

Working Memory Training

How a scientific discovery is changing the way we understand and overcome the limits of the brain



Working memory — a critical brain function — has gained broad acceptance as a primary indicator of academic, professional and personal performance. And after nearly a decade of research evidence and clinical success, the concept of training working memory to increase focus and cognitive reasoning is being heralded as a major development in neuroscience.

Constrained by the brain

In June of 2006, nineteen-year-old Chris Tonelli from Cleveland, Oh., was afraid of operating the cash register at the concession stand where he worked during the summer. Normally a very outgoing and likable personality, he shrank from this seemingly simple task because no matter how hard he tried, he couldn't keep track of the correct change each customer was owed. Somehow, in the seconds it took him to open the register drawer, the details of each transaction would slip away, leaving him to awkwardly fumble with the money as the customer's patience expired.

This wasn't the first time that Chris had been held back by his inability to focus. Diagnosed with ADHD at a young age, school had constantly been a struggle for him. He couldn't keep track of the teacher's instructions and it took him much longer to complete assignments and tests. His problem wasn't lack of effort. In fact, he was a highly regarded hockey player with excellent work ethic. The real barrier was something else.

In just a few short weeks, Chris' life was about to change dramatically. His physician recommended he try a new cognitive training program that was just beginning to be accepted as an intervention for attention problems. The program was based on a concept called "working memory training" and followed a wave of scientific research that was turning heads in the fields of medicine and psychology. Working memory is the cognitive skill that allows us to hold and process information for brief periods of time. It's a simple concept but it's hugely significant in daily life and mounting evidence shows it to be the basis for learning, reasoning and planning.

For Chris, the goal was to rigorously exercise the part of his brain that was supposed to keep him focused on the task at hand and help him reason quickly under pressure. The idea seemed like a long shot but he had nothing to lose. He threw all his effort into the training. And soon he found himself able to focus more clearly, as if the world around him had slowed down. At the concession stand, he began to handle multiple orders without missing a beat. His bosses were astounded at the turnaround. He felt as if a great barrier had been removed from his mind and his confidence soared.

Chris wasn't the first to see these life-altering changes and he isn't the last. Today, thousands of children and adults around the world have also unlocked their potential by improving working memory. Some, like Chris, were born with deficits in working memory, including those with ADHD and other learning disabilities. Others acquired deficits through stroke or the normal process of aging. Still others were held back simply because of the hectic and demanding environment in which they struggled to focus.

Today, hundreds of experts in the fields of medicine and psychology are embracing working memory training. They've brought the breakthrough approach into practices and schools around the world and are helping people of all ages succeed in areas of their lives that were once constrained by poor working memory. Researchers at top universities are confirming the effectiveness of the approach and exploring new applications for working memory training, examining its powerful impact on a range of populations such as children who have undergone chemotherapy and victims of traumatic brain injury. Together, these researchers and medical professionals are redefining the way we prepare for success in the classroom, on the sports field, in the office and beyond.

The magical number: why some people perform at a higher level

“Seven, plus or minus two.” That was the so-called “magical number” introduced in 1956 by Princeton cognitive psychologist Dr. George A. Miller. What Miller proposed, based on extensive research, was that on average people could remember seven things at once. For some of his research colleagues, the magic number was five. Some even concluded the limit was one.

But, what Miller and a growing number of researchers were really investigating was a much bigger question: Why are some people’s brains better suited for success? And their findings seemed to keep pointing to a new concept called “working memory” as a key part of the answer.

Working memory represents the brain’s ability to hold and process the discrete information about what you are doing at the present moment. Here’s one way of looking at it. Imagine you’re watching television and you’ve hit at a commercial break. You quickly compose a mental list of tasks and set off to accomplish everything before your show starts again. Your thought process goes like this: “Go to the refrigerator. Get a drink. Get a snack. Check your email. Hurry back.” But as the word “email” pops into your head, you remember that you need to notify your colleague at work that the next morning’s meeting has been rescheduled. Suddenly, you find yourself staring into the refrigerator thinking, “What am I looking for?”

As this scenario clearly depicts, working memory has limits. If we try to focus on too many things at once or get distracted, information which we were trying to retain can fall off our mental radar. This scenario is precisely what Miller and his colleagues were trying to understand and define. And with good reason – it is one thing to forget why you went to the refrigerator, but the same cognitive processes and abilities at work in this example impact thousands of daily activities of much greater importance.

It is for this reason that the concept of working memory held such great promise for researchers like Miller. For the first time, it offered a logic by which they could understand variations in a person’s ability to process information. It suggested a new layer beyond intelligence by which we could better understand why some succeed when others fail. Most importantly, it gave scientists a way to articulate why people like Chris Tonelli had so much difficulty with certain tasks.

Intense discussion and continued research followed Miller’s initial work. Studies began to show that learning, reasoning, organizing priorities, managing time, staying focused and handling stress were all dependent on a healthy working memory capacity. New analogies were devised to aptly describe its fundamental importance. Some even called it “the engine of learning” or the brain’s random access memory (RAM). Researchers began to conclude that deficits in working memory may lie at the core of attention problems and learning disabilities, and may explain why some people are prone to choke under pressure.

There was widespread agreement that through working memory, scientists were making important new steps in understanding the workings of the human mind. And then, quickly, the buzz around working memory slowed to a halt.

A fixed capacity

The new findings and intriguing insights that were being uncovered about working memory were challenged by a bigger question: If it’s functioning poorly, can we do anything about it?

The answer to that question from the fields of medicine, psychiatry and psychology was a resounding “no.” Working memory was long understood to be a fixed characteristic – something you were born with that couldn’t change. The realization of this reality in the scientific community effectively killed the conversation that had grown up around the concept of working memory.

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Dr. Sander Weckstein, a child and adolescent psychiatrist from Traverse City, Mich., witnessed the declining attention paid to working memory. “We didn’t really talk about working memory because the assumption was that if it was weak you can’t do anything about it,” he says. “It was an interesting concept and we could see that it was of central importance but if you don’t have a way to address it, does it even matter?”

Renewed interest in working memory

Interest in working memory went into relative hibernation until a series of breakthroughs in neuroscience dramatically changed what we understood to be the limitations of the brain. With the development of fMRI technology, scientists had a penetrating new lens into the brain by which they could better observe how it works and how it reacts to external and internal influences. One of the critical discoveries was that the brain was plastic, that it actually physically changes and grows in relation to repeated activity. For example, today research has shown that the left inferior parietal cortex is larger in bilingual brains than in monolingual brains. On a more dramatic scale, people have taught their brains to rewire after traumatic accidents that decades ago would have left them with terminal damage.

“We thought that if we could train working memory the improvements might transfer to many other cognitive abilities and have a real impact on daily life.”

– Dr Torkel Klingberg

In 1999, Dr. Torkel Klingberg, then a post-doctoral student at the Karolinska Institute in Stockholm, was inspired by discoveries like these. Having researched working memory for several years, he wanted to see if he could improve working memory through computerized training.

But building a program to train working memory was no small task. To do so, he teamed up with Jonas Beckeman and David Sjolander, programmers with a background in game development for young children. They understood Klingberg’s concept and were especially interested in participating in a project that could help kids with attention problems. Within a few months, they had developed a video-game-like program that was able to engage the user and appeal to his or her sense of competition.

With the computer program in place, Klingberg began a small study to see if working memory capacity could be improved through training. If successful, the study would fundamentally challenge the notion of working memory as a fixed ability.

“I had seen from my research that working memory impacted many different functions” says Klingberg. “We thought that if we could train working memory the improvements might transfer to many other cognitive abilities and have a real impact on daily life.”

A research breakthrough

Working with Helena Westerberg, then a doctoral candidate student in psychology, Klingberg assembled a small sample of fourteen children who would each complete a set number of computerized training exercises several days a week for five weeks. They decided that the study would include only children with ADHD because that population tends to exhibit pronounced working memory problems and any improvements due to training would likely be more visible.

On the first day following the pilot study, Westerberg, who was blind as to which students belonged in the control group, was conducting post training tests when she came across some remarkable results. She noticed that some of the students had dramatically increased their ability to recall information.

“I remember very clearly that Helena was blown away on the very first day,” says Klingberg. “And I think that was the first time it occurred to me that we may have hit on something very important.”

Their enthusiasm increased as the remaining data was collected and analyzed. The results showed that the training had substantially impacted the working memory capacities of those children in the treatment group.

“We were very surprised and immediately saw that this would have big implications, not just for people with ADHD but for any number of people who are held back by working memory capacity,” says Klingberg.



Missing Information - A healthy working memory capacity is able to keep many pieces of information in mind at one time (see the diagram on the left). But a weak working memory can only hold a few items, leaving that person at a mental disadvantage (see the diagram on the right.)

Falling short: deficits in working memory

Many people are constrained by the limits of the working memory. Some are born with poor working memory; others acquire working memory problems through certain illnesses or natural aging and still others experience working memory problems because their environment places too many demands on their working memory.

Native deficits

Many people experience poor working memory from a very young age and it affects their ability to focus attention, control impulses, stay organized and solve problems. In the case of commonly diagnosed attention problems, such as ADHD, it is become clear that working memory deficits are more than just a contributing factor. "We have really changed our understanding of working memory and how it relates to attention problems," said Dr. Theresa Cerulli a prominent psychiatrist from Andover, Mass., who has been treating children with ADHD for many years. "We used to view working memory as co-existing deficit in ADHD but now we see that it is the core deficit."

Acquired deficits

Some people acquire working memory deficits after traumas such as stroke victims, pediatric

cancer survivors and war veterans who have experienced traumatic brain injury. Most commonly, working memory deficits develop gradually during the process of normal aging.

Environmental deficits

Working memory isn't just a constraint for those whose capacity falls in the lower percentage of the population. Many people – including very intelligent people – experience strains on their working memory because of external causes, namely the hectic environment in which they struggle to perform.

One experience that can challenge anyone's working memory is stress. A growing list of research studies is shedding important light on why normally intelligent people fail under pressure and how the answer is centered on understanding working memory.

In one example, Robert Rydell at the University of California, Santa Barbara and Allen McConnell at Miami University showed that a group of college women who normally perform well in math struggled significantly on a test when they were told they were competing against a group of men. During post-experiment interviews, many women admitted they were nervous and distracted by the news they were being compared to men. The conclusion of this study, and many others like it, is that stress takes up working memory and leaves less capacity for the task at hand.

Klingberg immediately began a second and more ambitious study. It was conducted at multiple sites in Sweden using the gold standard in scientific research: a randomized, double-blind, controlled design. Users were divided into two groups, one using working memory training, the other using a placebo program. Working memory and other executive functions were measured before, immediately after and three months after training, as were parent and teacher ratings of ADHD symptoms. The results were clear – the training worked.

The study was eventually published in the *Journal of the American Academy of Child and Adolescent Psychiatry (JAACAP)* – and drew the attention of some of the world’s leading researchers and experts.

“There was a lot of skepticism after our first study, because people really thought working memory was a fixed characteristic – I even had my doubts,” says Klingberg. “But when the second study was released, it truly challenged that notion.”

Beyond the lab

After the very promising success of his early research studies, Klingberg and his team decided to found Cogmed in 2001 appointing Jonas Jendi as the CEO and president. The goal of the company was to take the training methodology that was so effective in the laboratory and make it work in every day life.

The results showed that the training had substantially impacted working memory.

“There had been a lot of hype about brain training,” says Jendi. “We chose to set a new standard by never making claims that exceeded what had already been shown in serious, peer-reviewed research.”

In fact, the company was so committed to ensuring that the training be effective, they spent two full years refining their approach before launching the first commercial program in Sweden in 2003.

During the years prior to launching the program, the Cogmed team made improvements to the software but more importantly, they developed a distinct coaching methodology to ensure that students who begin the five-week program see it through to completion. These efforts paid off tremendously, dramatically improving compliance and winning the praise of healthcare professionals.

Since the Cogmed program first became available in 2003, 90 percent of users who have started training complete the program. The rate of compliance has remained high over several years due to the ongoing input that Cogmed welcomes from researchers, psychologists, neuroscientists and users.

When Cogmed first became available in Sweden in 2003 there was understandably broad skepticism. The approach was unlike anything that people had seen before and the claim – to alter the brain in just five weeks – sometimes seemed too good to be true.

As with the research, the first clinical trainings focused on children with attention problems, including many who had been diagnosed with ADHD. Cogmed’s team of psychologists worked closely with the first users, coaching them through the program and offering encouragement. The results were astounding.

“We knew about the powerful impact of the training from the research studies,” said Jonas Jendi. “But to hear about the benefits from the end-users themselves was so much more colorful because they could talk about it in very personal and specific ways – it was thrilling to hear their stories.”

Parent after parent related accounts of boys and girls whose behavior dramatically changed after training: *He remembers to bring his books home from school and turn in his homework – without being asked. Her room used to be a disaster but she’s begun to self organize. Grades improved, teachers were stunned and many students found it easier to relate with their peers and make friends.*

Over the course of the next three years hundreds of students in Sweden completed the training. The overall results were consistent with the research findings. More than eighty percent experienced significant improvements in daily life. By 2005, the Swedish phenomenon was drawing interest from around the world, especially from the U.S.

Skeptical pioneers

As Klingberg's research began to appear in leading scientific journals, Cogmed's success was turning heads in the U.S. It was Dr. Arthur Lavin, a pediatrician from Cleveland, Ohio, who introduced Chris Tonelli to working memory training in the summer of 2006. Just a couple years earlier, Lavin was unaware of the training method. He first came across it after reading an article discussing working memory training in *Nature Neuroscience* in December 2003, but his previous experiences caused him to remain skeptical.

"The American marketplace loves to hype," said Lavin. "I've encountered all kinds of supplements, exercises and computer programs that claim to make you smarter. But in every instance, when I do my due diligence, I've found there is very thin evidence for most of these interventions."

But he wasn't prepared to discount the article. And after further investigation, he was dialing the Karolinska Institute in Sweden, where the research was conducted. "I needed to talk with them directly to ask them 'does this really work?'" said Lavin.

Only a few months later, Dr. Barbara Ingersoll, a noted author and an expert on Attention Deficit Hyperactivity Disorder, was stepping on a plane for Stockholm, Sweden. In her bag was the February 2005 edition of the *JAACAP*, which featured Klingberg's second research study indicating that working memory could be improved through computerized training. Ingersoll was flying to Sweden to meet him.

"When I read the research, I knew that it was a breakthrough and I was excited to see what they were doing over there in Sweden."

– Dr. Barbara Ingersoll

"My husband was stunned because I am a reluctant traveler, at best. But, when I read the research, I knew that it was a breakthrough and I was excited to see what they were doing over there in Sweden, so I packed my bags."

Ingersoll was one of several medical professionals from around the U.S. who saw the research published in the *JAACAP* and were eager to learn more about the feasibility of training the mind. In fact, what they were about to discover was that the research that appeared in the *JAACAP* was just one important part of an emerging body of evidence that Klingberg and his team were assembling – all of it indicating that it was possible to stretch the brain – or at least working memory.

Lavin and Ingersoll were two of the early pioneers of Cogmed in the United States. They were joined by other prominent psychologists and psychiatrists such Dr. Bill Benninger from Columbus, Ohio, Dr. Theresa Cerulli from Andover, Mass., Dr. Paul White from Wichita, Kan., and Dr. Jay Tarnow from Houston. Their clinical successes soon matched the results in Sweden and drew the attention of their colleagues across the U.S. Major clinics and hospitals began offering Cogmed and within two years more than 100 practices in the U.S. had qualified to provide the training and were finding that the results could be life transforming.

Putting the training to the test

As medical professionals began to implement the Cogmed training, independent researchers from leading universities took it upon themselves to put the training to the test. Scientists at Notre Dame, Harvard and NYU, initiated research to examine the impact of the training program. Like Klingberg, they concluded that it delivered on its promises, with eighty percent of those trained experiencing tangible benefits in daily life.

Another researcher who chose to evaluate the training was Dr. Susan Gathercole, a world-renowned expert on working memory and head of the psychology department at York University in England. Her highly regarded research on working memory has shed new light on its importance for academic success, but she admits she was skeptical of training. "For many years I believed it simply wasn't possible to train working memory."

As a result, part of her research efforts had focused on finding ways to reduce demands in the classroom for students with weak working memory. "We thought we had to bring the environment to the child, rather than work on expanding working memory," she says.

But having now completed a thorough investigation of the Cogmed program, her views on this matter have changed. "The impact of the Cogmed training program is actually immense," she says. "We started out from

a fairly skeptical basis but our data are very clear: you get major gains with working memory training. In fact, we've found that the majority of these kids go from the deficit range to the average or above average range in working memory capacity."

The results of Gathercole's study on working memory training were published in *Developmental Science* in April 2009.

International growth

When Dr. Bill Benninger, one of the first Cogmed providers in the U.S., began to implement the training, he wasn't sure how kids would respond. "When you look at the discipline needed to complete a five week program, I think there was a sense in the U.S. that it's all well and good for Swedish kids but Americans will never stick with it," he says. "Of course, what we found is that kids are kids and brains are brains – it worked just the same."

"We started out from a fairly skeptical basis but our data are very clear: you get major gains with working memory training."

– Dr. Susan Gathercole

And this has been the case for many other countries as well. The program's proven software and coaching support make it effective to a broad group of users around the world. In 2006, practices in Switzerland and the U.S. made Cogmed available for the first time. In 2007, Canadian practices also began to offer the program. And in 2008, Japan, Singapore, Germany and Holland followed suite. Australia made the training available in early 2009, and other countries are close behind.

To date, more than 10,000 people around the world have completed Cogmed training, including the hundreds who have used it in research studies.

ADHD and beyond

From Klingberg's initial research to the first clinical trainings, Cogmed's initial focus was to help children with ADHD. Given the link between attention and working memory, this population was an obvious first choice for the training. From a research perspective, changes in daily behavior were more likely to impact children with ADHD and be observed by their parents and teachers. At the same time, clinicians were eager to assist these children who were at risk of seriously underperforming in the classroom, often in spite of average or high intelligence.

As a result, numerous studies have been conducted to better understand how working memory training affects attention deficits. At the Karolinska Institute alone, Klingberg's colleagues have published research on working memory training and ADHD in several of the world's leading journals. Among them are the *Journal of the American Academy of Child and Adolescent Psychiatry*, *Developmental Science*, *Journal of Clinical and Experimental Neuropsychology*, and *Child Neuropsychology*.

Together, research and clinical experience have demonstrated the substantial benefits for students with ADHD who in many cases are able to turn their lives around by performing better in school, improving interaction with their peers and being able to follow instructions from parents and teachers.

For these reasons, researchers and medical professionals continue to see people with attention deficits as a primary target for working memory training. At the same time, it was apparent from the beginning that the promise of working memory training was not limited to children with ADHD.

Working memory training and adults

Like attention deficits, working memory training does not only impact children. In fact, adults with attention problems began to use the Cogmed training very early on and saw benefits on par with those observed in children. But researchers and clinicians have not stopped there. Many are exploring the use of the training for others who could benefit from improved working memory.

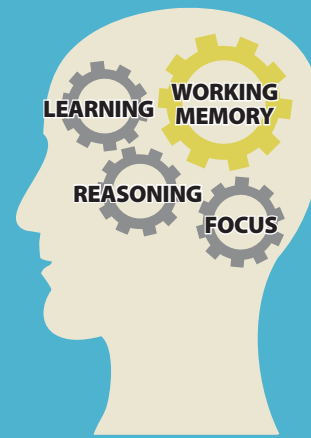
Who is affected by working memory?

Dr. Rosemary Tannock is a professor of psychiatry and special education at the University of Toronto and a senior scientist at the Hospital for Sick Children. A leading expert on working memory, she says that it is important for everyone. “We use working memory almost constantly in daily life,” she says. “It’s required for learning, problem solving, reading, listening and many other tasks of large and small importance.” A steady stream of recent research has affirmed the importance of working memory to a broad range of populations, including:

Students — Nowhere is working memory more crucial than in the classroom. Math, reading and the processes we use to internalize information are utterly dependent on a healthy working memory capacity. Without working memory, learning could not take place. In her book, *Working Memory and Learning: A Practical Guide for Teachers*, Dr. Susan Gathercole a renowned expert from the University of York, calls working memory “the engine of learning” because it has shown to be the primary indicator of academic performance.

Test takers — High school, college and graduate students around the U.S. determine their future in large part by their performance on standardized tests such as the SAT, ACT, GMAT, LSAT and MCAT. Lasting several hours, these tests require students to focus at a very high level, meticulously manage their time and perform well under pressure. To do so effectively, students need strong working memory. Research from leading neuroscientists indicates that working memory is the most important indicator of academic success. In a testing environment, working memory is what allows the student to quickly recall information, make mathematical and logical computations and stay focused as a time limit approaches.

Athletes — Athletes thrive on their ability to make split-second decisions. Working memory, which is crucial for performing under stress, is a tremendous asset on the sports field. “Athletes have to take in and hold onto different sets of information on the



field or the court,” says Dr. Paul White, a clinical psychologist from Wichita, Kan. “Working memory impacts their ability to make decisions and be effective.”

Professionals — Professionals are challenged more than ever to stay on track, prioritize activities and overcome the persistent distractions that slow productivity. Working memory is crucial in this environment. Professionals with strong working memory capacity are efficient with their time and well equipped to multi-task. They perform well under pressure, remain organized and stay focused on the task at hand.

People with attention deficits — When working memory is impaired, the impact on daily life can be quite debilitating. Working memory problems are present in a range of medical conditions including many who have been diagnosed with ADHD, victims of stroke and traumatic brain injury and cancer survivors who have undergone chemotherapy. Understanding the way that working memory functions and how it is made stronger or weaker is crucial for effectively improving the daily functioning for these populations.

Aging adults — Working memory reaches its peak between 25 and 30 and then begins a gradual decline. Around the age of 55, impairments in working memory become noticeable in daily life. “It is natural for working memory to decline with age,” says Dr. Lee Hyer, a psychologist from Georgia who specializes in senior care. “As a result, it becomes more difficult to think, organize, plan and do several things at once. When you look at aging brains, there are the areas that are affected both by the normal aging process and other brain areas that, for many, represent a degenerative process, such as dementia. Working memory is almost always involved in all decline processes.”

Dr. Helena Westerberg, a researcher at the Karolinska Institute's Aging Research Center (and former member of Klingberg's team), was the first to study the effects of working memory training on an adult population when she conducted research on stroke victims in 2003 using the Cogmed program. The results were consistent with previous studies and the subjects, who suffered from impaired working memory following stroke, took significant steps to improve their daily lives.

More recently, Westerberg conducted a broader study of more than 100 adults with normal working memory capacities. Surprisingly, they also saw significant improvements to working memory after using Cogmed. In particular, those users between the ages of 60 and 70 "returned" to the pre-training levels of the 20 – 30 year olds.

This study, and others that are being conducted currently, suggest a broader reality about working memory and performance. "We're finding that there is a potential for most people to improve their working memory capacity through training," said Westerberg. "For normally functioning persons the effects will probably be most apparent when they are involved in cognitively demanding activities such as strenuous academic studies or intellectually demanding professional work."

New populations benefit from working memory training

At Duke University, Dr. Kristin Hardy is examining another new application for working memory training by using the Cogmed program for pediatric cancer survivors whose working memory was impaired due to radiation chemotherapy. In Georgia, Dr. Lee Hyer, a professor of psychiatry at the Mercer Medical School, is exploring the use of working memory training for seniors whose working memory has declined with age. Executive coaches are finding the training to be effective for professionals of all levels who work in hectic environments. And many around the country are evaluating the training for test takers and athletes who are looking to for better focus under pressure.

"When Torkel Klingberg first discovered that working memory could be trained, it didn't take him long to realize that the implications of his discovery would affect many people who need stronger working memory for one reason or another," says Jendi. "We are now seeing leaders in the fields of medicine and psychology make this a reality by bringing the training into their work with people of all ages and conditions."

Working memory enters the mainstream

In recent years, the excitement about working memory that exists among scientific community has begun to spill over to the mainstream. The global media have taken a new interest in cognitive fitness and have begun to discuss the importance of working memory and how it relates to professional success, education, attention, time management and many other areas of interest to the general public.

In particular, the issue of information overload has become a popular topic among professionals who simply can't handle the barrage of digital distractions that follow them wherever they go. This discussion acquired a somber tone after the New York Times reported that "in the United States, more than \$650 billion a year in productivity is lost because of unnecessary interruptions, predominately mundane matters."

Klingberg has written a book on this very topic titled *The Overflowing Brain: Information overload and the limits of working memory*. Published by Oxford University Press, it has received broad international acclaim.

As the concept working memory gains prevalence in the mainstream, Cogmed has also achieved distinction in the broader scientific community. Perhaps, one of the best examples of this is Klingberg's latest study which was published in February of 2009 in the prestigious journal *Science*. Led by Klingberg, the study demonstrated for the first that mental activity – in this case Cogmed Working Memory Training – can alter the brain's biochemistry. The study provides new insights into the physical and chemical realities underlying the brain's plasticity.

"It's very rewarding for us to see that Cogmed – which has gone to great lengths to hold to the highest scientific standards – now again finds itself at the center of what will likely be viewed as a landmark development for neuroplasticity and cognitive training," says Jendi.

"In the United States, more than \$650 billion a year in productivity is lost because of unnecessary interruptions."

– *The New York Times*

Training working memory

A teenager sits at a home computer wearing headphones. She watches the screen intently as a sequence of lights appear and disappear on several asteroids floating in space. She uses the mouse to repeat the sequence and the asteroids explode in a flash of light.

So, what is really going on here?

Like thousands of others around the world, this student is training her brain using Cogmed Working Memory Training. She will participate in these computerized working memory exercises from home for approximately 30 minutes every weekday for five weeks. The exercises are designed to train both the visuo-spatial and verbal working memory. With each click of the mouse, the level of difficulty adjusts based on her real-time performance, ensuring that the program is rigorously strengthening the working memory without becoming too frustrating.

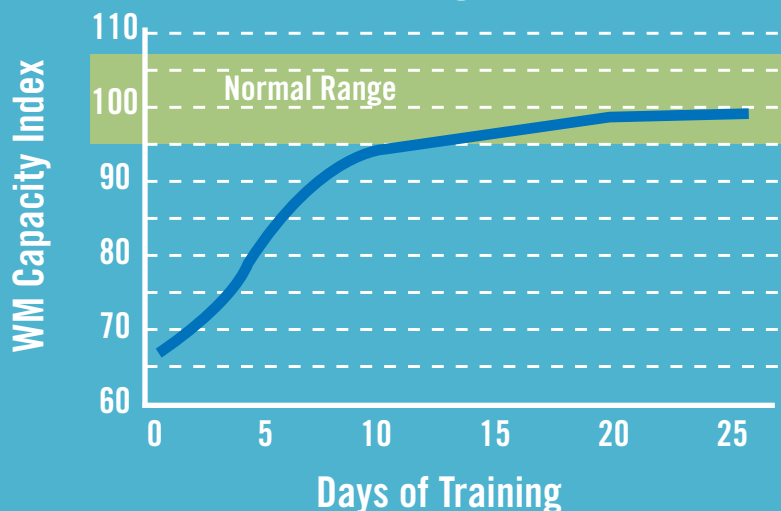
The training is available through professional channels around the world. Each training is led by a Cogmed-qualified coach who analyzes the results online and works with the user to provide feedback and encouragement over the phone.

No pain, no gain

The dramatic impact of Cogmed training has been documented in numerous research studies and across thousand of clinical users. But it is by no means a “quick fix.” Like any training, it requires hard work and perseverance. Those who put the most into it get the most out.

The program is challenging and often fun, but after the first few weeks it can be a struggle to keep up with the program. It is for precisely this reason that Cogmed is offered only through qualified practices and guided by a qualified coach. This has been the key to ensuring successful compliance, which exceeds 90 percent in the U.S.

Training Curve



Over 25 days of training, students and adults who use Cogmed training improve their working memory substantially, often reaching the normal range. The graph above depicts the average improvement of Cogmed users.

Working memory training changes how we prepare for success

The growing awareness of working memory's importance is fundamentally changing the way that the scientific community understands individual performance at all stages of life. At the same time, the discovery that working memory can be substantially improved through training changes the game for anyone who is or may one day be constrained by their working memory. Needless to say, the convergence of these two realities has very real implications for the future. Below are ten key ways in which working memory and its training will change our overall approach to mental performance:

- **Working memory will be seen as a primary indicator of success.** Whether in the classroom, the office, the sports field or the retirement community, a strong working memory capacity will be recognized as one of the core necessities for performance. It will be a key factor in preparing for success in life.
- **Cogmed and some other brain fitness programs will become increasingly viewed as a critical part of mental development and maintenance.** Working memory training won't be a popular New Year's resolution or be added next to gyms anytime soon. But for anyone with a measurable working memory deficit or for anyone that needs to boost their ability to concentrate, working memory training will, in most cases, produce tangible results. Students, teachers, coaches professionals and employers will view it as a key tool for success.
- **Psychologists and doctors will keep a steady eye on cognitive training research and interventions, offering proven methods to their patients.** As the research behind Cogmed becomes more widely known, medical professionals will begin to view evidence-based cognitive training as a viable option for patients to address specific needs. With its commitment to research, Cogmed has set the standard for other training programs to be considered legitimate interventions.

A strong working memory capacity will be recognized as one of the core necessities for performance.

- **Studies will show that working memory is behind many learning disabilities.** A surge in research studies will examine the impact of working memory training to address learning disabilities and treat mental impairments. Working memory will continue to be identified as a root cause that underlies many such issues. Addressing these issues will become more a matter of improving specific abilities – like working memory – rather than trying to alleviate symptoms or compensate for impairments.

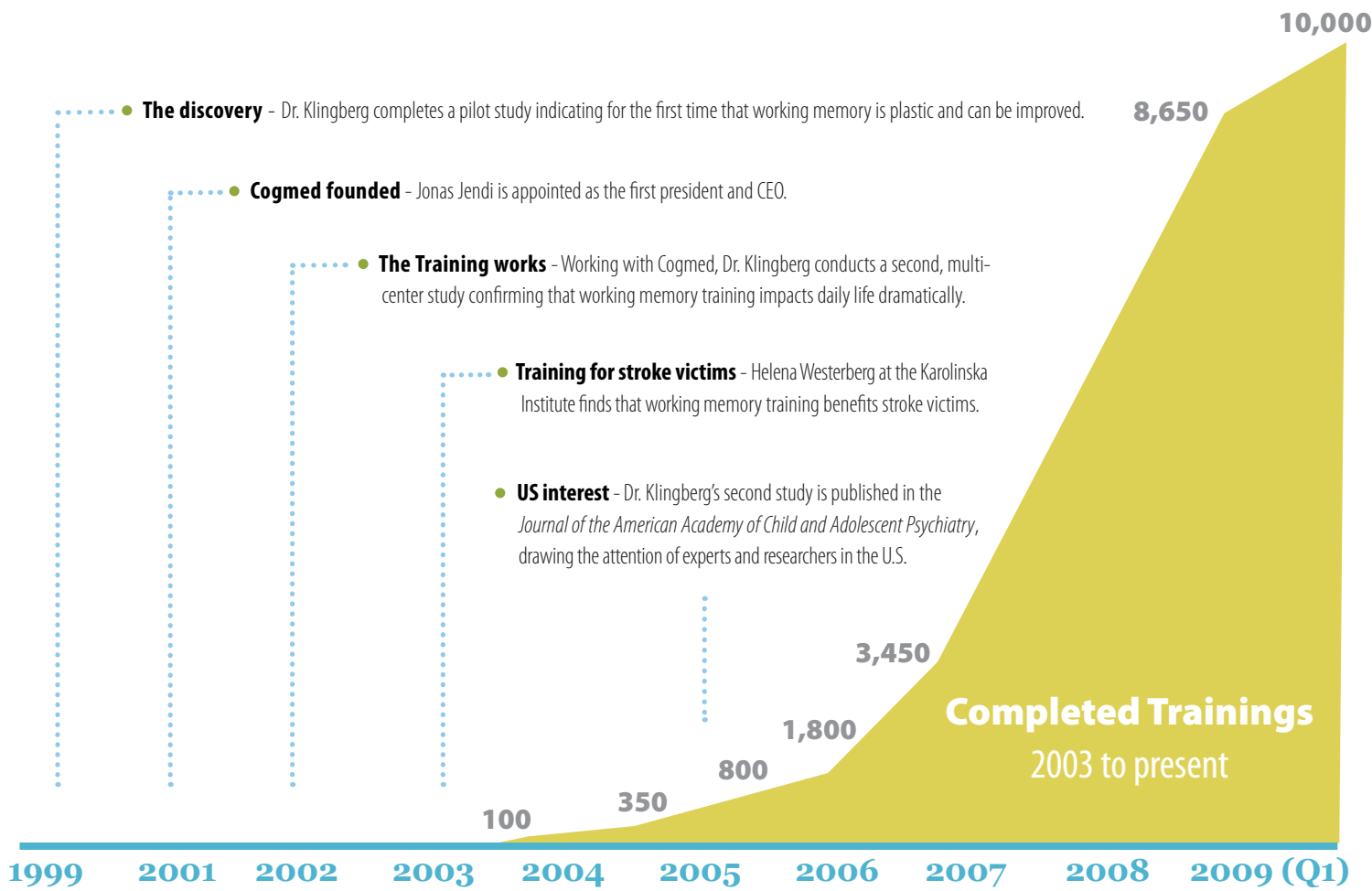
- **Training will complement medication as a core treatment of attention deficits.** Parents and professionals will be drawn to interventions that address the core problem of attention deficits in a lasting manner. Training will continue to address areas that medication cannot.
- **Families struggling with the stigma and symptoms of ADHD will have a proven intervention as a new option.** Because training addresses the key deficit behind inattention, it is liberating for the end-user and a very positive experience with a beginning, middle and end.
- **Educators will see the value of strengthening cognitive abilities.** School administrators will invest in developing the core skills of their students, so curriculum can be learned more effectively, impacting performance and scores on a broad scale.
- **Professionals will turn to cognitive reinforcement to better manage information overload.** Looking to thrive in a multitasking world, professionals will use working memory training to gain a lasting edge.
- **Stroke victims and veterans of recent wars will have a new tool for recovery.** The debilitating attention issues that often emerge in victims of stroke and Traumatic Brain Injury (TBI) will be directly addressed through training, so that cognitive rehabilitation is of equal importance to physical rehabilitation in the recovery process.
- **Ageing adults will improve their quality of life.** Seniors will be able to regain the focus they had in their younger years through training and will be able to stay active and independent for longer as a result.

Moving beyond the brain's limits

Since its arrival in the scientific community, the concept of working memory has revealed new insights into the success and failure of the human mind in key circumstances. Working memory has been pushed into the mainstream as people begin to understand their performance in the context of this critical function. It is becoming an essential part of how we address questions like why can't I complete tasks at work? Why is my daughter struggling with math? Why is my father losing his mental edge?

But it is only during the past decade of intense research that the real impact of working memory has begun to be realized, most importantly, through the discovery that working memory can be substantially improved through training. This breakthrough changes the game for millions of people who are constrained by their working memory in one way or another. Thousands have embraced working memory training with dramatic success. Psychologists have begun to change the way they approach attention issues. Researchers are unlocking ways to help those with cognitive impairments regain control of their lives. Working memory training is helping move science and medicine into a new era in which the intricacies of the brain are better understood and addressed to improve quality of life on a broad scale.

The growth of working memory training



- **North American launch** - Cogmed opens its North American headquarters in Naperville, IL and subsequently continues to expand across Europe, Asia and Australia
- **Early pioneers** - Drs. Lavin, Benninger, Katz and Ingersoll visit Cogmed's headquarters in Stockholm, becoming the first U.S. practitioners to offer the Cogmed Working Memory Training.
 - **Research validation** - Dr. Bradley Gibson at the University of Notre Dame presents an independent study confirming the results of Dr. Klingberg's initial research.
 - **A program for adults** - Cogmed announces Cogmed QM, a program designed especially for adults who want to improve working memory.
- **Training for professionals** - Westerberg shows that normal adults of all ages can dramatically improve their working memory through training.
- **Ongoing validation** - Dr. Chris Lucas at New York University replicates Klingberg's research, again showing the effectiveness of Cogmed training for students with ADHD.
 - **Training for pre-schoolers** - Cogmed introduces Cogmed JM, a program for pre-school children to train their working memory.
 - **Changing the brain** - Dr. Klingberg publishes a study in the prestigious journal *Science*, showing for the first time that training can impact the biochemistry of the brain.
 - **Working memory and learning** - Dr. Joni Holmes, Darren Dunning and Dr. Susan Gathercole at the University of York publish research in *Developmental Science*, showing that Cogmed training improves academic performance.

References

- G.A. Miller, "The Magical Number Seven, Plus or Minus Two: Some Limits on our Capacity for Processing Information," *Psychological Review* 63 (1956): 81-97.
- Klingberg T, Forssberg H, Westerberg H (2002) Training of working memory in children with ADHD. *J Clin Exp Neuropsychol* 24:781-791
- Olesen P, Westerberg H, Klingberg T (2004) Increased prefrontal and parietal brain activity after training of working memory. *Nature Neuroscience* 7:75-79
- Westerberg H, Hirvikoski T, Forssberg H, Klingberg T (2004) Visuo-spatial working memory: a sensitive measurement of cognitive deficits in ADHD. *Child Neuropsychology* 10 (3) 155-61.
- Mechelli, A., Crinion, J.T. Noppeney, U., O'Doherty, J., Ashburner, J., Frackowiack, R. S., et al. (2004). Structural plasticity in the bilingual brain. *Nature*, 431, 757.
- Klingberg T, Fernell E, Olesen P, Johnson M, Gustafsson P, Dahlström K, Gillberg CG, Forssberg H, Westerberg H (2005) Computerized Training of Working Memory in Children with ADHD – a Randomized, Controlled, Trial. *J American Academy of Child and Adolescent Psychiatry* 44 (2):177-186.
- H. Westerberg; H. Jacobaeus; T. Hirvikoski; P. Clevberger; M-L. Östensson; A Bartfai; T. Klingberg. Computerized working memory training after stroke – A pilot study. *Brain Injury*, (2007); 21(1): 21–29
- Beilock, S. L., Rydell, R. J., & McConnell, A. R. (2007). Stereotype threat and working memory: Mechanisms, alleviation, and spillover. *Journal of Experimental Psychology: General*, 136, 256-276.
- Thorell, L B, Lindqvist S, Bergman S, Bohlin G, Klingberg T (2008) Training and transfer effects of executive functions in preschool children. *Developmental Science*, 11(6): 969–976.
- McNab F, Varrone A, Farde V, Jucaite A, Bystritsky P, Forssberg H, Klingberg T. Changes in Cortical Dopamine D1 Receptor Binding Associated with Cognitive Training. *Science*, 323, 800 (2009)
- Holmes, J., Gathercole, S., Dunning, D. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*.

Additional resources

About brain plasticity

Doidge, Norman *The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of the Brain Science*, by Norman Doidge

SharpBrains, a market research company focused on the brain fitness and cognitive health market, www.sharpbrains.com

About working memory

The Overflowing Brain: Information Overload and the Limits of Working Memory, by Torkel Klingberg

Baddeley A (2003) Working memory: looking back and looking forward. *Nat Rev Neurosci* 4:829-839.

Conway (ed) Variation in working memory (2007) Oxford Univ. Press.

www.aboutworkingmemory.com

Working memory and ADHD

Barkley RA (1997) Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychol Bull* 121:65-94.

Barkley RA, Murphy KR (2006) *Attention-deficit hyperactivity disorder: a clinical workbook*. New York: The Guilford Press.

Castellanos FX, Tannock R (2002) Neuroscience of attention-deficit/ hyperactivity disorder: the search for endophenotypes. *Nat Rev Neurosci* 3:617-628.

Martinussen R, Hayden J, Hogg-Johnson S, Tannock R (2005) A meta- analysis of working memory impairments in children with attention- deficit/hyperactivity disorder. *J Am Acad Child Adolesc Psychiatry* 44:377-384.

Westerberg H, Hirvikoski T, Forssberg H, Klingberg T (2004), Visuo- spatial working memory: a sensitive measurement of cognitive deficits in ADHD. *Child Neuropsychology* 10 (3) 155-61.

Attention Research Update, David Rabiner, www.helpforadd.com

About working memory and aging

Wilde NJ, Strauss E, Tulskey DS (2004). *J Clin Exp Neuropsychol*, 26.

About working memory and education

Gathercole SE, Pickering S (2003) Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology* 70:177-194.

Gathercole, S, Alloway, T.P. (2009) *Working memory and learning – a practical guide for teachers*.

