Working Memory

Working memory is our ability to remember and process information over a short period. The best way to think of working memory is as the brain’s “Post-it Note”; we make mental scribbles of bits of information we need to remember and work with. For example, we use working memory to remember directions while driving or someone’s name and phone number. Without it, we would be literally lost; we wouldn’t know how to get to that important meeting and would forget important contacts. Working memory is critical for many activities at school, from complex subjects such as reading comprehension, mental arithmetic, and word problems to simple tasks like copying from the board and navigating the halls.

We have a limited space for processing information, and the size of various individuals’ Post-it Notes can vary greatly. For example, a seven-year-old who has working-memory problems may have a Post-it Note the same size as an average four-year-old’s. This student will likely find it difficult to keep up with what the teacher says, will struggle to remember instructions, and will mix up words. In contrast, another seven-year-old may have working-memory skills the same size as an average ten-year-old’s. This student will be the first to finish individual work, will respond quickly to questions during group time, and may even be bored by school.

How do these differences in working-memory capacity affect learning? I have carried out several large-scale studies to investigate the impact of working-memory difficulties. In a screening of more than 3,000 primary-aged children in mainstream schools, 10 percent were identified as having working-memory difficulties. There were several key findings regarding their cognitive skills (Alloway et al. 2009).

• Most students with working-memory problems performed below age-expected levels in reading and mathematics. This suggests that low working-memory skills constitute a high risk factor for educational underachievement. These findings correspond with evidence that working memory affects all areas of learning, from kindergarten to college. Crucially, evidence suggests that working memory is even more important to learning than other cognitive skills such as IQ. For example, while studying typically developing five-year-olds, I found that their working-memory skills, rather than their IQs, were the best predictor of reading, spelling, and math outcomes six years later (Alloway 2009).

• Teachers typically judged children with working-memory difficulties as having short attention spans and being highly inattentive and easily distracted. Teachers said that the children failed to complete tasks and that they forgot instructions, things they had learned, and even what they were doing right then. In everyday classroom activities, children often made careless mistakes, particularly in writing, and had difficulty solving problems. In contrast, relatively few of the children were judged to exhibit high levels of hyperactive and impulsive behaviours.

• Children with working-memory difficulties take much longer to process information. They are unable to cope with timed activities and fast presentations of information. As a result, they often end up abandoning activities altogether out of frustration. One way to overcome this difficulty is to give them shorter activities and to allow for more time during tests.

Studies such as these demonstrate that children with working-memory difficulties are relatively common in the classroom and are at extremely high risk of making poor academic progress. Without early intervention, working-memory deficits cannot be made up over time and will continue to compromise a child’s likelihood of success (Alloway 2009). What can we as educators do to support these students’ learning?

Exciting research is emerging on the benefits of cognitive training. So what works? Previous research outlines training programs that ask students to remember a random sequence of numbers or locations daily for a few weeks. Improvements in students’ working memory after cognitive training have been reported.
But there are clear limitations to these studies. First, while there appear to be genuine increases in working memory as a result of training, to date there is no evidence that such training also leads to improvements in learning outcomes. It is possible that some cognitive training programs are just “training for the test”—if students practice remembering numbers backwards for a few weeks, then it is reasonable to expect that they will perform better on a backward-digit-recall test than students who didn’t practice. Similar improvements, known as a “practice effect,” have been found in studies using IQ tests.

The second limitation to the existing reports is that they have been restricted to special populations, such as children with ADHD. Therefore, it is not clear whether students with general learning difficulties will also benefit from similar training. It is possible that ADHD children showed gains in working memory after training because the discipline of sitting down daily led to better focus. Also, the cognitive training study on children with ADHD reported improvements in attention at home, but not necessarily at school.

To address these issues, I recently conducted a study to investigate the potential benefits of cognitive training. The study had two objectives—to extend existing evidence to students with general learning difficulties rather than a specific clinical problem, and to investigate whether possible gains from training working memory would ultimately transfer to learning outcomes in literacy and numeracy.

The Study

Fifteen children (median age 7.3 years) participated in the study. All the children were classified as having moderate learning difficulties severe enough to warrant special educational support, but no physical, sensory, or behavioral impairment. Eight children (trial group) participated in working-memory training, while the remaining seven (control group) continued receiving Individual Education Programme (IEP) support in school as usual.

Students took assessments of verbal and visuo-spatial working memory. In the verbal working-memory task, students were shown a letter on the computer, immediately followed by another letter. They had to verify whether the letters were the same and remember them in the correct sequence. In the visuo-spatial working-memory task, students were shown a colored shape, immediately followed by another shape. They had to say whether the shapes were the same color and shape and then remember their location in the correct sequence. The children also took spelling and numerical-operations assessments. The memory and learning measures were administered to both the control and trial groups before and after the study.

The trial group trained using an eight-week program, Jungle Memory©, which includes three games with up to 30 levels in each. The student has to successfully answer 8 out of 10 trials in each level to collect enough bananas to move the title character, the Monkey, to the next level. The program adapts to the student’s age and ability so that the student will continue to be motivated during training.

The first game trains verbal working memory and processing speed by requiring the student to visually encode letters as fast as possible. Level 1 begins with single letters and gets progressively harder as it moves to familiar word endings (-at, -it, -ot), to three-letter words using those endings (cat, bit, cot), to longer word endings (-ack, -ock), and to longer words (back, lock). Students must scan a grid quickly and remember the location of the specified letter or word. As the levels get harder, the amount of information on the grid increases and the time allotted for responses decreases.

The second game trains visual working memory using letter recognition. Students must process letter rotations, starting with simple rotation (is the letter facing up or down?) and progressing to more complex rotations (mirror image). They must remember increasingly more letter locations as they move through the levels.

Game three trains working memory related to mental arithmetic. In Level 1, the student has to solve one addition problem. As students move up the levels, they have to solve increasingly harder problems (such as multiplication, double-digit addition, and subtraction) and remember more problems (up to six) in correct sequence.

Results and Discussion

The graph below shows the difference in scores between the control and trial groups before and after training. Scores below 0 (marked by the line) indicate that the group performed worse when tested eight weeks later than they did at first. Scores above 0 indicate improvements.
The results were dramatic. The control group did not perform much better without intervention, and in some instances they performed worse. In contrast, the trial group demonstrated clear gains, not only in working-memory tasks but in learning outcomes as well. For example, their spelling scores increased almost 10 standard score points.

Are these score increases meaningful? Yes. They represent the difference between the grades of C and B, or between B and A—after just eight weeks of training. Would they have made this improvement without training? No—two pieces of evidence support this conclusion. First, the control group, who did not participate in training, showed no improvement and even performed worse in some cases. The second piece of evidence comes from a previous study. I tested a group of eight- to ten-year-olds who displayed moderate learning difficulties on a range of working memory, IQ, and learning (math, reading, and spelling) tests. These students were all receiving IEP support and continued to do so for two more years, when I retested them. None of the students had improved. Two years later, they remained in the bottom-10th percentile compared with their same-aged peers, despite receiving IEP and small-group support (Alloway 2009). Both studies indicate that without cognitive training, students with poor working memory will not “catch up” with their peers.

During the past 50 years, IQ scores have risen steadily. The cause is under discussion (some suggest it is due to better education and diet), but the documented rise is about three points per decade. Compare that with the increase reported here: the same increase (three points) in math and a much larger rise (eight points) in spelling after just eight weeks of cognitive training. This is remarkable.

This is an exciting step in demonstrating that the right cognitive intervention can effectively boost learning outcomes. Why did this study find gains while others did not? One possibility is that other programs’ training tactics, such as backwards memorization, train working memory as an abstract skill and do not directly apply to classroom learning. In contrast, Jungle Memory® works in the context of key learning activities such as reading, letter decoding, and math.

Conclusions

In light of the extensive evidence that working memory is linked to learning outcomes throughout a student’s academic career, it is critical to support students who are struggling to learn by first identifying their working-memory profile. The most effective and reliable way to do this is by using the Automated Working Memory Assessment (AWMA), a cognitive test that takes five minutes and offers educators an informative first step in supporting students’ learning. It gives educators a profile of a student’s verbal and visuospatial working-memory skills, as well as how their skill level will affect their learning. Given that 10 percent of children in a typical classroom have working-memory difficulties, it is important that students are screened to determine who needs shorter classroom activities and more time for test taking. Once educators know students’ working-memory strengths and weaknesses, they can determine if they need cognitive training.

This study demonstrates the efficacy of using Jungle Memory®, which trains working memory in the context of key learning activities. This is an exciting step in supporting students who would otherwise continue to struggle throughout their academic career. Evidence also suggests that children with developmental disorders such as dyslexia, language impairments, motor dyspraxia, and ADHD would also show learning gains from cognitive training.

For information on research in working memory, please contact Tracy Alloway at tracy@memoryandlearning.com. A weekly blog, www.tracyalloway.com, addresses working-memory issues, from nutrition to useful classroom strategies.

Resources
Automated Working Memory Assessment: www.pearson-uk.com/ AWMA.

References

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