# Working hard or working memory?

## Taking learning capacity into consideration in the classroom.

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Philip loves to play basketball. He's 11 years old, has many friends, and a lot of energy. While he excels at everything in the physical domain, he has the hardest time with most of his school work. His reading fluency is below grade level and he struggles with math. He wants to perform well at school, but even basic things like listening to his teacher's instructions for a new assignment are overwhelming and he falls behind almost immediately. Philip has started to wonder what the point is in trying.

While some people seem to simply absorb information by glancing at a book or pick up math concepts by looking at the problem, most others need deliberate practice, effort, and time to succeed. How can this be? We are all born with a genetic blueprint of our potential abilities which sets the most extreme boundaries of our capacities, whether it be how fast we will theoretically be able to run or how clear our eyesight will be. Exactly where our capacities will actually end up within those boundaries is determined by our experiences. Our experiences can either turn on or turn off the genetic expression that underlies our ability levels, creating a delicate interplay between our environment and biology throughout our lives. If you run track and put effort into training your leg muscles, speed, and aerobic fitness, you will be able to reach closer to the boundaries of your genetic limitations than if you don't. That doesn't mean you will be better than someone who only trains moderately, but who has a genetically determined advantage to you, making it easier for them to achieve the same level that you had to work hard for. It's what makes life unfair, but also magical. Because for many of our capacities, our experiences can even out our genetic disadvantages. That makes our experiences extremely important and give us the incentive to work hard and reach for our dreams. It is why we love when the underdog wins.

Philip is a typical academic underdog. He is likely being held back by his (to a large degree genetically predetermined) cognitive functioning. That doesn't mean that he isn't smart, it just means that something is holding him back. So what can we do as educators to support Philip, meet him at his level, and help him evolve from there? First of all, we need to understand which brain functions determine ease of learning. This is complex and while the research field is still tackling this question, a few key players have been identified. Metacognitive skills and intellectual functioning, for instance, are for instance are two important factors (1). But the single most evident predictor of academic performance, beyond for instance IQ, is *working memory* (2,3,4). Not only does it predict our achievement level, but working memory capacity, measured at age three, also predicts whether we give up all together or not, measured as the risk of dropping out of high school (5).

**Working memory**

When we concentrate, we can hold a certain amount of information in focus and work with that information, whether solving a multi-step math problem or receiving instructions on how to get to the train station. This storage capacity is called working memory and it has limited resources both in terms of the time you can hold information before it decays, and the amount of information that can be held when storing one more piece of information will cause another piece to fall out. This happens to all of us on a daily basis; we forget why we went into a certain room in the house, or forget to attach the file to that email you worked on for too long before sending. In fact, it is normal. **Our working memory is limited and we all know it.**

We all use tricks and strategies to support our working memory without thinking about it; we repeat the numbers just heard until we find a way to jot them down, we write grocery lists before we go shopping, we create automatic reminders and ask our kids to keep their volume down so we can concentrate, etc. We do all of this because we know that our working memory might fail us, causing that crucial piece of information to be permanently lost from our mind. Imagine if this didn't just happen sometimes, but all the time. Philip, like so many others, probably has poor working memory capacity. Other signs of poor working memory include:

- **Short attention span**
- **Trouble following instructions**
- **Easily distracted by environmental stimuli and/or mind wandering**
- **Reluctance to join in group activities**
- **Difficulties completing tasks, often abandoning them midway**
- **Disruptive behavior in the classroom**
- **Slow progress in literacy and numeracy**
- **Trouble integrating new information with already learned information**

**What can the teacher do to help?**

Many of the students with these types of behaviours could most likely perform the task at hand, but would perhaps need the workload to be adjusted to their working memory capacity. This can be done by breaking down the instructions into smaller pieces, making a plan of how to complete the task, and reminders of what to do next, and perhaps also more time to complete it. These are things that a teacher can help with in the classroom, reducing the load placed on working memory by providing structure and using mnemonic tools to aid Philip and others with poor working memory.

These are all efforts worth considering since statistically speaking, it is expected that in a classroom of 30 seven-year-olds, at least three will have the working memory capacity of the average four-year-old (6). These are the children that are most at risk of falling behind academically. Not because they aren't intelligent, but because their working memory limits their performance on tasks they would perhaps otherwise understand.

Of children with low working memory capacity, research shows that 80% also have difficulties in reading and math (6).

Poor working memory can disrupt reading both during the acquisition of reading skills (as the phonetic rules must be remembered and applied while trying to decode the words) and during the comprehension of text (7, 8). Reading fluency and comprehension rely on working memory both in keeping track of the content of what's being read and placing it in context with previously learned information – a difficult task if working memory capacity is limited, forcing the reader to go back and re- read many sentences (9). (Don't worry, we all do that for long sentences like that one). Math performance has also been shown to have a strong link to working memory capacity as it usually involves juggling several pieces of information at the same time (10,11). For instance, you may have to carry out a calculation in multiple steps, remembering and applying the rules of the mathematical expression in the correct order while storing and working with both the partial solutions and the numbers in the problem in working memory. Consequently, both reading and solving math problems place a heavy load on working Memory. This explains why Philip struggles in both of these domains.

Luckily, there is a lot that can be done to help Philip. There are basically two ways to tackle working memory problems in the educational setting, either by reducing the load placed on working memory when possible or by letting the student increase their working memory capacity. This latter option was not even thought possible last century, however groundbreaking research on neuroplasticity has demonstrated that the brain and working memory in particular are much more malleable than previously thought (e.g. 12,13).

You can actually train your working memory to hold and work with more information with meaningful and lasting effects (14).

The best outcomes for a student would most likely come from combining these efforts of using strategies to support working memory in the classroom, and improving the storage capacity.

**What can the student do?**

Philip, once he is aware of the source of his underachievement, can undergo Cogmed working memory training. The research on Cogmed working memory training has shown that it is possible to improve working memory capacity around 25-30%. This has been shown in studies of children with ADHD (12,15,16,17), learning difficulties (18, 19, 20), typical children (21, 22), children born preterm (23, 24), and other clinical groups (e.g., epilepsy cancer, Down's syndrome). Recent studies also demonstrate the that the neural underpinnings may lie in an increased neural efficiency of the brain after Cogmed, showing that repeated stimulation of the same network actually changes the brain's structure and connectivity strength (25).

The original protocol consisted of 25 sessions of computerized working memory tasks for the student to train on for around 45 min/ day, 5 days/week for 5 weeks. This has since evolved and validation studies have shown that less intense and shorter sessions may be even more beneficial (14, 26, 27). Cogmed working memory training can be performed at school or at home, – on any web-enabled device – 15-20 min/day. The student has a coach, either a parent, teacher, or assistant that helps support them throughout the training. The training can be done intensely (5 days/week) or more spread out (3 days/week) which allows for the entire period to span between 5 and 12 weeks.

**What effects are to be expected?**

The effects typically seen varies a great deal between trainees and are usually most noticeable in the areas that have previously been most difficult due to the low working memory capacity. The research has demonstrated effects on tests of attention (16, 21, 28), cognitive control (14), and reasoning ability (12, 15, 25) in different samples of both children and adults. One study of children with ADHD had raters (blind to which children had undergone Cogmed working memory training and which had not) observe the children while they were performing an academic task both before and after the training period was complete. The results showed that the examiners rated the children in the Cogmed training group as better at staying on task. Specifically, along with improvements in working memory the results showed that the students looked away from their task fewer times and played with distracting objects less after training (29).

This means that the training helped them to improve their ability to focus on the task at hand.

This type of change in behaviour may result in more efficient learning and may also explain the results from other studies showing actual improvements on academic measures after training.

While some studies have demonstrated improvements in reading (19, 30) and math (18, 31) directly following training, some studies have seen delayed effects (32, 33), most likely reflecting an improved learning capacity with the new and improved level of working memory capacity. One study tracked the academic development across two years for two typically achieving classrooms in the same school where one class had trained with Cogmed and the other had not (33). During the two years, the trained class showed a steeper development on both standard reading and math tests than the other class, again reflecting benefits in learning after Cogmed working memory training. The size of the effects were in a range well above what has been described by world leading educational psychology researcher, John Hattie, as a "desirable effect size" (set to >0.4) (34) with effect sizes around 0.6 in both reading and math.

So, while Philip may need assistance in adjusting the environment to his working memory capacity, there are also advantages in increasing his own capacity. Raising his own working memory capacity could benefit him in situations where the environment is not adjusted to his limitations (which will be the case in most circumstances in life) and could very well impact the future course of his academic development and life choices. We may be born with different strengths and weaknesses and most of these differences have little impact on our lives. Working memory capacity however, is not one of those. In our society, it matters and has a large influence on the rest of our lives. Luckily, we can do something about it.

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