

and
Working
Memory

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by Tracy Packiam Alloway, PhD

JEREMY IS IN A BAD MOOD. He fought with his mother on the way to school, and now someone has taken the ball on the playground. He runs over and demands that the boy give it to him. But he can't wait, so he pushes the boy and grabs the ball. He is sent to the principal's office. When asked why he acted that way, he says, "I don't like being different. Everyone knows I am. I have a good side and a bad side in my brain and the bad side wins a lot. I can't help it, I just go bad like The Hulk and start pushing things over."

The Hulk also surfaces in the classroom, according to his teacher. Jeremy has trouble sitting still, struggles to complete tasks on time, and is easily distracted. His working memory difficulties make it hard for him to keep track of what he needs to do. He has a difficult time reading information on the board. He is one of the first students to hand in his work, but it is always full of errors, and sometimes is not even complete.

The ADHD brain

A number of studies have investigated how the brain influences ADHD. Students with ADHD often have an underactive prefrontal cortex (PFC), the home of working memory. When students without ADHD get an urge to get up and walk around, or let their thoughts wander off to a television show they like, their working memory takes over and helps them suppress the urge. But the working memory of a student with ADHD often isn't strong enough to exert control. This may be because students with ADHD often have a reduction in brain volume in the PFC.

At the same time, the motor cortex, which is responsible for planning and controlling motor functions, is overly active. This is like having a big, powerful engine under the hood of a car, constantly revving and trying to peel out. The motor cortex is like the engine and the PFC (working memory) is the brake. If the brake isn't working that well, the result can be a behavior meltdown.

Linked but distinct problems

Working memory is critical for a variety of activities at school, from reading comprehension and math to copying from the board and navigating around school. In the classroom, we use verbal working memory to remember instructions, learn language, and complete reading comprehension tasks. Visual-spatial working memory is linked to math skills and remembering sequences of patterns, images, and locations. See the sidebar for specific examples of activities requiring working memory taken from real classrooms.

The DSM-5 recognizes that while students younger than twelve may display attentional and behavior problems, evidence shows that many of them will outgrow these patterns by the time they are twelve years old.

Classroom Activities that Involve Verbal Working Memory

- Remembering and carrying out lengthy instructions. Here is an example from a classroom of six-year-olds: *Put your sheets on the green table, Put the arrow cards in the packet, put your pencil away, and Come and sit on the carpet.* Students with poor working memory are usually the first ones to sit down on the carpet—because they only carried out the first part of the instruction but forgot the rest!
- Remembering and writing down text, including words, sentences, paragraphs.
- Remembering sentences with complicated grammatical structure, such as *To save the princess, the knight fought the dragon,* which is harder to understand than *The knight fought the dragon to save the princess.*

Classroom Activities that Involve Visual-Spatial Working Memory

- Solving a mental math problem.
- Keeping track of their place when writing a sentence from the board. The student with poor working memory will often repeat or skip letters.
- Using pictures or images to retell a story. The student with poor working memory may get confused about the order of events in the story or even leave out key events.

It is also important to recognize that while some features of ADHD (like inattentive behaviors) and poor working memory are closely related, they are also distinct problems. While students with ADHD have a poor working memory, not all students with a poor working memory have ADHD. On the one hand, boys are four times more likely than girls to be diagnosed with ADHD, possibly because they act out their impulses, whereas girls internalize them by daydreaming instead. On the other hand, my research on over three thousand children demonstrated that boys are not more likely than girls to have working memory problems (Alloway et al., 2009).

In addition to the characteristic hyperactive and impulsive behavior, students with ADHD also exhibit classroom behavior typical of working memory problems. Teachers report that these students have short, poor attention spans and are easily distracted. They

often forget what they are currently doing and things they have learned, fail to remember instructions, and leave work incomplete. Because of their poor working memory, they find it effortful to process classroom information and, as a result, often make careless mistakes, particularly in writing, and have difficulty in solving problems.

Students with ADHD struggle when they have to process information. This deficit is evident when they are asked to remember lengthy instructions, keep track of their place in multi-step problems, or undertake activities that require multi-tasking. They will frequently complete only the first part of the instruction, lose track of where they are in the problem, or only complete one of the required activities.

Visual-spatial working memory deficits are also evident in the individual with ADHD. These deficits are so pervasive that a student with ADHD can be

CASE STUDY

Helping "Stephen"

COMBINED ADHD PROFILE

Stephen's behaviors in relation to the DSM-5:

- Often does not seem to listen when spoken to directly
- Is often forgetful in daily activities
- Often runs about or climbs in situations where it is not appropriate
- Often blurts out an answer before a question has been completed
- Often interrupts or intrudes on others (for example, butts into conversations or games)

Ten-year-old Stephen consistently struggled with his schoolwork. In class, he often drifted off into deep thought, or I would catch him sneaking cars from the toy bin in the room. He used these toys to keep himself occupied during lessons, rolling the cars around on his lap, or on top of his desk. When I called on him to answer a question, he usually responded before I finished asking the question. When class assignments were given, he forgot what he was supposed to do. When I restated the directions, he didn't pay attention.

distinguished from students without ADHD by their low visual-spatial working memory scores. In one study, I gave students with ADHD a range of executive function tests, such as inhibition, shifting, and planning actions, as well as working memory, to see which of these tests could best identify students with ADHD from their typically developing peers. Out of all the tests, visual-spatial working memory scores were the most accurate in identifying a student with ADHD in the classroom (Holmes et al., 2010). This tells us that visual-spatial working memory deficits are such a prominent feature of students with ADHD that it can be used as an additional diagnostic tool to identify them. 🗣️

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memory and education, and she has developed the internationally recognized Automated Working Memory Assessment (Pearson). The author of over seventy-five scientific articles and books on working memory and learning, she was the 2009 winner of the prestigious Joseph Lister Award from the British Science Association.

ADDITIONAL READING

Tracy P. Alloway, Julian G. Elliott, and Joni Holmes, "The Prevalence of ADHD-Like Symptoms in a Community Sample," in *Journal of Attention Disorders*, 2010:14.

Tracy P. Alloway, Julian G. Elliott, and Maurice Place, "Investigating the Relationship Between Attention and Working Memory in Clinical and Community Samples," *Child Neuropsychology*, 2010:16.

Tracy P. Alloway, Susan E. Gathercole, Joni Holmes, Maurice Place, and Julian G. Elliott, "The Diagnostic Utility of Behavioral Checklists in Identifying Children with ADHD and Children with Working Memory Deficits," in *Child Psychiatry & Human Development*, 2009:40.

Joni Holmes, Susan E. Gathercole, Maurice Place, Tracy P. Alloway, and Julian G. Elliott, "An Assessment of the Diagnostic Utility of EF Assessments in the Identification of ADHD in Children," in *Child & Adolescent Mental Health*, 2010:15.

Another problem was his social relationships. When it was time for recess, he pushed his way to the front of the line, angering his fellow classmates. On the playground, he climbed trees and ran around continuously ignoring the teachers who told him to stop. If he did stop, he imposed himself into the other students' activities, often interrupting games of hide and seek by running around and finding everyone before the designated "finder" had a chance. This behavior often caused arguments between Stephen and his peers, and prevented him from forming friendships with his classmates.

EFFECTIVE STRATEGIES

- **Minimize distractions so working memory is not overwhelmed**
I maintained eye contact with Stephen whenever I gave him instructions. This meant that Stephen's working memory did not have to work overtime to inhibit his impulsive behavior.
- **Shorten instructions to reduce the working memory load**
Stephen had a problem listening in class, so I began asking him shorter questions and verbally rewarded him if he did not interrupt. If he did interrupt or got the wrong answer, I simply restated the question until he was able to answer it correctly.
- **Break down information to reduce working memory processing**
I gave Stephen simple questions, like "There are three apples in a basket and you ate two of them, how many do you have left?" I then walked him through the steps of the question so he could understand the process. This turned out to be beneficial for the entire class as the detailed explanations also helped the other students retain the information.
- **Repeat information to boost working memory**
I encouraged Stephen to repeat the question back to me, to ensure that he was paying attention, as well as to allow him to verbalize and understand the information.
- **Shorten study periods to reduce the working memory load**
To make it easier for Stephen to stay on track, I allowed him to take frequent breaks during his class activities. I asked him to stand and stretch to release some energy. This allowed him to get out his "wiggles" and focus on his classwork after his break.
- **Reward intermittently**
For recess, I also incorporated shortened activities. Stephen had to choose a short play activity with other students and stick with it. If he stayed with that group, I allowed him to choose his play activities on an intermittent basis. If he left his group, he had to stand next to me until the end of recess.
Over time, he was able to control his impulses and made friends with classmates that he played with every day. With patience and consistent reinforcement, Stephen was able to drastically improve over the school year, becoming calmer and performing better on assessments.