minds wander. In neurotypical children, this network shows lower levels of activity while they're engaged in a task that requires paying attention, and higher levels of activity when they're awake but simply daydreaming or recalling a memory. In children with ADHD, the network still shows a high amount of activity during active tasks that require focused attention. This difference may explain why kids with ADHD struggle to focus or concentrate in the classroom.

The unusual DMN activity seen in people with ADHD may also be explained by what's called its "functional connectivity" to other networks in the brain. The concept of functional connectivity refers to the idea that certain areas in the brain are connected if their functional behaviors are frequently correlated with each other. This could be a positive or negative correlation. For instance, there is another network in the brain called the "task-performing network" that allows us to perform attention-demanding tasks. In terms of functional connectivity, the DMN normally has a negative correlation to this network. This means that the DMN is less active while the task-performing network is more active. In children with ADHD, the DMN is thought to have a *reduced* negative correlation with this network due to weakened connectivity. This means that it's more active than it's supposed to be, which can lead to lapses in attention during goal-oriented tasks. Therefore, the minds of children with ADHD may wander during a task that demands attention, like homework.

Studies have also discovered that in people with ADHD, there is an unusually high level of functional connectivity between the brain regions that form part of a mechanism called the "selective visual attention system." This system allows us to determine what's important to notice or pay attention to in the moment. Irregular connectivity within this system may cause children with ADHD to notice irrelevant things in their field of vision, making it hard to know what to focus on.

Differences in Neurochemistry

In addition to differences in structure and connectivity, chemical imbalances in the brain may also play a role in causing ADHD symptoms.

Serving as our control center, the brain needs to both send and receive electrical signals or “messages” throughout the body. The brain is able to do this via nerve cells (neurons). However, there are gaps between neurons. Neurotransmitters are the chemical messengers that fill the gap and allow for messages to be passed along.

One very important *neurotransmitter*

is dopamine, which has several functions. There are pathways in the brain that allow the transport of dopamine from one region to another to relay important information. There are four major dopamine pathways, and two of them are thought to contribute to the impairment of cognitive functioning we often see in kids with ADHD.

The first pathway is called the “dopamine reward pathway.” When we experience something that’s pleasurable such as eating tasty food, an increased amount of dopamine is released along this pathway and activates feelings of pleasure and euphoria. It is theorized that these feelings of pleasure are reinforced by the connection between a part of the brain that processes pleasure and the hippocampus, which plays an important role in memory. That is, we remember what food is associated with this feeling of pleasure and it motivates us to eat it again.

The second pathway, known as the “mesocortical pathway,” connects an area of the brain that’s rich in dopamine to the prefrontal cortex. Via the transmission of dopamine, this pathway helps the prefrontal cortex facilitate executive functions such as cognition, working memory, and decision-making.

In children with ADHD, these two pathways are thought to be disrupted, which can lead to impairment of cognitive and motivational functioning. Scientists believe that these disruptions could be due to an unusual number of dopamine transporters in the brains of people with ADHD. A dopamine transporter is a protein that is responsible for removing dopamine from the gap between neurons and terminating dopamine transmission. An increased number of these transporters can lead to unusually low amounts of dopamine in the brain. One piece of evidence

for this theory is that stimulant medications such as Adderall are often successful in reducing ADHD symptoms, and these medications suppress the reuptake, or removal, of dopamine.

While we may not know the exact causes of ADHD symptoms, advances in research have given us a better understanding of the disorder. Identifying the structural and chemical differences in the brains of children with ADHD will not only validate their struggles but may also lead to significant improvements in treatment.

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