Avner Stern, Ph.D.
Licensed Psychologist, KS & MO
Behavioral Health Specialists, Inc.
8400 W. 110th St., Suite 230
Overland Park, KS 66210
913-906-9559 astern@bhsks.com

Working Memory and Learning

Avner Stern, Ph.D.

What is Working Memory (WM)?

Working memory is a key cognitive function, used in daily life that allows individuals to hold information - "online"- for brief periods of time, typically a few seconds, in order to complete a task. **In other words, working memory is the ability to control attention in the face of distractions.**

Recent scientific research conducted in the U.S. and Europe demonstrates that working memory is one of our most crucial cognitive capabilities, essential for countless daily activities like sustaining attention, following directions, carrying out multistep instructions, remembering information momentarily, complex reasoning or staying focused on a task or project. This broadened understanding of the importance of working memory can provide great hope to a range of people who suffer from working memory deficits, including children and adults with attention problems, people with learning disabilities, and victims of stroke and traumatic brain injury among others.

Working Memory Essentials

- WM is a key cognitive function used in daily life that helps you to hold information in mind -"online"- for brief periods of time (typically a few seconds).
- WM develops during childhood and adulthood; it reaches maximum capacity at around 30 years of age.
- WM gradually declines during aging.
- About 50% of the variance in general intelligence between individuals can be explained by differences in working memory capacity.
- Individuals with working memory difficulties may not "stick to" an activity and may fail to complete tasks
- WM is important because it provides a mental workspace in which we can hold information while mentally engaged in other relevant activities
- WM impairments are found in ADHD, learning disabilities, language processing disorders, stroke and traumatic brain injury victims, among others

Background

The term "working memory" has existed for several decades. Early conceptions date back to the late 19th century when American psychologist William James proposed the distinction between a "primary" memory with a limited capacity and a long-term memory. Psychologist Dr. Alan Baddeley later defined working memory as a multifaceted function that captures visual and auditory information, directs attention, and coordinates processes. This model, still widely accepted, has been modified following exhaustive research demonstrating that working memory is definitively linked to attention control.

Working Memory and ADHD

Cognitive problems are primary rather than secondary features of ADHD. Current theories propose that the behavioral symptoms of ADHD are not primary features of the disorder but are attributable to underlying deficits in cognitive control processes that guide both behavior and cognitive functioning (Barkley, 1998).

Working memory is one type of cognitive control process implicated in ADHD. Recent research indicates that working memory plays a major role in helping the mind focus and screen out distractions. Scientists have shown that even well-functioning, healthy adults become highly distractible when they have to think hard and continually rehearse information, which puts a heavy load on working memory. In other words, "the ability to act upon relevant information and ignore irrelevant distracters depends upon the availability of working memory".

How do we use working memory?

As technology continues to place endless amounts of information at our fingertips, working memory has become even more essential to our ability to function successfully since it allows us to focus our attention and organize and prioritize the things we do every day.

- Socially, you use it in the moment you are meeting someone and hearing their name for the first time.
- Academically, it is used when you're reading and find it hard to comprehend what you've just read and have to reread material.
- Professionally, working memory is what drives your ability to concentrate and not lose your train of thought.

Living with a poor working memory would be like running many software programs simultaneously on a computer with little random access memory (RAM) — it would be slow, frustrating and very inefficient. In short, it wouldn't work the way it needed to.

Working Memory and Academics

- WM is one of our most crucial cognitive capabilities, essential for sustaining attention, following directions, carrying out multistep instructions, remembering information momentarily, complex reasoning or staying focused on a project
- WM helps us to control attention and resist distractions
- WM is crucial for math, reading comprehension, complex problem solving and test taking.
- WM skills at four years are excellent predictors of children's achievements several years later; the better child's working memory skills the better they will perform in school.

Why is working memory so crucial to learning?

- WM is crucial to many learning activities in the classroom, because children often have to hold information in mind while engaged in an effortful activity.
- For example, WM is required for such tasks as remembering the sentence you have to write while trying to spell the individual words, or the list of instructions given by the teacher while carrying out individual steps in the task.
- Children with small working memory capacities will struggle in these activities, simply because they are unable to hold in mind sufficient information to allow them to complete the task.
- Losing crucial information from working memory will cause them to forget many things: instructions they are attempting to follow, the details of what they are doing, where they are in a complicated task, etc.
- Because children with small working memory capacity fail in many different activities on many occasions due to these kinds of forgetting, they will struggle to achieve normal rates of learning and so typically will make poor general academic progress.
- For these reasons, working memory is a" bottleneck" for learning.

What is the typical profile of a child with working memory impairments?

Common characteristics of children with working memory impairments

- well adjusted socially;
- reserved in group activities in the classroom, rarely volunteering answers and sometimes not answering direct questions;
- behave as though they have not paid attention, for example forgetting part or all of instructions or messages;
- frequently lose their place in complicated tasks which they may eventually abandon;
- forget the content of messages and instructions;
- Poor academic progress in areas such as reading comprehension, math, listening
- Frequently failure to complete learning activities;
- Low ability to multi-task;

Does working memory vary between people?

- Individuals vary in their working memory capacity
- WM capacity increases with age during childhood. Young children typically have very small capacities that increase gradually until the teen age years, when adult levels are reached (approximately 2 to three times greater than that of four-year-old children).
- Differences in working memory capacity between young children can be very large. Individuals who have poor working memory capacities in childhood do not catch up with average children even by the end of childhood.

Can working memory capacity be measured?

- Several tests have been developed to measure both verbal and visual spatial working memory capacity. These include both behavioral rating scales, computerized working memory tests, and indivdually adminisatered tests as part of a neuropsychological assessment.

Can working memory be strengthened through training?

Although working memory has been studied for decades in both animals and humans, only recently did Swedish neuroscientist Dr. Torkel Klingberg prove it to be a “plastic” function of the brain, able to be strengthened through rigorous training. Dispelling the long-held belief that working memory is a fixed property of the individual, Klingberg's breakthrough research, performed at Stanford University and at the prestigious Karolinska Institute in Stockholm, has shed new light on the treatment of working memory and attention deficits. From his research a home-based software working memory training program – **Cogmed Working Memory Training** - has been developed for children and adults. The training consists of a specific set of working memory tasks that are performed on a computer, five days a week over five weeks, the tasks continually adjusted to match the individual’s performance. As a result, individuals are consistently challenged to perform at their highest possible level. Results from several research studies indicate that systematic training of working memory can improve cognitive performance - including improved attention, better complex reasoning skills, and better ability to organize and multi-task - in children and adults. For further information, see www.cogmed.com

Classroom and home support for children with working memory impairments

The following recommendations are reproduced from Gathercole & Alloway's excellent booklet "Understanding Working Memory: A Classroom Guide, with their permission.

Much can be done to enhance learning in children with impairments of working memory. The recommended approach involves effective management by teachers and parents of children's working memory loads in the classroom with the aim of alleviating the disruptive consequences on learning of excessive working memory loads.

The following recommendations should be used to guide both the development of lesson plans for children with working memory impairments and the monitoring of children's performance in class and at home. In each case, the aim is to minimize the chances that the child will fail to complete the intended learning activity successfully due to working memory failures. A summary of working memory problems and solutions is provided in Table 1.

Monitor the child

It is important to monitor the child's working memory regularly in the course of demanding activities. This will include:

- looking for warning signs of memory overload (see the section on Recognize working memory failures);
- ask the child directly – for example, ask for details of what s/he is doing and intends to do next.

In cases when the child has forgotten crucial information:

- repeat information as required;
- break down tasks and instructions into smaller components to minimise memory load;
- encourage the child to request information when required.

Evaluate the working memory demands of learning activities

Activities that impose heavy storage demands typically involve the retention of significant amounts of verbal material with a relatively arbitrary content. Here are some examples of activities with working memory demands that are likely to exceed the capacities of a child with working memory deficits:

- remembering sequences of three or more numbers or unrelated words (e.g., *5, 9, 2, 6*, or *cat, lion, kangaroo*);
- remembering and successfully following lengthy instructions (e.g., *Put your sheets on the green table, arrow cards in the packet, put your pencil away, and come and sit on the carpet*);
- remembering lengthy sentences containing some arbitrary content to be written down (e.g., *To blow up parliament, Guy Fawkes had 36 barrels of gunpowder*)
- keeping track of the place reached in the course of multi-level tasks (e.g., writing a sentence down either from memory or from the white board)

Reduce working memory loads if necessary

In order to avoid working memory-related failures (see 1), working memory loads in structured activities should be decreased. This can be achieved in a number of ways, including:

- reducing the overall amount of material to be stored (e.g., shortening sentences to be written, or number of items to be remembered);

- increasing the meaningfulness and degree of familiarity of the material to be remembered;
- simplifying the linguistic structures of verbal material (e.g., using simple active constructions rather than passive forms with embedded clauses in activities involving remembering sentences, and instructions);
- reducing processing demands (see 5 below);
- re-structuring multi-step tasks into separate independent steps, supported by memory aids if possible;
- making available and encouraging the use of memory aids (e.g., making available 'useful spellings' on white boards and cards, and providing number lines).

Be aware that processing demands increase working memory loads

Although children may be capable of storing a particular amount of information in one situation, a demanding concurrent processing task will increase working memory demands and so may lead to memory failure, as illustrated in the two examples below of children with working memory deficits.

Example 1

The children in Nathan's class were asked to identify the rhyming words in a text read aloud by the teacher. They had to wait until all four lines had been read before telling the teacher the two words that rhymed: *tie* and *fly*. This task involves matching the sound structures of a pair of words, and storing them. Nathan was unable to do this, although he was able to remember two words under conditions where no concurrent processing was required.

Example 2

An activity in Jay's class involved the teacher writing number sequences on the white board with some numbers missing. She counted the numbers aloud as she wrote them, and asked the class what numbers she had missed out. In each case, there was more than one number missing (e.g., *0, 1, 2, 4, 5, 7, 8*). In this activity, the child has to use his/her number knowledge to identify each missing number, and store them. On all occasions, Jay was unable to identify the missing numbers.

In such cases, steps should be taken to modify the learning activity in order to reduce working memory loads (see the section on Evaluate the working memory demands of learning activities).

Frequently repeat important information

It is good practice when working with children with working memory deficits to regularly repeat information that is crucial to ongoing activities. This will include:

- general classroom management instructions;
- task-specific instructions (what the whole activity consists of, broken down into simple steps);
- detailed content intrinsic to an activity (for example, the particular sentence to be written).
- Children should also be encouraged to request repetition of important information in cases of forgetting.

Encourage the use of memory aids

A variety of tools that support memory are in common use in classrooms – these include number lines, Unifix blocks and other counting devices, cards and personalised dictionaries with useful spellings, teacher notes on the class white board, and wall charts. These tools can help in several different ways to reduce working memory loads – they may reduce the processing demands of the activity (e.g., useful spellings, and Unifix blocks), and they may also reduce the storage load of the task and so help the child keep their place (e.g., number lines).

Develop the child's use of memory-relieving strategies

Children with working memory deficits are typically aware of when they have forgotten crucial information, but often do not know what to do in such situations. An important role for the teacher is to encourage the child to develop strategies for overcoming memory problems. These will include:

- use of rehearsal to maintain important information;
- use of memory aids (see the section on Encourage the use of memory aids);
- organizational strategies – breaking tasks down into component parts where possible;
- asking for help when important information has been forgotten.

Table 1

Effective management of working memory loads in the classroom/home: Some problems and solutions

Problem	Solutions
Child forgets the task	Give brief and simple instructions, broken down into separate steps if task is very complex Check the child can remember the instructions. Repeat instructions if necessary
Child cannot meet combined processing and storage demands of activities	For activities involving sentences, reduce sentence length, reduce syntactic complexity (simple active sentence forms are the easiest), and/ or increase familiarity of the vocabulary
Child loses place in a complex task	Use external memory aids such as number lines and useful spellings. Ensure that the child has plenty of prior practice in the use of the aids before using them in more complex task settings Find ways of marking for the child their progress in a complex task structure

References

aboutworkingmemory.org

thecogmedstory.com

Dehn, M. Working Memory and Academic Learning: Assessment and Intervention. Wiley, 2008.

Gathercole, S, Alloway, T. Understanding Working Memory: A Classroom Guide http://www.york.ac.uk/res/wml/ArticlesTeachers.htm.

Gathercole, S. & Alloway, T. Working Memory & Learning: A Practical Guide for Teachers. Sage Publications, 2008.

Gathercole, S, Alloway, T. Working Memory in Classroom Learning, Professional Association of Students with Specific Learning Difficulties. (2004) vol.17

Klingberg, T. The Overflowing Brain. Oxford, 2008

Martinussen R., Tannock, R. Teach ADHD: Teacher's Resource Manual. The Hospital for Sick Children, 2005