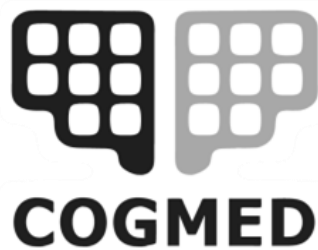


COGMED

RESEARCH CLAIMS & EVIDENCE



Cogmed Working Memory Training

Pearson
Clinical Assessment

Version 1.3

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INTRODUCTION

At the core of Cogmed Working Memory Training are its foundations in academic research. Following a study confirming that visuo-spatial working memory (WM) is a deficit structure in children with ADHD (Westerberg et al., 2004), Torkel Klingberg and collaborators developed and tested Cogmed, an adaptive, computerized training program aimed at increasing WM capacity. Research using Cogmed has revealed that individuals of all ages have improved WM capacity in both the visuo-spatial and verbal domains. Average improvements found in Cogmed research are 26% and 23% for visuo-spatial and verbal WM respectively. In some studies of children with ADHD, increased WM has also shown transfer to executive functions such as attention, inhibition, and reasoning (Klingberg et al., 2002; 2005). Cogmed studies have investigated the impact of WM training from the most fundamental level of genetics (Brehmer et al., 2009; Bellander et al., 2011; Söderqvist et al., 2011), biochemical functioning (McNab et al., 2009), neuronal activity (Olesen et al., 2004; Westerberg & Klingberg, 2007; Brehmer et al., 2011) to its affect on learning (Holmes et al., 2009) and behavioral assessment (Klingberg et al., 2005, Green et al., 2012). In terms of attention, there are at least three randomized, controlled investigations demonstrating improved attention in everyday life (Klingberg et al., 2005; Brehmer et al., 2012; Green et al., 2012) from three distinct research groups, meeting the Cochrane criteria for highest level of acceptance for an intervention.

Combined, the current body of Cogmed training literature refutes the long held belief that WM is static. Further, the essence of these training studies point towards a compelling message: adaptive and sustained WM training is associated with training-induced plasticity in a common neural network for WM, which may remediate the limitations imposed on those with low WM capacity. The increased interest in and use of Cogmed in clinical, school, and research settings worldwide is a testament to the growing acceptance of WM training in the scientific community as well as a step forward in the field of evidence-based cognitive training. As Cogmed continues to evolve, both as a program and a business, research will play an integral role in processes of development, implementation, and integration with clinical assessments.

“The observed training effects suggest that WM training could be used as a remediating intervention for individuals for whom low WM capacity is a limiting factor for academic performance or everyday life”

-Torkel Klingberg

In order to convey the close relationship between the Cogmed program and its backing in academic research, it is essential to have an understanding of the findings to date. This document provides an outline of the current claims that can be made about Cogmed and the evidence for such claims. Questions commonly asked about Cogmed and appropriate answers based on findings from research and clinical practices using Cogmed are also presented here.

EVIDENCE-BASED COGNITIVE TRAINING

I. What makes Cogmed an evidence-based intervention?

Research

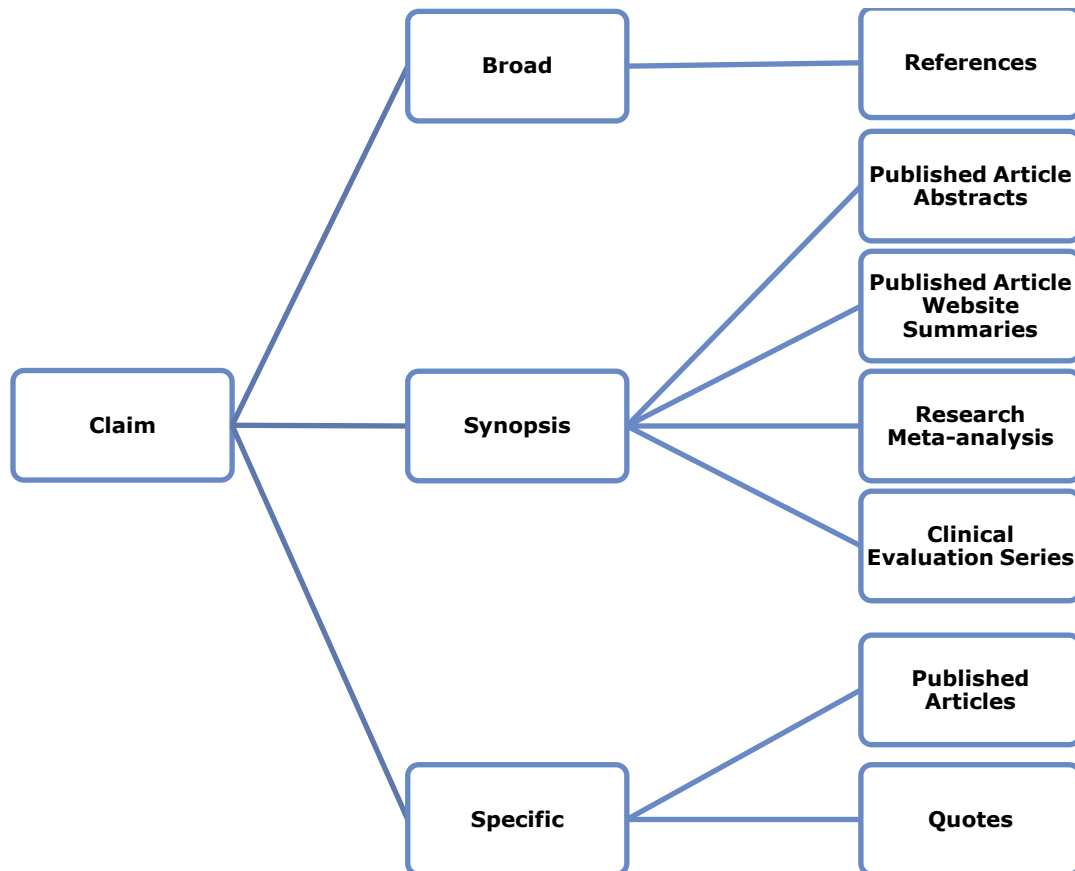
The efficacy of Cogmed has been demonstrated through a credible body of scientific work. First emerging as a research discovery at the Karolinska Institute in Stockholm, Sweden, the effect of Cogmed on WM has since been investigated by independent researchers at world-renowned institutions. Through these studies, not only has evidence been gathered about WM and related executive functions in the form of data but also, the findings have been presented at professional conferences and have been published in leading peer-reviewed scientific journals. The presence of Cogmed in peer-reviewed journals ensures that experts have assessed the results from Cogmed studies and have critically evaluated how the research will build upon the extant body of literature. Publication in journals that rigorously investigate the intentions, methods, and ethical nature of submitted studies supports the growing acceptance of Cogmed as an effective cognitive intervention by the scientific community at large.

Clinical

Beyond the scope of academic WM training research, there is strong evidence that WM training impacts the individual in the real world. Although investigating the efficacy of Cogmed in research is crucial to understanding the underlying mechanisms of WM training, the population(s) for which this type of intervention is most useful, and the ways in which cognitive and behavioral changes should be assessed, these findings are typically gleaned within the tightly controlled and highly structured research setting. Beyond the lab, Cogmed is used by a range of licensed professionals including clinical psychologists and psychiatrists, as well as educators. Since 2006, over 300 clinical practices and 90 schools in the United States have integrated Cogmed Working Memory Training with the aim of helping improve individuals' WM, attention, and behavioral symptoms. As of 2012, the Cogmed Coaches in these venues have supported the training of 10,000 End-Users. Based on Coach reports, the variability of findings in the WM training literature reflects the clinical experience with Cogmed, as the impact of training with regards to near and far transfer are dependent on the cognitive profile of the End-User. Thus, although the research literature surrounding WM training continues to improve, to evolve, and to be challenged, the outlook from Cogmed Coaches is that Cogmed is an efficacious intervention for WM deficits.

II. How to approach the body of evidence: hierarchy of detail

The utility of Cogmed can be conveyed through a series of claims linking the Cogmed training protocol to specific improvements in WM capacity for people with and without WM deficits. Evidence can be presented at varying levels of detail depending on the audience being addressed: broad, synopsis, or specific. Broadly, one can provide evidence for each claim by making *reference* to a Cogmed study published in a peer-reviewed journal that supports the specific claim. Beyond citing particular training studies, the article *abstract* is a more detailed synopsis of the research supporting a claim. *Review articles* and *summaries* of training studies, that are available on the Cogmed website, can also provide a condensed description of what has been found in each study. For statistical evidence to support the claims, the *Cogmed Research Meta-analysis* provides the average percent change and effect size values, as based solely on information available in the published texts. Further, the Clinical Evaluation Series gives an analysis of data from Cogmed participants provided by clinical practices worldwide. Finally, for the most in depth evidence for a Cogmed claim, it is vital to go directly to the text, to read the published Cogmed articles, and to take note of quotes that directly support each claim.



CLAIMS AND EVIDENCE

EXECUTIVE SUMMARY

- I. WM is key to attention and learning
- II. WM can be improved by training, using right tool and protocol: Cogmed
- III. WM can be improved by training in all age ranges
- IV. Training-related improvement can be shown on three levels of assessment: fMRI/PET, neuropsychological testing, and rating scales
- V. Improved WM generalizes to improvements in daily functioning
- VI. Improvements in WM and behavioral outcomes are sustained at 6 months post training
- VII. Effects of WM training are specific: WM and its derived functions are improved, but there is no cross-the-board-improvement
- VIII. Training effects have substantial real world impact on individuals impaired by their WM capacity

The evidence for these claims is taken directly from 26 published peer-reviewed Cogmed Working Memory Training studies, 2 reviews, and 1 book chapter that are publicly available for individual review and that are summarized on the Cogmed website.

Cogmed Working Memory Training Published Research Table

Year	Publication	Title	Author(s)	Population
2002	Journal of Clinical & Experimental Neuropsychology	Training of working memory in children with ADHD	Klingberg et al.	Children w/ ADHD
2004	Nature Neuroscience	Increased prefrontal and parietal activity after training of working memory	Olesen et al.	Adults w/ normal WM
2005	Journal of the American Academy of Child & Adolescent Psychiatry	Computerized training of working memory in children with ADHD: a randomized, controlled trial	Klingberg et al.	Children w/ ADHD
2007	Brain Injury	Computerized working memory training after stroke - a pilot study	Westerberg et al.	Adults w/ stroke
2007	Physiology and Behavior	Changes in cortical activity after training of working memory - a single-subject analysis	Westerberg et al.	Adults w/ normal WM
2008	Developmental Science	Training and transfer effects of executive functions in preschool children	Thorell et al.	Preschool children w/ normal WM
2009	Science	Changes in cortical dopamine D1 receptor binding associated with cognitive training	McNab et al.	Adults w/ normal WM
2009	Developmental Science	Adaptive training leads to sustained enhancement of poor working memory in children	Holmes et al.	Children w/ poor WM
2009	Neuroscience Letters	Working memory plasticity modulated by dopamine transporter genotype	Brehmer et al.	Adults w/ normal WM
2010	Applied Cognitive Psychology	Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD	Holmes et al.	Children w/ ADHD
2010	Advances in Child Development and Behavior, Vol. 39	Poor working memory: Impact and interventions	Holmes et al.	Book Chapter
2010	School Mental Health	Working memory training for children with attention problems or hyperactivity: A school-based pilot study	Mezzacappa et al.	Children w/ ADHD
2010	Trends in Cognitive Sciences	Training and plasticity of working memory	Klingberg	Review
2010	Brain Injury	Computerized working memory training in a group of patients suffering from acquired brain injury	Lundqvist et al.	Adults w/ brain injury
2010	Journal of Clinical Child & Adolescent Psychology	A controlled trial of working memory training for children and adolescents with ADHD	Beck et al.	Children w/ ADHD
2011	Journal of Speech, Language, & Hearing Research	Working memory training for children with cochlear implants: A pilot study	Kronenberger et al.	Children w/ cochlear implants
2011	The Journal of Pediatrics	Computerized working memory training improves function in adolescents born at extremely low birth weight	Løhaugen et al.	Adolescents form w/ ELBW
2011	Reading and Writing	Effects of working memory training on reading in children with special needs.	Dahlin	Children w/ special needs

2011	Developmental Science	Gains in fluid intelligence after training non-verbal reasoning in 4-year-old children: A controlled, randomized study	Bergman Nutley et al.	Typically functioning preschool children
2011	Child Neuropsychology	Component analysis of verbal versus spatial working memory training in adolescents with ADHD: A randomized, controlled trial	Gibson et al.	Children w/ ADHD
2011	NeuroImage	Neural correlates of training-related working-memory gains in old age	Brehmer et al.	Typically functioning adults
2011	Neuropsychologia	Preliminary evidence that allelic variation in the LMX1A gene influences training-related working memory improvement	Bellander et al.	Typically functioning adults
2011	Developmental Psychology	Dopamine, working memory, and training induced plasticity: Implications for developmental research.	Söderqvist et al.	Typically functioning children
2011	Science	Interventions shown to aid executive function development in children 4 to 12 years old	Diamond & Lee	Review
2011	Learning and Individual Differences	The impact of working memory training in young people with social, emotional and behavioural difficulties	Roughan & Hadwin	Children w/ SEBD
2012	Scandinavian Journal of Occupational Therapy	Working memory training for patients with acquired brain injury: Effects in daily life	Johansson & Tornmalm	Adults w/ ABI
2012	Frontiers in Human Neuroscience	Working-memory training in younger and older adults: Training gains, transfer and maintenance	Brehmer et al.	Typically functioning adults
2012	Neurotherapeutics	Will working memory training generalize to improve off-task behaviour in children with Attention-Deficit/Hyperactivity Disorder?	Green et al.	Children w/ ADHD
2012	Journal of Applied Research in Memory and Cognition	Component analysis of simple span vs. complex span adaptive working memory exercises: A randomized controlled trial	Gibson et al.	Typically functioning adolescents

CLAIMS AND EVIDENCE

Below are the claims made by Cogmed and the summaries of evidence supporting each of the claims. The evidence has been numerically end noted to coordinate with quotes and references that can be found in the appendix of this document.

I. WM is key to attention and learning

WM is the ability to retain and manipulate information for brief time periods and is important for complex cognitive activities. In addition to the phonological and visuo-spatial stores within WM, the central executive is proposed to function in a supervisory role in controlling attention (Baddeley & Hitch, 1974). As attention is required for maintaining and manipulating information in WM, they are essentially not separable. In addition to being linked functionally, brain areas responsible for allocating selective attention (ie., the prefrontal and parietal regions) largely overlap those activated during WM tasks (See Figure 1).¹

WM and attention support learning. Using the Automated Working Memory Assessment (AWMA), researchers have found that 80% of children who scored in the lowest 10% for WM also experienced substantial problems in math, reading, or both.² School-based activities such as math, reading, and science depend on a student's ability to pay attention to instructions or information, to hold that information in mind, and to integrate that information so to derive meaning from it. For example, solving a math problem requires attending to the stimulus and temporary storage of numbers and functions while simultaneously extracting learned rules from long term memory, such as the guidelines for multiplying two numbers together and then performing the desired operation. Children with poor WM capacity become overloaded during academic tasks, as they struggle to remember multi-step instructions or to keep track of the particular stage of a task they are trying to complete.³

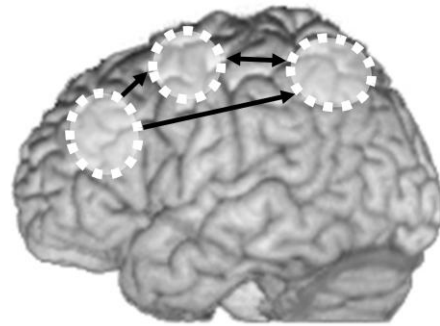


Figure 1. The ringed areas represent sections of the parietal lobe and the upper part of the front lobe that are activated during the delay period of WM tasks, when participants are required to retain spatial information. The same areas are also activated for controlled attention. The arrows indicate how the areas are believed to communicate with one another during WM tasks (Curtis & D'Esposito, 2003).

Reference(s): Klingberg, 2010¹; Holmes et al., 2009²; Holmes et al., 2010³

II. WM can be improved by training, using right tool and protocol: Cogmed

WM can be improved using Cogmed, an adaptive WM training program, and the prescribed training protocol. Cogmed End-Users train intensively for 30 to 40 minutes, 5 days a week for 5 weeks. It is during this sustained training period that the End-User engages in 8 out of 12 visuo-spatial and verbal exercises per day that continually adjust in difficulty based on End-User performance. Although it is the adaptivity and intensity of the training that is believed to underlie the training effect, support from a trained Cogmed Coach ensures compliance with the Cogmed protocol, fidelity to the training plan, and assessment of WM with non-trained tasks (ie., sound measurement of WM gains).

Adaptive WM Training

A hallmark of effective WM training is adaptivity. In a 2011 review of interventions shown to aide executive functions in children, researchers noted that executive functions such as WM must be continually challenged to see improvements and non-adaptive training does not lead to gains.⁴ This assertion is supported by blinded, randomized, controlled trials comparing adaptive Cogmed training to both non-adaptive (placebo) Cogmed training⁵ and non-adaptive commercially available video games.⁶ Additionally, research with children with cochlear implants⁷ and adults with acquired brain injury⁸ has shown that training according to an adaptive staircase method that adjusts on a trial by trial basis is essential, as it forces the user to perform at or near their WM capacity.

Sustained and Intense WM Training

Not only is adaptivity crucial but also, training must be sustained and intense. In order to uphold the rigorous training plan, a Cogmed Coach provides regular support and feedback to each End-User. Importantly, Cogmed research has been able to rule out the hypothesis that Coach support is a probable explanation for improvements in participants' WM. Numerous randomized, placebo controlled studies have included the standard, adaptive Cogmed training as well as non-adaptive (placebo) Cogmed training so to control for the impact of Coach support and other variables that may influence training outcomes.

Green et al. (2012) described the role of the Coach in controlled research as supporting implementation by providing general feedback for the use of the program and advice for parents in reinforcing their child during training. Coaching in each group was controlled to ensure equal levels of support were given to each child. The only difference between the standard Cogmed group and the placebo group was the adaptivity of the training program. Consistent with the Cogmed literature, only participants in adaptive training

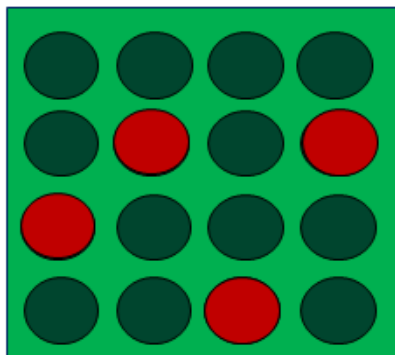
experienced significantly improved WM with large effect sizes.⁹ Thus, the role of the Cogmed Coach ensures compliance to and support for the rigorous training regimen which in turn challenges the capacity of the WM system.

Assessing WM Training

Properly assessing the impact of adaptive, supported, and intense WM training is also essential for demonstrating that WM is improved after Cogmed. Researchers have shown that WM gains have generalized beyond improvements in task-specific performance by using non-trained assessments of WM.¹⁰ Non-trained tests measure the underlying ability (i.e., WM) that was trained but, using assessments that differ in configuration, presentation, and response mode than the tasks used in training (See Figure 2). By employing non-trained tests, the improvements to WM after adaptive training cannot be attributed to practice.

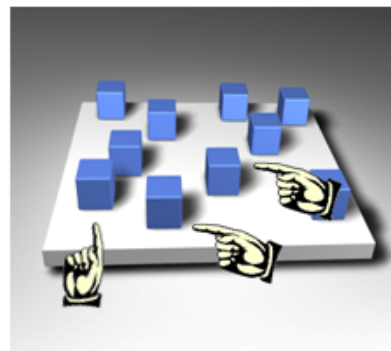
Figure 2. Trained computerized grid visuo-spatial WM task vs. non-trained span board visuo-spatial WM task

A note on trained vs. non-trained WM tasks



Trained visuo-spatial WM task
-Simple span forward

Presentation mode: Computerized
Stimuli: Grid, circles light up
Stimuli configuration: Regular 4 x 4 grid
Response mode: Mouse click



Non-trained visuo-spatial WM task
-Simple span forward

Presentation mode: Real blocks
Stimuli: Blocks on a board
Stimuli configuration: Irregular pattern
Response mode: Hands on

In one study of children with ADHD by Klingberg et al. (2005), users who did adaptive Cogmed training showed a 19% improvement on a non-practiced visuo-spatial WM task compared to the non-adaptive training group.¹¹ Furthermore, over 20 additional published studies using the adaptive Cogmed solution and protocol have resulted in improvements on non-trained tasks of WM. In a recent meta-analysis conducted by Cogmed and based solely on

information available in the published texts, research participants in the standard adaptive Cogmed training group improved an average 26% in visuo-spatial WM and 23% in verbal WM from baseline to post-test on non-trained WM tests.*

Reference(s): Diamond & Lee, 2011⁴; Holmes et al., 2009⁵; Thorell et al., 2009⁶; Kronenberger et al., 2011⁷; Lundqvist et al., 2010⁸; Green et al., 2012⁹; Holmes et al., 2009¹⁰; Klingberg et al., 2005¹¹; Appendix A*

III. WM can be improved by training in all age ranges

Gains in WM capacity after Cogmed Working Memory Training have been observed in pre-school children, school-aged children, adolescents, and adults. In 2009, Thorell et al. found that it was feasible to train 4 and 5 year olds and that training effects transferred to non-trained WM tests.¹² These findings are supported by significant improvements in visuo-spatial and verbal WM in a study of pre-school children by Bergman Nutley et al. (2011).¹³

School-aged children have also shown improvements in WM post-Cogmed training. Klingberg et al. (2002) observed a significant effect on the span-board, a non-trained assessment of visuo-spatial WM in children ages 7 to 15 years. In 2005, Klingberg et al. replicated these findings in a group of children, 7 to 12 years of age, with improvements in both verbal WM (digit span) and visuo-spatial WM (span board). More recently, Green et al. (2012) demonstrated that children 7 to 14 years old who did standard Cogmed (adaptive training) significantly improved compared to the placebo group (non-adaptive training) on the widely used Working Memory Index (WMI) of the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV).¹⁴

In 2010, Løhaugen et al. found that adolescents (ages 14 to 15 years) born at extremely low birth weight (ELBW) improved in both visuo-spatial and verbal WM immediately after Cogmed and at 6 month follow-up compared to their baseline performance. This significant training effect was also observed in a healthy born, age-matched comparison sample. Thus, Cogmed was just as effective in improving WM in adolescents with demonstrated WM deficits (ELBW group) as in healthy-born adolescents.

Adults have also shown improved WM after Cogmed training. Brehmer et al. (2012) revealed that adaptive training of typically functioning 20 to 30 and 60 to 70 year olds led to significant improvements on non-trained verbal (digit span forward) and visuo-spatial (span board backward) WM tests. Younger adults gained the most from training, with higher baseline cognitive functioning scores and larger differences in performance gains (trained and non-trained WM tasks) between the adaptive and placebo groups than older adults. The younger adults in adaptive training however had significantly larger gains on trained and non-trained measures of WM compared to age-matched placebo controls. These findings are consistent

with previous literature showing significantly greater gains in WM for participants who train adaptively. Older adults in the adaptive training group also had significantly larger gains on trained and non-trained measures of WM compared to older adults in the non-adaptive (placebo) training group. These findings imply that the training paradigm is sensitive enough to impact even older adults but, that younger adults have larger gains. Importantly, WM gains in the younger and older adaptive groups were maintained at 3 month follow-up.¹⁵

Reference(s): Thorell et al., 2009¹²; Bergman Nutley et al., 2011¹³; Klingberg et al., 2002; Klingberg et al., 2005; Løhaugen et al., 2010; Green et al., 2012¹⁴, Brehmer et al., 2012¹⁵

IV. Training-related improvement can be shown on three levels of assessment: fMRI/PET, neuropsychological testing, and rating scales

The impact of Cogmed Working Memory Training has been shown at 3 levels: physiological, neuropsychological, and behavioral assessments (rating scales). Neuro-imaging studies using PET and fMRI scans have revealed that improvements in WM capacity post Cogmed are associated with changes in the density of cortical D1 dopamine receptors and decreases in D1 dopamine receptor binding potential, which in turn impacts the transmission of dopaminergic signals.¹⁶

Cogmed Working Memory Training is also associated with both increases and decreases in brain activity. As discussed in Brehmer et al. (2011), the relationship between activation changes and performance after cognitive intervention is still an open issue¹⁷. The findings from Cogmed reflect this debate. Research with fMRI has shown increased activation in the frontal and parietal regions of the brain that support WM function.^{18 & 19} Differently, research by Brehmer et al. (2011) revealed that adaptive Cogmed training led to selective BOLD (fMRI) decreases in frontal, temporal, and occipital regions compared to non-adaptive training. Additionally, larger activation decreases were observed for high load WM tasks, indicating that the benefits of WM training unfold under more challenging conditions. These findings are consistent with an efficiency interpretation, pointing to less neural energy being required to attain the same performance level post training.²⁰

Beyond imaging data, neuropsychological testing in almost all Cogmed studies have shown that participants demonstrate near transfer to non-trained tests of WM. Far transfer to tasks that involve similar underlying processes including, attention, inhibition, and non-verbal reasoning have also been demonstrated (Klingberg et al., 2002, 2005; Westerberg et al., 2007; Brehmer et al., 2012). In a study of children with social, emotional, and behavioral problems, Roughan and Hadwin (2011) found that after Cogmed training, users improved not only on a composite rating of WM (including both digit span and spatial span) but also, that children improved on measures of inhibition (Go/No Go computer task) and IQ (Raven's

Standard Progressive Matrices). Although only the gains in WM were maintained at 3 month follow-up and Cogmed does not claim to improve inhibition or IQ, these findings imply that the immediate impact of WM training extends beyond simply increasing WM capacity.²¹

The effect of training has also been observed on parental ratings of inattention and hyperactivity/ impulsivity both immediately post Cogmed and at follow-up three months later (Klingberg et al., 2005). Other studies have since provided further evidence for behavioral change after Cogmed training. For example, Beck et al. (2010) found that parent report of inattentive behaviors and ADHD symptoms for a group of ADHD children decreased significantly post-Cogmed and at four month follow-up²² and Mezzacappa and Buckner (2010) found that teacher ratings of ADHD symptoms decreased by 26% in a sample of 9 children, ages 7 to 12.²³

These research results are further substantiated by evidence for behavioral change that has emerged from the clinical setting. Data from 769 children collected pre and post-Cogmed at three distinct practices in Singapore, the Netherlands, and Canada has revealed that on average, Cogmed End-Users improved their inattentive symptoms, as rated on the DSM-IV Parent Rating Scale, by 30% from baseline to post-test. On average, 82% of the children experienced gains and when parsed out from the total sample, this group improved their inattentive symptoms on average by 36% from baseline to post-test. Data from 120 adults collected in Singapore and the Netherlands also revealed that on average, Cogmed End-Users improved their inattentive symptoms, as reported on the DSM-IV Adult Rating Scale, by 28% from baseline to post-test. On average, 80% of the adults from Singapore and the Netherlands experienced gains and when parsed out from the total sample population, this group improved their inattentive symptoms on average by 36% from baseline to post-test.**

Reference(s): McNab et al., 2009¹⁶; Brehmer et al., 2011¹⁷; Olesen et al., 2004¹⁸; Westerberg & Klingberg, 2007¹⁹; Brehmer et al., 2011²⁰; Klingberg et al., 2005, Westerberg et al., 2007; Brehmer et al., 2012; Roughan & Hadwin, 2011²¹; Beck et al., 2010²²; Mezzacappa & Buckner, 2010²³, Appendix B**

V. Improved WM generalizes to improvements in daily functioning

In addition to laboratory measures of WM and attention, participants also improve on self-reported assessments of daily functioning following WM training. Beyond the gains reported for improved attention and decreased ADHD symptoms (Klingberg et al., 2005; Beck et al., 2010; Mezzacappa & Buckner, 2010; Gibson et al., 2010; Roughan & Hadwin, 2011), Cogmed users have reported decreased cognitive failures and improved occupational outcomes. In a study by Westerberg et al., 2007, stroke patients who trained with Cogmed not only improved significantly on the span board (visuo-spatial WM), digit span (verbal WM)

and PASAT (WM and attention), but also on the Cognitive Failures Questionnaire (CFQ), a self-report behavioral assessment of cognitive failures.²⁴ Significant improvements on the CFQ were replicated with a typically functioning sample of younger and older adults (Brehmer et al., 2012). Both younger and older adults who trained adaptively reported less memory complaints than their age-matched peers who trained with the placebo (non-adaptive training).²⁵

Self report of improved occupational performance has also been reported in addition to decreased cognitive symptoms. In a 2010 study by Lundqvist, brain injured participants who used Cogmed were assessed with the Canadian Occupational Performance Measure (COPM). The COPM is a self-report measure of occupational performance and satisfaction with performance on the basis of a participants' defined problem areas in self-care, productivity, and leisure. Lundqvist et al. (2010) found that after Cogmed, participants reported significant improvements in self-estimation of occupational performance and satisfaction with performance. These findings suggest a training effect on cognitive functioning in daily living.²⁶ Further, these results were replicated in a study of brain injured adults by Johansson and Tornmalm (2012), with decreased report of cognitive failures on the CFQ and improved occupational performance on the COPM.²⁷

Reference(s): Klingberg et al., 2005; Beck et al., 2010; Mezzcappa & Buckner, 2010; Gibson et al., 2011; Roughan & Hadwin, 2011; Westerberg et al., 2007²⁴; Brehmer et al., 2012²⁵; Lundqvist et al., 2010²⁶; Johansson & Tornmalm, 2012²⁷

VI. Improvements in WM and behavioral outcomes are sustained at 6 months post training

Researchers have observed training-related gains in WM that have been sustained for up to 6 months post-intervention.^{28 & 29} Increases in WM capacity have also transferred to behavioral improvements that have been sustained for up to 6 months. It should be noted that after Cogmed the *nature* of behavioral improvement is dependent on the population studied and on the core areas of deficit experienced by that population. For example, in a study of hearing impaired children, Kronenberger et al. (2011) observed increased performance on a sentence repetition task at both post-intervention and 6 month follow-up. Maintenance of gains relating to language, sentence perception, and speech production may be crucial for hearing impaired children and could have positive impacts on academic and social outcomes as they develop.³⁰ Differently, Johansson and Tornmalm (2012) found that brain injured adults self-reported decreased cognitive failures immediately after training that were maintained at 6 months.³¹ Thus, not only are improvement in WM capacity sustained but also, transfer effects that have particular implications for the specific population researched.

Reference(s): Holmes et al., 2009²⁸; Holmes et al., 2010²⁹; Kronenberger et al., 2011³⁰; Johansson & Tornmalm, 2012³¹

VII. Effects of WM training are specific: WM and its derived functions are improved, but there is no across-the-board-improvement

WM training improves WM capacity. Transfer of training effects have been seen in the improved attention, reasoning, inhibition, academic ability, daily functioning, and occupational performance of trained populations. Enhancement of these related systems and skills are not surprising, as they are linked functionally and possibly share common neural networks.

It is important to note however that Cogmed neither claims to improve all brain functions nor to improve systems distinct from WM. For example, Cogmed has been shown to improve WM but not to improve long- term memory in general³². Cogmed training has led to gains on an inhibition measure, the Stroop task, in ADHD youths and typical adults but not in stroke patients (Klingberg et al., 2010). Cogmed has been attributed to gains on reasoning measures such as Raven's Colored Progressive Matrices in ADHD groups (Klingberg et al., 2002, 2005) but not to improvements in global scores of IQ that depend on other factors such as experience and knowledge³³. Even in the sphere of learning, Cogmed has led to improvements on WM-related reading functions such as comprehension but, not orthographic reading that involves understanding letters and spelling.³⁴ Thus, gains in WM after Cogmed are strongly supported by the literature whereas across the board improvements in some executive functions and abilities have not yet been demonstrated with consistency warranting a formal claim.

Reference(s): Westerberg et al., 2007³²; Klingberg et al., 2010; Klingberg et al., 2002, 2005; Roughan & Hadwin, 2011; Holmes et al., 2010³³; Dahlin, 2011³⁴

VIII. Training effects have substantial real world impact on individuals impaired by their WM capacity

Improvements in WM have been observed in individuals of all ages and various WM profiles. Although typically functioning pre-school children (Thorell et al., 2009; Bergman Nutley, 2011) and adults (Bellander et al., 2011; Brehmer et al., 2011) have all improved significantly after training, Cogmed is perhaps most beneficial and yielding of larger real world gains for WM impaired individuals. This group includes both those meeting specific diagnostic criteria for a disorder and/or those primarily exhibiting low WM.

In 2012, Green et al. studied a sample of 26 children, ages 7 to 14 years, diagnosed with ADHD (combined or inattentive type) in a randomized, placebo controlled Cogmed Working Memory Training trial. Prior to and post-training, children in both groups were assessed using the Restricted Academic Situations Task (RAST), an observational system used to assess aspects of off-task behavior during the completion of an academic task. At the start of the task, children were provided a toy or game of their choice to play with and after 5 minutes, the researcher re-entered the room and moved the game to the side while telling the child to complete a set of academic worksheets for 15 minutes. Before the researcher left the room, they instructed the child not to leave their seat or play with any toys. The researcher then observed through a one way mirror and coded the occurrences of five behaviors during the academic task: off task (looks away from the paper), out of seat (leaves chair), fidgets (repetitive purposeless motion), vocalizes, and plays with objects (touches any object in the room unrelated to the task). At post-test, children in the adaptive training condition demonstrated significantly improved WM on the Working Memory Index of the WISC-IV as well as, decreased behaviors in the off task category and the plays with objects category. These findings imply that the influence of training had a significant effect on inattentive behaviors that are frequently associated with ADHD and which are related to academic functioning. Thus, Green et al. (2012) demonstrated that children in adaptive Cogmed training improve not only on standardized assessments of WM but also, on an ecologically valid measure of observable ADHD-associated behaviors that would substantially impact their functioning the real world.

In addition to real world improvements for participants with particular diagnosis, Holmes et al. (2009) demonstrated that children screened for simply for low WM experienced improved WM, instruction following, and math ability regardless of whether they had predetermined learning disabilities, ADHD, or any other clinical disorder.³⁵ Therefore, participants who had fallen below the radar for typical diagnostic categories but with low WM experienced a real and measurable impact post-training. Dahlin (2011) also posited that WM training would be useful for children with reading comprehension problems and attention problems within the general category of "special needs" and found improved performance in a sample of 42 school children after training.³⁶ Thus, Cogmed addresses WM constraint, whether having emerged over the normal course of development or manifesting as symptoms of a specific clinical disorder.

Reference(s): Thorell et al., 2009; Bellander et al., 2011; Brehmer et al., 2011, Green et al., 2012, Holmes et al., 2009³⁵; Dahlin, 2011³⁶

WHAT CANNOT BE CLAIMED?

- Cogmed is a cure for ADHD and associated behavioral issues
- Cogmed improves long term memory
- Cogmed results in higher IQ scores
- Cogmed is only for people with a diagnosed disorder
- Cogmed impacts all individuals equally
 - 20% see no training effects
- Cogmed reverses or cures organic brain disease
- Training gains from Cogmed will last forever
- Cogmed will result in a student getting better grades in school

QUESTIONS & ANSWERS

ADHD

Can Cogmed ameliorate the inattentive and hyperactive symptoms seen in individuals with ADHD?

Yes. Numerous Cogmed studies have shown that individuals with ADHD evidence improved inattentive and hyperactive symptoms after Cogmed (see Klingberg et al. 2002; 2005; Beck et al., 2010; Mezzacappa & Buckner, 2010; Løhaugen et al., 2011, Green et al., 2012)

Does Cogmed cure ADHD?

No. Cogmed does not claim to be a *cure* for any deficit or disorder. There is however a strong body of evidence supporting Cogmed as a viable intervention for improving WM deficits.

LEARNING

Can Cogmed lead to improvement in academic performance?

Yes. Cogmed has been shown to improve learning outcomes such as reading comprehension (Dahlin, 2011) and mathematic ability (Holmes et al., 2009). However, more evidence is needed to reinforce the findings of improved academic skills after WM training. Such investigations should assess participants at six months post-intervention and beyond, as the improved WM system aids in acquiring new skills and takes time to manifest in academic assessment.

Does Cogmed increase a user's IQ?

No. There is no evidence to suggest that Cogmed improves IQ. Although WM capacity is related to one's ability to pay attention, to reason, and to problem solve, global assessments of IQ also include factors related to previously learned knowledge and experience. It is possible that WM training may impact measures of IQ but numerous factors that contribute to an IQ score must also be considered.

AGING

What evidence is there for improvements in normally aging adults after Cogmed?

It is well established that WM capacity increases with development until about 20 years of age and then begins decline with the normal aging process. Cogmed has been shown to improve WM in younger adults, ages 20 to 30 years, and older adults, ages 60 to 70 years. A study by Brehmer et al. (2012) revealed that younger adults who trained with Cogmed improved most on non-trained WM assessment and reports of attention and cognitive problems. Older adults who trained with Cogmed not only improved in WM, attention, and cognitive failures compared to older adults who had trained non-adaptively, but also improved to levels comparable to that of 20-30 years olds who had trained non-adaptively.

Can Cogmed reverse or cure dementia?

No, Cogmed should not be framed as a "cure" for any disorder or disease. Unlike the WM deficits experienced with normal aging, organic brain diseases such as dementia and Alzheimer's involve physical degradation of brain matter that impact memory. As a computerized training solution, Cogmed does not claim to reverse the physical decline of the brain. Rather, Cogmed is an intervention known to improve WM and attention and is associated with improving the plasticity of existing neural networks in the brain.

SUPPORTING QUOTES

I. WM is key to attention and learning

1. "Attention is thus closely linked to WM. Controlled, or top-down, attention refers to the voluntary allocation of selective attention and relies on parietal and prefrontal regions that largely overlap with activation during WM tasks in both the parietal and prefrontal cortex. Control of attention is necessary in WM tasks, for example when selecting only relevant information."

Reference: Klingberg, T. (2010). Training and plasticity of working memory. *Trends in Cognitive Sciences, 14*(7), 317 -324. doi: 10.1016/j.tics.2010.05.002

2. "Individual differences in complex span tasks that rely on the attentional component of WM are closely related to children's abilities in reading (Gathercole & Pickering, 2000; Swanson & Sachs-Lee, 2001) and mathematics (Geary, Hoard, Byrd-Craven & De Soto, 2004), and are effective longitudinal predictors of later academic attainment (Gathercole, Brown, & Pickering, 2003)".

Reference: Holmes, J., Gathercole, S.E., & Dunning, D.L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science, 12*(4), F9 -F15. doi: 10.1111/j.1467-7687.2009.00848x

3. "These children also struggle to successfully complete a range of tasks that are designed to aid learning at school. Common classroom activities that require large amounts of information to held in mind are particularly challenging for children with poor working memory. One of the most crucial aspects of classroom learning is following spoken instructions given by the teacher, and this is particularly difficult for children with small working memory capacities. Teacher instructions are often multistep, directing children where they or their classroom objects should be, contain vital information about learning activities, or relate to a sequence of actions that must be carried out. To perform these actions, children must be able to remember the different parts of the instruction whilst carrying out the various steps to complete the action successfully. Children with poor working memory typically either carry out the first command of a multistep instruction, skip straight to the last step, or simply abandon the task all together as they are unable to remember all the necessary parts of the sequence (Gathercole & Alloway, 2008; Gathercole, Lamont, & Alloway, 2006)."

Reference: Holmes, J., Gathercole, S.E., & Dunning, D.L. (2010). Poor working memory: Impact and interventions. In J. Holmes (Ed.), *Advances in child development and behavior* (Vol. 39, pp. 1- 43). Burlington: Academic Press.

II.WM can be improved by training, using right tool & protocol: Cogmed

4. "Coaching was used to enhance compliance with completing the sessions for both the placebo and training condition. The same licensed clinical psychologist coached all participants during each week of training on the telephone at least once a week. Coaching involved answering questions regarding the use of the computer program and troubleshooting software issues, general feedback for the use of the program, and addressing parental concerns of how to engage their child in the training protocol. Coaching was kept to a minimum so as to reduce any possible differences between groups in amount or type of feedback."

Reference: Green, C.T., Long, D.L., Green, D., Iosif, A., Dixon, F., Miller, M.R., Fassbender, C., & Schweitzer, J.B. (2012). Will working memory training generalize to improve off-task behavior in children with Attention-Deficit/Hyperactivity Disorder? *Neurotherapeutics*. Advance online publication. doi:10.1007/s13311-012-0124-y

5. "EFs must be continually challenged to see improvements. Groups assigned to the same program, but without difficulty increasing, do not show EF gains."

Reference: Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old [Special section]. *Science*, 333, 959-963. doi: 10.1126/science.1204529

6. "In all cases, the training gains were significantly greater for the adaptive than the non-adaptive group. Importantly, training gains in each of these three aspects of WM remained significant after 6 months for the adaptive group: visuo-spatial STM...verbal WM...visuo-spatial WM.... The same pattern of selective enhancement with adaptive training extended to the classroom analogue test of WM, the following instructions task...These gains also persisted 6 months after training for the adaptive group..."

Reference: Holmes, J., Gathercole, S.E., & Dunning, D.L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, 12(4), F9 -F15. doi: 10.1111/j.1467-7687.2009.00848x

7. "With regard to the WM tasks, the results showed a significant effect of training on both visuo-spatial WM and verbal WM. Planned comparisons showed that for both

types of WM, the WM group, but not the inhibition group, showed significantly larger improvement over time compared to the control group. The effect size for the comparison between the WM group and the control groups was large for both spatial and verbal WM.”

Reference: Thorell, L.B., Lindqvist, S., Bergman Nutley, S., Bohlin, G. & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science*, 12(1), 106 -133. doi:10.1111/j.1467-7687.2008.00745

8. “The results of this pilot study demonstrated statistically significant short-term improvement in verbal working memory capacity, nonverbal working memory capacity, and real-world working memory behaviors in a sample of nine children with CI’s, following completion of a 5-week working memory training program.”

Reference: Kronenberger, W.G., Pisoni, D.B., & Henning, S.C., & Colson, B.G., & Hazzard, L.M. (2010). Working memory training for children with cochlear implants: A pilot study. *Journal of Speech, Language, and Hearing Research*, 54(4), 1182 -1196.

9. “This study shows that an individually structured and intense WM training can improve a person’s WM function. It found effects at the function level of non-trained WM tasks as well as at the activity level of self-reported performance and satisfaction with performance and for global health ratings.”

Reference: Lundqvist, A., Gundström, K., & Rönnerberg, J.(2010). Computerized working memory training in a group of patients suffering from acquired brain injury. *Brain Injury*, 24(10), 1173- 1183.

10. “Gains in measures of verbal and visuo-spatial WM associated with the central executive component of WM (Alloway et al., 2006) and in visuo-spatial STM were maintained 6 months after training.”

Reference: Holmes, J., Gathercole, S.E., Place, M., Dunning, D.L., Hilton, K.A., & Elliot, J.G. (2010). Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD. *Applied Cognitive Psychology*, 24(6), 827-836. doi: 10.1002/acp.1589

11. “... the treatment group that undertook high-intensity training of WM improved significantly more than the comparison group on the main outcome measure: the span-board task, which was a nonpracticed measure of visuospatial WM. This

effect also remained at follow-up. In addition, there were treatment effects for response inhibition (Stroop task), verbal WM (digit span), complex reasoning (Raven's task), and for parent ratings of ADHD symptoms. The span-board task differs from the trained visuo-spatial WM tasks with respect to the stimuli that are used...stimulus configuration...as well as response mode...and the testing situation. The improvement on the span-board task is therefore evidence that the training effect generalized to a nontrained visuospatial WM task. The treatment effect...corresponds to a 19% improvement, and the effect size was 0.93."

Reference: Klingberg, T., Fernell, E., Olesen, P.J., Johnson, M., Gustafsson, P., Dahlström, K., Gillberg, C.G., Forsberg, H., & Westerberg, H. (2005). Computerized training of working memory in children with ADHD – a randomized, controlled trial. *Journal of the American Academy of Child & Adolescent Psychiatry*, 44(2), 177-186.

III. WM can be improved by training in all age ranges

12. "This study is the...first study of WM training in children below school-age. The main findings were that WM training was effective even among preschool children insofar as it had significant effects on non-trained WM tasks within both the spatial and the verbal domains, as well as significant transfer effects on laboratory measures of attention....The finding of a significant effect of WM training on non-trained WM tasks within both the spatial and the verbal domains is in line with previous studies of WM training in school-aged children (Klingberg et al., 2002, 2005)."

Reference: Thorell, L.B., Lindqvist, S., Bergman Nutley, S., Bohlin, G. & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science*, 12(1), 106 -133. doi:10.1111/j.1467-7687.2008.00745

13. "Our results replicate previous findings that it is possible to train WM, and that it transfers to non-trained WM tests (Holmes et al., 2009; Klingberg et al., 2005, Klingberg et al., 2002; Thorell et al., 2009). The transfer to these non-trained tests show that the effect is not simply an improved strategy, but enhancement of underlying ability."

Reference: Bergman Nutley, S., Söderqvist, S., Bryde, S., Thorell, L.B., Humphreys, K., & Klingberg, T. (2011). Gains in fluid intelligence after training non-verbal reasoning in 4-year-old children: a controlled, randomized study. *Developmental Science*, 14(3), 591 -601. doi: 10.1111/j.1467-7687.2010.01022.x

14. "To examine whether training effects transferred to nontrained WM tasks, we analyzed the effect of the training on the WISC WMI. There were no significant differences between the 2 groups pre-intervention. As hypothesized, there was a significant interaction between group and time...this interaction was driven by a significant improvement on WM tests in the treatment group that was not present in the placebo group."

Reference: Green, C.T., Long, D.L., Green, D., Iosif, A., Dixon, F., Miller, M.R., Fassbender, C., & Schweitzer, J.B. (2012). Will working memory training generalize to improve off-task behavior in children with Attention-Deficit/Hyperactivity Disorder? *Neurotherapeutics*. Advance online publication. doi:10.1007/s13311-012-0124-y

15. "Although younger adults showed larger training gains than older adults during the first week, both age groups gained similarly after the second week. Both younger and older adults gained more in some criterion and non-trained WM tasks (Digit Span) in comparison to controls receiving low-level practice, although we observed larger gains and transfer effects for the young in other criterion and near-transfer tasks (Span Board)."

Reference: Brehmer, Y., Westerberg, H., & Bäckman, L. (2012). Working-memory training in younger and older adults: Training gains, transfer, and maintenance. *Frontiers in Human Neuroscience*, 6(63), 1-7. doi:10.3389/fnhum.2012.00063

IV. Training-related improvement can be shown on three levels of assessment: fMRI/PET, neuropsychological testing, and rating scales

16. "...a negative correlation dominated for all regions, with larger decreases in D1 BP being associated with larger improvements in WM. This is consistent with the finding that low doses of a D1 antagonist enhance the delay activity of prefrontal neurons during performance of WM tasks....the present results demonstrate a high level of plasticity of the neuronal system defined by cortical D1 receptors in human volunteers...The training induced changes emphasize the reciprocal interplay between behavior and the underlying brain biochemistry..."

Reference: McNab, F., Varrone, A., Farde, L., Jucaite, A., Bystritsky, P., Forsberg, H., & Klingberg, T. (2009). Changes in cortical dopamine D1 receptor binding associated with cognitive training. *Science*, 323, 800 - 802. doi:10.1126/science.1166102

17. "With regard to neural correlates of training-related WM gains, an important point concerns whether the intervention results in increases or decreases of brain activity. Whereas increases are thought to reflect individuals' latent potential by recruiting additional brain regions (i.e., additional cortical units or increasing the level of activity within a specific region), decreases in brain activity are often discussed in terms of processing being more efficient... In intervention research on higher-order cognitive functions such as WM, practice has been associated with both decreases...and increases... of brain activity...in task-relevant brain regions. The relation between these activation changes and performance is still an open issue."

Reference: Brehmer, Y., Rieckmann, A., Bellander, M., Westerberg, H., Fischer, H., & Bäckman, L. (2011). Neural correlates of training-related working-memory gains in old age. *NeuroImage*, 58(4),1110-1120.doi:10.1016/j.neuroimage.2011.06.079

18. "Brain activity was measured with functional magnetic resonance imaging (fMRI) before, during and after training. After training brain activity that was related to working memory increased in the middle frontal gyrus and superior and inferior parietal cortices. The changes in cortical activity could be evidence of training-induced plasticity in the neural systems that underlie working memory."

Reference: Olesen, P.J., Westerberg, H., & Klingberg, T. (2004). Increased prefrontal and parietal activity after training of working memory. *Nature Neuroscience*, 7(1), 75- 79. doi: 10.1038/nn1165.

19. "...brain activity was measured with functional magnetic resonance imaging (fMRI) during performance of a WM and a baseline task. Practice on the WM tasks gradually improved performance and this effect lasted several months. The effect of practice also generalized to improve performance on a non-trained WM task and a reasoning task. After training, WM-related brain activity was significantly increased in the middle and inferior frontal gyrus. The changes in activity were not due to activations of any additional area that was not activated before training. Instead, the changes could best be described by small increases in the extent of the area of activated cortex."

Reference: Westerberg, H., & Klingberg, T. (2007). Changes in cortical activity after training of working memory – a single-subject analysis. *Physiology and Behavior*, 92(1-2), 186 -192. doi: 10.1016/j.physbeh.2007.05.041

20. "...adaptive training led to selective BOLD decreases in frontal, temporal, and occipital regions (intervention specific effects) compared to low-level practice. Thus, in general, the imaging data paralleled the behavior data, indicating intervention related effects in both groups, although these effects were more pronounced among those receiving adaptive training. Note that greater activation decreases for the adaptive training group compared to the controls were only observed for the WM-high load condition, indicating the benefits of adaptive WM training unfold only under more challenging conditions. Note also that our finding that cognitive training is associated with reduced BOLD activity in neocortical areas is in line with several previous studies..."

Reference: Brehmer, Y., Rieckmann, A., Bellander, M., Westerberg, H., Fischer, H., & Bäckman, L. (2011). Neural correlates of training-related working-memory gains in old age. *NeuroImage*, *58*(4),1110-1120.doi:10.1016/j.neuroimage.2011.06.079

21. "The present study found that (compared with a non-intervention passive control group) young people with SEBD who completed WM training showed short-term positive change in WM, IQ, and behavioural inhibition, as well as teacher-report emotional symptoms, behavioural difficulties and attentional control, and self-report test anxiety. Group differences in WM were also evident three month following training. These findings indicate that the immediate impact of WM training goes beyond simply increasing WM capacity and suggests that it could have a positive impact on performance in school and behaviour more generally."

Reference: Roughan, L., & Hadwin, J.A. (2011). The impact of working memory training in young people with social, emotional and behavioral difficulties. *Learning and Individual Differences*, *21*, 759-764.doi:10.1016/j.lindif.2011.07.011

22. "The most robust finding in the current study was found when comparing the experimental group immediately following treatment to the waitlist control group who had not yet started training. The present study's moderate to strong effect sizes on parent ratings of ADHD symptoms ($d = 0.76$), inattention ($d = 0.79$), and reduction in attentive *DSM-IV-TR* symptoms ($d = 1.29$) are similar to the effect sizes in Klingberg et al. (2005), for parent-rated inattention ($d = 0.89$)... These results indicate that WM training had a beneficial effect of reducing parent-reported inattentive behaviors and ADHD symptoms post-treatment and at 4-month follow-up."

Reference: Beck, S.J., Hanson, C.A., Puffenberger, S.S., Benninger, K.L., & Benninger, W.B. (2010).A controlled trial of working memory training for children

and adolescents with ADHD. *Journal of Clinical Child and Adolescent Psychology*, 39(6), 825 -836. doi: 10.1080/15374416.2010.517162.

23. "Our primary outcome, teacher ratings of total ADHD symptoms, improved on average by 26%...Supporting this result were comparable improvements in the WISC Digit Span Backward of 36%...and WRAML Finger-Windows of 33%...which are the scores for verbal and visuo-spatial working memory, respectively."

Reference: Mezzacappa, E. & Buckner, J.C. (2010). Working memory training for children with attention problems or hyperactivity: A school-based pilot study. *School Mental Health*, 2(4), 202- 208. doi: 10.1007/s12310-010-9030-9

V. Improved WM generalizes to improvements in daily functioning

24. "This pilot study evaluated the effect of intense, adaptive WM training in various visuo-spatial and auditory modalities for a group of patients with stroke. The treatment group improved significantly more than the passive control group on the non-trained tests that measured WM and attention. Furthermore, there was a significant treatment effect, as indicated by the self-rating on symptoms of cognitive failures (as measured by the CFQ). The results suggest that the method for WM training used here (i) improved cognitive functioning as measured by neuropsychological tests and (ii) affected the subjective experience of cognitive functioning in daily living."

Reference: Westerberg, H., Jacobaeus, H., Hirvikoski, T., Clevberger, P., Östensson, M.L., Bartfai, A., & Klingberg, T. (2007). Computerized working memory training after stroke – a pilot study. *Brain Injury*, 21(1), 21-29. doi: 10.1080/02699050601148726

25. "...both younger and older adults receiving adaptive training showed larger performance gains in a test measuring sustained attention (PASAT) and reported less memory complaints (CFQ) after the 5 weeks of intervention than the controls. Further, the observed training gains and transfer effects were maintained across a 3-month time interval."

Reference: Brehmer, Y., Westerberg, H., & Bäckman, L. (2012). Working-memory training in younger and older adults: Training gains, transfer, and maintenance. *Frontiers in Human Neuroscience*, 6(63), 1-7. doi:10.3389/fnhum.2012.00063

26. "Structured and intense computerized WM training improves subjects' cognitive functioning as measured by neuropsychological WM-demanding tests, rated occupational performance, satisfaction with performance and rated overall health. The training probably has an impact on the rehabilitation outcome, returning to work, as well as on daily activities for individuals with verified WM impairments."

Reference: Lundqvist, A., Gundström, K., & Rönnerberg, J.(2010). Computerized working memory training in a group of patients suffering from acquired brain injury. *Brain Injury*, 24(10), 1173- 1183.

27. "Cognitive problems decreased significantly post-intervention, as measured by CFQ and COPM. The perceived reduction in cognitive failures in daily life, as rated on CFQ, remained at the six-month follow-up. The ratings on COPM post-training indicated that participants felt that they performed better and were more satisfied on issues they had chosen and perceived as important. Data from CFQ and COPM were also supported by the qualitative data...This might indicate that it was possible for participants to benefit from increased working memory capacity in daily life activities."

Reference: Johansson, B., & Tornmalm, M. (2012). Working memory training for patients with acquired brain injury: Effects in daily life. *Scandinavian Journal of Occupational Therapy*, 19(2), 176-183. doi:10.3109/11038128.2011.603352

VI. Improvements in WM and behavioral outcomes are sustained at 6 months post training

28. "The majority of children who completed the adaptive program, which involved intensive training of 35 minutes a day in school for at least 20 days, improved their WM scores substantially over this period and for a further 6 months after training had been completed. The gains generalized to independent and validated WM assessments that were not trained..."

Reference: Holmes, J., Gathercole, S.E., & Dunning, D.L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, 12(4), F9 -F15. doi: 10.1111/j.1467-7687.2009.00848x

29. Gains in measures of verbal and visuo-spatial WM associated with the central executive component of WM (Alloway et al., 2006) and in visuo-spatial STM were maintained 6 months after training."

Reference: Holmes, J., Gathercole, S.E., Place, M., Dunning, D.L., Hilton, K.A., & Elliot, J.G. (2010). Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD. *Applied Cognitive Psychology, 24*(6), 827-836. doi: 10.1002/acp.1589

30. "Improvements in the sample mean Sentence Repetition score at Posttraining and 6-Month Follow-Up were highly significant and nearly universal in all children studied in the sample...These findings suggest that the improvement found in Sentence Repetition (reflecting core underlying skills of language/sentence perception, memory, and speech production) was clinically meaningful...and may be more durable, lasting a longer period of time than improvement in working memory as measured by conventional span measures."

Reference: Kronenberger, W.G., Pisoni, D.B., & Henning, S.C., & Colson, B.G., & Hazzard, L.M. (2011). Working memory training for children with cochlear implants: A pilot study. *Journal of Speech, Language, and Hearing Research, 54*(4), 1182 -1196.

31. "Self-rating on the Cognitive Failures Questionnaire (CFQ) indicated a reduction of cognitive problems experienced by the participants...At the six month follow-up the result was stable..."

Reference: Johansson, B., & Tornmalm, M. (2012). Working memory training for patients with acquired brain injury: Effects in daily life. *Scandinavian Journal of Occupational Therapy, 19*(2), 176-183. doi:10.3109/11038128.2011.603352

VII. Effects of WM training are specific: WM and its derived functions are improved, but not across-the-board-improvement

32. "There was no significant treatment effect, nor any trend for an improvement ($ES = 0.05$) for the declarative memory task. The lack of improvement in the declarative memory task suggests that the training specifically targets WM, not memory in general."

Reference: Westerberg, H., Jacobaeus, H., Hirvikoski, T., Clevberger, P., Östensson, M.L., Bartfai, A., & Klingberg, T. (2007). Computerized working memory training after stroke – a pilot study. *Brain Injury, 21*(1), 21-29. doi: 10.1080/02699050601148726

33. "It should also be noted that the training gains observed in the present study did not extend to all cognitive assessments: IQ, which included individual tests of fluid cognitive ability such as block design, was unaffected by training. Unless the WM assessments were differentially sensitive to the non-specific benefits of the program, these findings favour a direct impact of training on WM."

Reference: Holmes, J., Gathercole, S.E., Place, M., Dunning, D.L., Hilton, K.A., & Elliot, J.G. (2010). Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD. *Applied Cognitive Psychology, 24*(6), 827-836. doi: 10.1002/acp.1589

34. "It may be argued that the improvements in reading comprehension were due to this increased reinforcement from teachers, parents, and the research team. But if so, then significant improvements should have been noted in all the measures used. This was not the case: for the reading tasks, only the most working memory-related reading comprehension task improved, while other tests such as orthographic reading did not. This mitigates against a general, non-working memory-related explanation of the training effect."

Reference: Dahlin, K. (2011). Effects of working memory training on reading in children with special needs. *Reading and Writing, 24*, 479-491. doi: 10.1007/s11145-010-9238-y

VIII. Training effects have substantial real world impact on individuals impaired by their WM capacity

35. "This adaptive WM training program meets the criteria we set in advance of the study for educational significance: its benefits extend to the many children who low WM abilities are accompanied by poor academic learning but who often fall below the radar of recognition for special needs, the gains generalize to a wide range of non-trained WM assessments, including a classroom analogue test of WM, and the training leads to detectable gains in academic skills."

Reference: Holmes, J., Gathercole, S.E., & Dunning, D.L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science, 12*(4), F9 -F15. doi: 10.1111/j.1467-7687.2009.00848x

36. "The present study indicates that training of working memory may be useful for children with reading comprehension problems, special-educational needs, and attention problems...working memory capacity may be valuable identifying children at risk poor scholastic progress...screening may be an alternative to clinical diagnosis for identifying those children who might benefit from working memory training."

Reference: Dahlin, K. (2011). Effects of working memory training on reading in children with special needs. *Reading and Writing, 24*, 479-491. doi: 10.1007/s11145-010-9238-y

COGMED PUBLISHED ARTICLE REFERENCES

- Beck, S.J., Hanson, C.A., Puffenberger, S.S., Benninger, K.L., & Benninger, W.B. (2010). A controlled trial of working memory training for children and adolescents with ADHD. *Journal of Clinical Child and Adolescent Psychology, 39*(6), 825 -836. Doi: 10.1080/15374416.2010.517162
- Bellander, M., Brehmer, Y., Westerberg, H., Karlsson, S., Fürth, D., Bergman, O., Eriksson, E., & Bäckman, L. (2011). Preliminary evidence that allelic variation in the LMX1A gene influences training-related working memory improvement. *Neuropsychologia, 49*, 1938 -1942. doi:10.1016/j.neuropsychologia.2011.03.021
- Brehmer, Y., Rieckmann, A., Bellander, M., Westerberg, H., Fischer, H., & Bäckman, L. (2011). Neural correlates of training-related working-memory gains in old age. *Neuroimage, 58*(4), 1110-1120. doi:10.1016/j.neuroimage.2011.06.079
- Brehmer, Y., Westerberg, H., & Bäckman, L. (2012). Working-memory training in younger and older adults: Training gains, transfer, and maintenance. *Frontiers in Human Neuroscience, 6*(63), 1-7. doi:10.3389/fnhum.2012.00063
- Brehmer, Y., Westerberg, H., Bellander, M., Fürth, D., Karlsson, S., & Bäckman, L. (2009). Working memory plasticity modulated by dopamine transporter genotype. *Neuroscience Letters, 467*, 117 -120. doi:10.1016/j.neulet.2009.10.018
- Bergman-Nutley, S., Söderqvist, S., Bryde, S., Thorell, L.B., Humphreys, K., & Klingberg, T. (2011). Gains in fluid intelligence after training non-verbal reasoning in 4-year-old children: A controlled, randomized study. *Developmental Science, 14*(3), 591 - 601. Doi:10.1111/j.1467-7687.2010.01022.x
- Dahlin, K. (2011). Effects of working memory training on reading in children with special needs. *Reading and Writing, 24*, 479-491. doi:10.1007/s11145-010-9238-y
- Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old [Special section]. *Science, 333*, 959-963. Doi: 10.1126/science.1204529
- Gibson, B.S., Gondoli, D.M., Johnson, A.C., Steeger, C.M., Dobrzanski, B.A., & Morrissey, R.A. (2011). Component analysis of verbal versus spatial working memory training in adolescents with ADHD: A randomized, controlled trial. *Child Neuropsychology, 17*(6), 546-563. doi:10.1080/09297049.2010.551186

- Gibson, B.S., Kronenberger, W.G., Gondoli, D.M., Johnson, A.C., Morrissey, R.A., & Steeger, C.M. (2012). Component analysis of simple span vs. Complex span adaptive working memory exercises: A randomized, controlled trial. *Journal of Applied Research in Memory and Cognition*. In Press.
- Green, C.T., Long, D.L., Green, D., Iosif, A., Dixon, F., Miller, M.R., Fassbender, C., & Schweitzer, J.B. (2012). Will working memory training generalize to improve off-task behavior in children with Attention-Deficit/Hyperactivity Disorder? *Neurotherapeutics*. Advance online publication. Doi:10.1007/s13311-012-0124-y
- Holmes, J., Gathercole, S.E., & Dunning, D.L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, 12(4), F9 - F15. Doi: 10.1111/j.1467-7687.2009.00848x
- Holmes, J., Gathercole, S.E., & Dunning, D.L. (2010). Poor working memory: Impact and interventions. In J. Holmes (Ed.), *Advances in Child Development and Behavior: Developmental Disorders and Interventions, Volume 39* (pp. 1- 43). Burlington: Academic Press.
- Holmes, J., Gathercole, S.E., Place, M., Dunning, D.L., Hilton, K.A., & Elliot, J.G. (2010). Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD. *Applied Cognitive Psychology*, 24(6), 827-836. Doi: 10.1002/acp.1589
- Johansson, B., & Tornmalm, M. (2012). Working memory training for patients with acquired Brain injury: Effects in daily life. *Scandinavian Journal of Occupational Therapy*, 19(2), 176-183. Doi:10.3109/11038128.2011.603352
- Klingberg, T. (2010). Training and plasticity of working memory. *Trends in Cognitive Sciences*, 14(7), 317 -324. Doi: 10.1016/j.tics.2010.05.002
- Klingberg, T., Fernell, E., Olesen, P.J., Johnson, M., Gustafsson, P., Dahlström, K., Gillberg, C.G., Forssberg, H., & Westerberg, H. (2005). Computerized training of working memory in children with ADHD – a randomized, controlled trial. *Journal of the American Academy of Child & Adolescent Psychiatry*, 44(2), 177-186.
- Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical and Experimental Neuropsychology*, 24(6), 781 -791.
- Kronenberger, W.G., Pisoni, D.B., & Henning, S.C., & Colson, B.G., & Hazzard, L.M. (2011). Working memory training for children with cochlear implants: A pilot study. *Journal of Speech, Language, and Hearing Research*, 54(4), 1182 -1196.

- Løhaugen, G.C.C., Antonsen, I., Håberg, A., Gramstad, A., Vik, T., Brubakk, A.M., & Skranes, J. (2011). Computerized working memory training improves function in adolescents born at extremely low birth weight. *Journal of Pediatrics, 158*(4), 555- 561.
- Lundqvist, A., Gundström, K., & Rönnerberg, J.(2010). Computerized working memory training in a group of patients suffering from acquired brain injury. *Brain Injury, 24*(10), 1173-1183.
- McNab, F., Varrone, A., Farde, L., Jucaite, A., Bystritsky, P., Forssberg, H., & Klingberg, T. (2009). Changes in cortical dopamine D1 receptor binding associated with cognitive training. *Science, 323*, 800 - 802.doi:10.1126/science.1166102
- Mezzacappa, E. & Buckner, J.C. (2010). Working memory training for children with attention problems or hyperactivity: A school-based pilot study. *School Mental Health, 2*(4), 202- 208.doi: 10.1007/s12310-010-9030-9.
- Olesen, P.J., Westerberg, H., & Klingberg, T. (2004). Increased prefrontal and parietal activity after training of working memory. *Nature Neuroscience, 7*(1), 75- 79.
Doi:10.1038/nn1165
- Roughan, L., & Hadwin, J.A. (2011). The impact of working memory training in young people with social, emotional and behavioral difficulties. *Learning and Individual Differences, 21*, 759-764.doi:10.1016/j.lindif.2011.07.011
- Söderqvist, S., Bergman Nutley, S., Peyrard-Janvid, M., Matsoon, H., Humphreys, K., Kere, J., Klingberg, T. (2012). Dopamine, working memory, and training induced plasticity: Implications for developmental research. *Developmental Psychology, 48*(3), 836-843.
Doi:10.1037/a0026179
- Thorell, L.B., Lindqvist, S., Bergman Nutley, S., Bohlin, G. & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 12*(1), 106 -133.doi:10.1111/j.1467-7687.2008.00745
- Westerberg, H., & Klingberg, T. (2007). Changes in cortical activity after training of working memory – a single-subject analysis. *Physiology and Behavior, 92*(1-2), 186 -192.
Doi:10.1016/j.physbeh.2007.05.041
- Westerberg, H., Jacobaeus, H., Hirvikoski, T., Clevberger, P., Östensson, M.L., Bartfai, A., & Klingberg, T. (2007). Computerized working memory training after stroke – a pilot study. *Brain Injury, 21*(1), 21-29.doi:10.1080/02699050601148726

Appendix A

COGMED PUBLISHED RESEARCH META-ANALYSIS V1.3

COGMED CLAIMS AND STATISTICAL SUPPORT

Cogmed Working Memory Training is an evidence based intervention for improving working memory (WM). Mounting research and clinical data supports the use of Cogmed in various clinical groups struggling with WM deficits. One key stance taken by Cogmed is that our claims be derived from the findings of research projects that have used Cogmed Working Memory Training and that have been reported in peer-reviewed, published articles.

Below is a list of the claims that Cogmed makes based on the research findings to date. To access detailed explanations of the evidence supporting each claim please see the full Cogmed Research Claims and Evidence document. Importantly, one can find support for some of these claims by examining the statistical information reported in the published articles.

This document thus provides a statistical analysis of the short and long term improvements in visuo-spatial WM, verbal WM, as well as behavioral rating scales that have been provided in the peer-reviewed published Cogmed studies. It is vital to note when reviewing this analysis, that various clinical populations and age groups have been merged. However, the nature of the training protocol, assessments, and control groups used are comparable across studies.

- WM is key to attention and learning
- WM can be improved by training, using right tool and protocol: Cogmed
- WM can be improved by training in all age ranges
- Training-related improvement can be shown on three levels of assessment: fMRI/PET, neuropsychological testing and rating scales
- Improved WM generalizes to improvements in daily functioning
- Improvements in WM and behavioral outcomes are sustained at 6 months post training
- Effects of WM training are specific: WM and its derived functions are improved, but there is no across-the-board-improvement
- Training effects have substantial real world impact on individuals impaired by their WM capacity

UNDERSTANDING THE STATISTICS FROM COGMED RESEARCH

Different kinds of statistics can be used in communicating about the results from Cogmed Working Memory Training studies. The improvements seen after training can be described in terms of percent (%) increases/decreases or effect sizes (Cohen's d ; Cohen, 1988).

The improvements reported in % are based on the average change in the adaptive training group on the outcome measure between baseline and post-test. The average % *improvement* that is seen on a group level is based on all published studies that present raw data regardless of whether or not a non-adaptive group was included.

The *effect size* (d) is the amount by which a given experimental manipulation (adaptive vs. non adaptive training) changes the value of the outcome measure, expressed in standard deviations. These statistics are thus based on studies including non-adaptive control groups. The effect size is a gauge of "net effect" of the intervention, obtained by subtracting the standardized change for the control group (non-adaptive Cogmed) from that of the experimental group (adaptive Cogmed).

- If $d \leq 0.2$, then the effect of adaptive training is small.
- If $0.2 < d < 0.8$, then the effect of adaptive training is moderate.
- If $d \geq 0.8$, then the effect of adaptive training is large.

Consider one group of participants that trained with adaptive Cogmed and one that trained with non-adaptive Cogmed (control group). The outcome measure is improvement on the Corsi Block test, a non-trained visuo-spatial WM task. If the type of training (adaptive vs. non-adaptive) had little impact on the participants' Corsi Block test scores and the distribution of scores for each group were very similar, then the distance between the distribution of scores for each group would be very small ($d \leq 0.2$).

However, if the adaptive group had greater improvements on the Corsi Block test than the non-adaptive group, then the type of intervention did impact performance on the non-trained visuo-spatial WM task. The difference (or distance) between each group's distribution of improvement scores, called the effect size, can be considered a gauge of how effective the adaptive training was for improving Corsi Block test performance and if $d \geq 0.8$, then the effect was large.

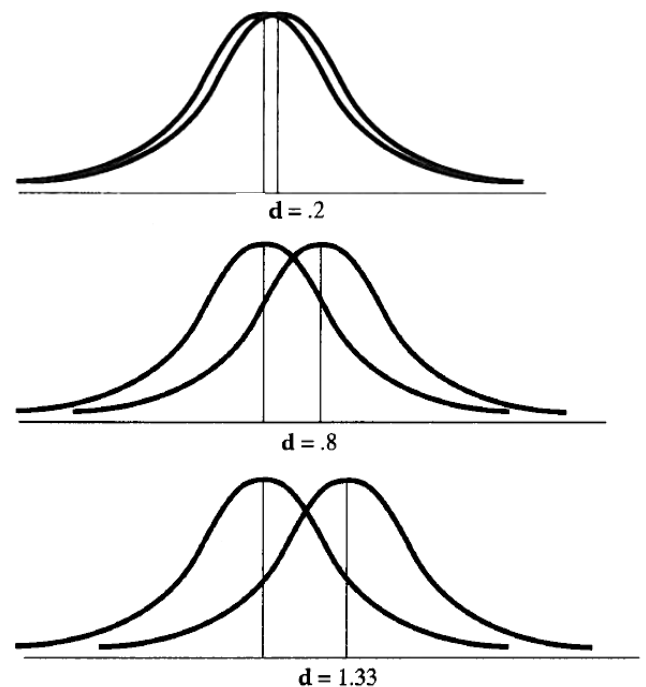


Figure 1. Overlap of group improvement on the Corsi Block test at post-intervention as a function of effect size

COGMED RESEARCH: TRAINING STATISTICS

Below is a summary of statistics based on a meta-analysis of data from published Cogmed studies available through July 2012. Included are statistics for improvements after training in visuo-spatial WM (see Table 1), verbal WM (see Table 2), and behavioral rating scales. Comments on academic and changes in everyday life are also provided. *Please note that this document will continue to change as more analysis is performed and new research data added.*

I. Visuo-spatial WM (baseline to post-test)

There is an average 26% improvement in visuo-spatial WM from baseline to post-test in the adaptive training group, based on analysis of 352 individuals in 16 studies (19 samples).

- For studies including children (< age 18), there is a 28% average improvement in visuo-spatial WM.
- For studies including adults (> age 18), there is a 21% average improvement in visuo-spatial WM.

Data from 375 Swedish children revealed that visuo-spatial WM capacity increased at about 7% per year (see Figure 2). Thus, the average improvement in visuo-spatial WM seen after training (26%) is equivalent to 3 to 4 years of typical development in children between the ages of 7 and 16 years.

The average effect size for the adaptive training group on visuo-spatial WM from baseline to post-test is 0.98. This statistic is based on analysis of 249 individuals in adaptive training and 204 in non-adaptive training from 11 studies (13 group comparisons).

II. Retention of improvements in visuo-spatial WM (3 to 6 month follow-up)

Based on 235 individuals in the adaptive training group from the 9 studies (11 samples) that included a follow up testing session:

- The average increase in visuo-spatial WM is 23% from baseline to post-test and 22% from baseline to follow-up. This corresponds to 94% retention of the effects up to 6 months after training.

In parsing out only placebo controlled studies with long term follow-up between 3 and 6 months, statistics obtained are based on 3 studies (4 group comparisons) with a total of 116 individuals in the adaptive training group and 94 individuals in the non-adaptive training group:

- The average effect size for adaptive training on visuo-spatial WM from baseline to post-test is 1.14 and from baseline to follow-up (between 3 and 6 months) is 1.12. This corresponds to 98% retention of the effects up to 6 months after training.

Figure 2. Visuo-spatial WM development in 375 children

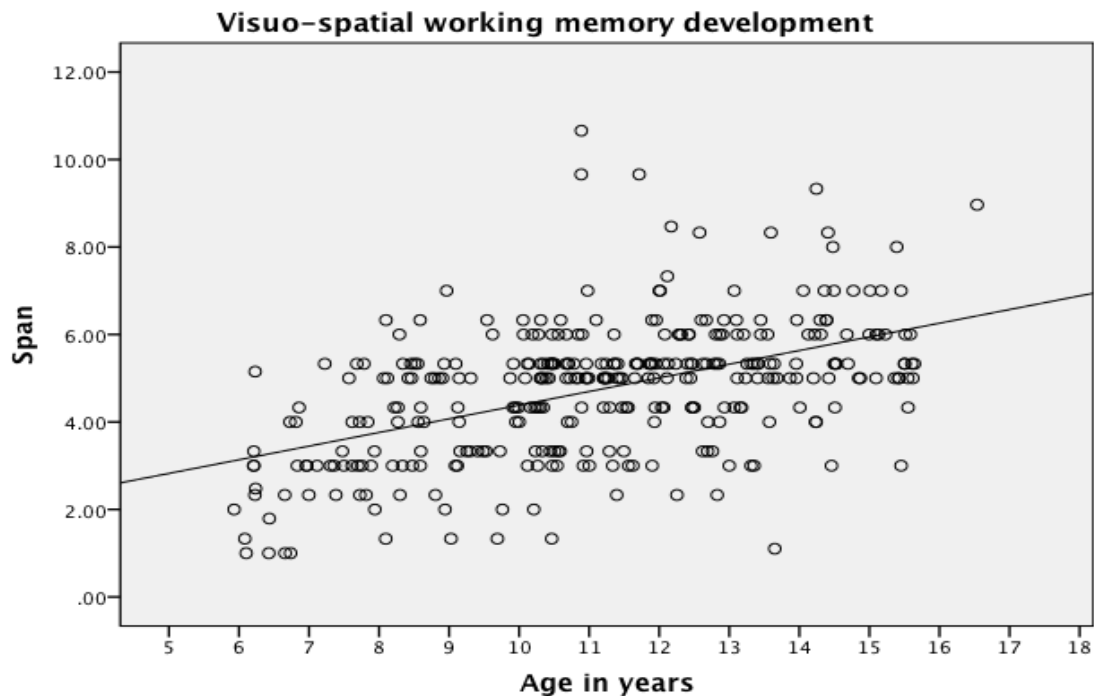


Figure 1 illustrates performance on a visuo-spatial working memory task for a typically developing sample of Swedish children with data collected by Cogmed Systems during the fall of 2011, n=375 (Females: n=196, Males: n=179).

III. Verbal WM (baseline to post-test)

There is an average 23% improvement in verbal WM from baseline to post-test in the adaptive training group, based on analysis of 354 individuals in 15 studies (18 samples).

- For studies including children (< age 18), there is a 19% average improvement in verbal WM.
- For studies including adults (> age 18), there is a 31% average improvement in verbal WM.

The average effect size for the adaptive training group on verbal WM from baseline to post-test is 0.77. This statistic is based on analysis of 264 individuals in adaptive training and 210 in non-adaptive training from 10 studies (12 group comparisons).

IV. Retention of improvements in verbal WM (3 to 6 month follow-up)

Based on 232 individuals from the 8 studies (10 samples) that included a follow up testing session:

- The average increase in verbal WM is 19% from baseline to post-test and 14% from baseline to follow-up. This corresponds to 75% retention of the effects up to 6 months after training.

In parsing out only placebo controlled studies with long term follow-up between 3 and 6 months, statistics obtained are based on 3 studies (4 group comparisons) with a total of 120

individuals in the adaptive training group and 90 individuals in the non-adaptive training group:

- The average effect size for adaptive training on verbal WM from baseline to post-test is 0.71 and from baseline to follow-up (between 3 and 6 months) is .52. This corresponds to 73% retention of the effects up to 6 months after training.

V. Behavioral rating scales

The average improvement after adaptive training on parent-rated symptoms of attention (DSM-IV) in the adaptive group is 31%, based on data from 103 children in 4 studies. The average effect size for the adaptive training group on parent-rated symptoms of attention (DSM-IV) from baseline to post-test is 0.96. This statistic is based on analysis of 47 individuals in the adaptive training groups and 48 individuals in the non-adaptive training group from 3 studies.

In 3 studies with a total of 82 adults, data reveals that the average improvement seen after training on self-reported cognitive failures (CFQ) in the adaptive group is 18%. The average effect size for adaptive training on self-reported cognitive failures (CFQ) from baseline to post-test is 0.60, based on 64 individuals in adaptive training group and 54 in a non-adaptive training group reported in 2 studies.

VI. Academic and benefits in daily life

In reviewing the published Cogmed research, one finds that there have been few studies to utilize academic outcome measures. As the current meta-analysis is based solely on data that can be found in the published texts, it is imperative that more data on reading and math outcomes be published before they are included in this analysis. However, it is important to recognize that Holmes et al. (2009) found improved mathematical reasoning at 6 months post-Cogmed in a group of low WM children and that Dahlin (2011) found improved reading comprehension in a group of special needs children. These results, the strong body of literature supporting the connection between WM capacity and learning, as well as many clinical observations, support the notion that improvements in WM after Cogmed can lead to transfer to academic outcomes.

The transfer of training to improvements in daily life including, behavior, occupational satisfaction, and quality of life, are all areas that are in need of greater research. The existing literature suggests that Cogmed impacts the lives of participants by improving subjective experience of daily living and occupational performance (Johansson & Tornmalm, 2012) as well as, self report of cognitive failures (Westerberg et al., 2007). Importantly, Green et al. (2012) demonstrated significantly decreased off-task behavior, which is related to inattention, in a sample of children with ADHD. This was found in a randomized, placebo controlled study where researchers blinded to the condition of the child objectively rated the adaptive group trainees as demonstrating less off-task behavior.

In addition, over 10,000 End-Users and coached by hundreds of clinicians have demonstrated that Cogmed is an effective intervention that leads to real world benefits. Evidence for improved day-to-day functioning after Cogmed Working Memory Training is typically reported by someone present in the End-User's daily life like a parent or spouse. Thus, the true benefits of Cogmed in regards to everyday functioning are best observed over time, within the End-User's typical environment, and with consideration of their baseline deficits. More independent academic research is expected to be published with data of this nature.

Table 1. Short and long term improvements on visuo-spatial WM from published research studies using Cogmed Working Memory Training.

Study (Year)	Sample (Years Old (YO))	Test	Treatment (n)	Control (n)	Treatment improvement (%)	Treatment improvement follow-up (%)	ES post-test (d)	ES follow-up (d)
Bergman Nutley et al. 2011	Typical 4 YO	Odd One Out (AWMA)	24	25	41		0.90	
	Typical 4 YO, half dose	Odd One Out (AWMA)	27		27		0.79	
Thorell et al. 2009	Typical 4-5 YO	Span board (back+front)	17	14	40		0.61	
	Typical 4-5 YO	Span board (back+front)		16				
Klingberg et al. 2005	ADHD 7-12 YO	Span board (back+front)	20	24	19	21	0.79	0.81
Klingberg et al. 2002	ADHD 7-15 YO	Span board (back+front)	7	7	45		0.13	
Kronenberger et al. 2011	Deaf (w/ CI) 7-15 YO	Span board (back)	9		25	11		
Holmes et al. 2010	ADHD 8-11 YO	Mr. X (AWMA)	25		13	10		
Mezzacappa et al. 2010	ADHD 8-10.5 YO	Finger Windows (WRAML)	8		33		0.73	
Dahlin 2011	Special Ed needs 9-12 YO	Span board (back)	41	25	30	26	0.74	0.65
Holmes et al. 2009	Poor WM 10 YO	Composite score (AWMA)	22	20	17	15	0.89	
Roughan & Hadwin 2011	SEBD ≈13 YO	Composite score (Span board & Digit Span)	7	8	24	29	2.29	
Løhaugen et al. 2010	Preterm (ELBW) 14-15 YO	Span board (back)	16	11	37	26		
	Typical 14-15 YO	Span board (back)	19		20	16		
Summary Child			242	150	28	19	0.87	0.73
Brehmer et al. 2012	Typical 20-30 YO	Span board (back)	29	26	27	28	1.72	1.36
	Typical (aging) 60-70 YO	Span board (back)	26	19	24	29	1.32	1.65
McNab et al. 2009	Typical 20-28 YO	Span board (back)	13		22			
Lundqvist et al. 2010	ABI 20-65 YO	Span board (back)	21		21	29		
Westerberg et al. 2007	Stoke 34 -65 YO	Span board (back+front)	9	9	19		0.83	
Brehmer et al. 2011	Typical (aging) 60-70 YO	Span board (back)	12	11	16		1.03	
Summary Adult			110	65	21	28	1.23	1.51
Summary Total			352	215	26	22	0.98	1.12

*Summarized effect sizes reported in this document have not been calculated to adjust for differences between sample sizes in the different studies. See the formula used to calculate the statistics below. Key to symbols: **d** = Cohen's d effect size, \bar{x} = mean (average of treatment and comparison condition), **s** = standard deviation, subscripts: **t** refers to the treatment condition and **c** refers to the comparison condition (or control condition).

$$d = \frac{\bar{x}_t - \bar{x}_c}{s_{\text{pooled (pre)}}$$

Table 2. Short and long term improvements on verbal WM from published research studies using Cogmed Working Memory Training.

Study (Year)	Sample (Years Old (YO))	Test	Treatment (n)	Control (n)	Treatment improvement (%)	Treatment improvement follow-up (%)	ES post-test (d)	ES follow-up (d)
Bergman Nutley et al. 2011	Typical 4 YO	Word span (back+front)	24	25	20		0.23	
	Typical 4 YO, half dose	Word span (back+front)	27		11		-0.02	
Thorell et al. 2009	Typical 4-5 YO	Word span (back+front)	17	14	31		1.07	
	Typical 4-5 YO	Word span (back+front)		16				
Klingberg et al. 2005	ADHD 7-12 YO	Digit span (back+front)	24	20	13	11	0.59	0.62
Kronenberger et al. 2011	Deaf (w/ CI) 7-15 YO	Digit span (back)	9		12	0		
Holmes et al. 2010	ADHD 8-11 YO	Digit span (back)	25		8	7		
Mezzacappa et al. 2010	ADHD 8-10.5 YO	Digit span (back)	8		37			
Dahlin 2011	Special Ed needs 9-12 YO	Digit span (back)	41	25	23	11	0.71	0.50
Holmes et al. 2009	Poor WM 10 YO	Composite score (AWMA)	22	20	23	20	1.46	
Green et al. 2012	ADHD 7 -14 YO	Composite score (WISC WMI)	12	14	7		0.81	
Løhaugen et al. 2010	Preterm (ELBW) 14-15 YO	Digit span (back)	16		27	19		
	Typical, 14-15 YO	Digit span (back)	19		24	14		
Summary Child			244	134	19	12	0.69	0.56
Brehmer et al. 2012	Typical 20-30 YO	Digit span (back)	29	26	33	35	1.17	1.04
	Typical (aging) 60-70 YO	Digit span (back)	26	19	14	9	0.35	-0.08
McNab et al. 2009	Typical 20-28 YO	Digit span (back)	13		66			
Lundqvist et al. 2010	ABI 20-65 YO	Listening span	21	11	15	19	0.33	
Westerberg et al. 2007	Stroke 34 -65 YO	Digit span (back+front)	9	9	40		2.21	
Brehmer et al. 2011	Typical (aging) 60-70 YO	Digit span (back)	12	11	16		0.34	
Summary Adult			110	76	31	21	0.88	0.48
Summary Total			354	210	23	14	0.77	0.52

**Four of the 14 studies reported digit span forward and backward as a composite measure for verbal WM.

Appendix B

COGMED CLINICAL EVALUATION SERIES: PART I

INTRODUCTION

Cogmed Working Memory Training is implemented and supported by a network of practitioners worldwide. Beyond the confines of the research lab, where Cogmed has its foundations, Cogmed Coaches bring working memory training into the real world, as they focus on the challenges faced by the individual. In the United States alone, over 300 coaches have backed more than 10,000 End-Users as they have embarked on their training experience. Globally, practitioners in 30 countries have contributed to the growth of Cogmed, now the leader in evidence-based cognitive training.

As a supplement to the Cogmed Claims and Evidence document, the Clinical Evaluation Series is intended to add a new level of support for the efficacy of Cogmed Working Memory Training. This document, Clinical Evaluation Series Part I, presents a summary of the de-identified clinical findings collected by Cogmed Coaches in three practices, one in each Singapore, the Netherlands, and Canada. In particular, this text focuses on parent ratings of inattentive symptoms in children and self report of inattention, ADHD symptoms, and cognitive failures in adults. Interestingly, the results from each of the practices are quite consistent: 80% of adults and children that train with Cogmed experience improvement at post-test and there is a 30% improvement in inattentive symptoms.

UNDERSTANDING THE STATISTICS FROM COGMED

In communicating about the results from Cogmed Clinical Evaluations, the improvements seen after training can be described in terms of the entire group of Cogmed End-Users, regardless if they improved or did not improve after training, or in terms of just those participants who improved after training. Percent (%) improvements are based on the change in the group of Cogmed End-Users on the outcome measure between baseline and post-test. This document reports:

- ✓ The percent of the total sample that improved (ie., experienced gains) after training.
- ✓ The percent improvement in symptoms for only the group that experienced gains after training.
- ✓ The percent improvement in symptoms for total sample.

CLINICAL EVALUATION

CHILDREN

Clinical data from 769 children collected at three distinct practices in Singapore, the Netherlands, and Canada revealed that on average, Cogmed users improved their inattentive symptoms, as rated on the DSM-IV Parent Rating Scale, by 30% from baseline to post-test. On average, 82% of the children experienced gains and when parsed out from the total sample, this group improved their inattentive symptoms on average by 36% from baseline to post-test. See Figure 3 for the data.

Singapore

- 78% of the 222 children who completed Cogmed improved on ratings inattentive symptoms.
- Children who improved after Cogmed showed a 38% reduction in inattentive symptoms.
- Considering the total sample of 222 children, the average improvement in inattentive symptoms was 31%.

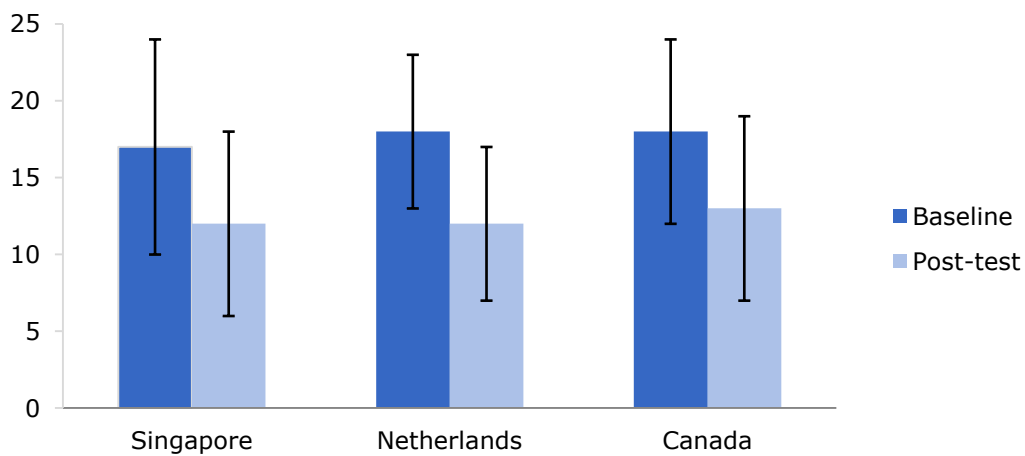
Netherlands

- 88% of the 500 children who completed Cogmed improved on ratings inattentive symptoms.
- Children who improved after Cogmed showed a 38% reduction in inattentive symptoms.
- Considering the total sample of 500 children, the average improvement in inattentive symptoms was 33%.

Canada

- 79% of the 47 children who completed Cogmed improved on ratings inattentive symptoms.
- Children who improved after Cogmed showed a 32% reduction in inattentive symptoms.
- Considering the total sample of 47 children, the average improvement in inattentive symptoms was 26%.

Figure 1. Mean baseline and post-test inattention scores for children from three Cogmed practices on DSM-IV Parent Rating Scale.



CLINICAL EVALUATION

ADULTS

Clinical data from 120 adults collected at two distinct practices in Singapore and the Netherlands revealed that on average, Cogmed users improved their inattentive symptoms, as reported on the DSM-IV Adult Rating Scale, by 28% from baseline to post-test. On average, 80% of the adults from Singapore and the Netherlands experienced gains and when parsed out from the total sample population, this group improved their inattentive symptoms on average by 36% from baseline to post-test. See Figure 3 for the data.

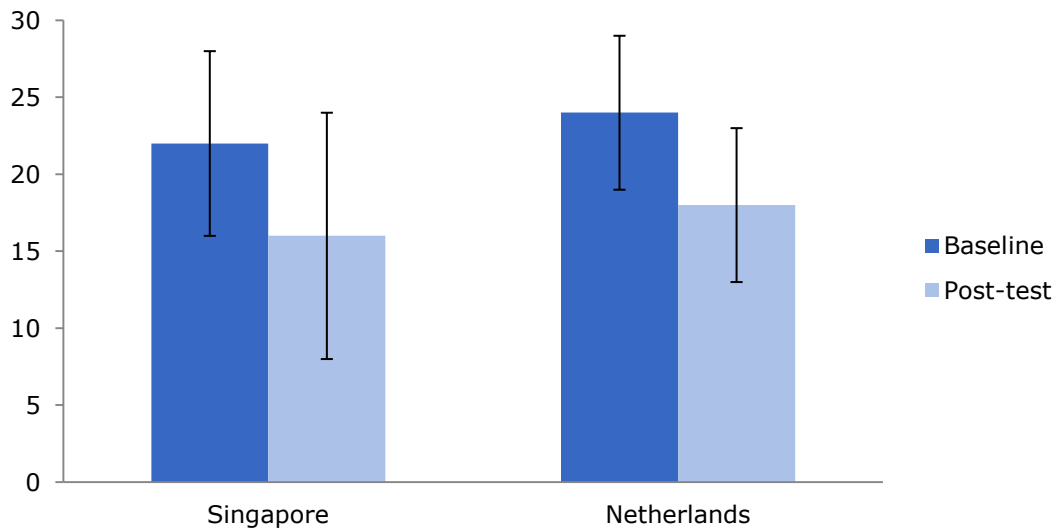
Singapore

- For the 8 adults who completed Cogmed, 75% improved on a measure of inattentive symptoms.
- Adults who improved after Cogmed showed a 42% decrease in inattentive symptoms
- Considering the total sample of 8 adults, the decrease in inattentive symptoms was 30%.

Netherlands

- For the 112 adults who completed Cogmed, 86% improved on a measure of inattentive symptoms.
- Adults who improved after Cogmed showed a 29% decrease in inattentive symptoms.
- Considering the total sample of 112 adults, the decrease in inattentive symptoms was 25%.

Figure 2. Mean baseline and post-test inattention scores for adults from three Cogmed practices on DSM-IV Self Rating Scale.



Canada

It should be noted that the clinical data from Canada includes a combined inattention and hyperactivity rating for ADHD and should thus be considered separately from measures solely of inattention. Self-report of cognitive failures in daily life were also collected by the Canadian practice using the Cognitive Failures Questionnaire (CFQ). Below, find a summary of the statistics. For data, see Figure 3.

ADHD

- 83% of adults improved on a measure of combined inattentive and hyperactive symptoms.
- Adults who improved after Cogmed showed a 25% decrease in combined inattentive and hyperactive symptoms.
- Considering the total sample of adults (N = 29), the decrease in combined inattentive and hyperactive symptoms was 19%.

Cognitive Failures

- 76% of adults improved on the CFQ, a self report measure of cognitive failures in daily life.
- Adults who improved after Cogmed showed a 27% decrease in self report of cognitive failures.
- Considering the total sample of adults (N =29), the decrease in cognitive failures was 18%.

Although the effect of Cogmed on symptoms in the Canadian practice was smaller than typically observed, it can be posited that poorer scores on the hyperactivity component of the scale may have attenuated the combined score. Consistent with Cogmed research and clinical experience, it is likely that Cogmed has less impact on hyperactivity symptoms than those related to attention. However, it is worth mentioning that over 83% of all participants improved on the measure of ADHD with a 19% reduction in symptoms.

Results from the Canadian practice on the adult report of cognitive failures are also encouraging, with a decrease on the CFQ of 18% for the entire sample. Three Cogmed research studies have used the CFQ with a total of 82 participants and have reported an average 18% improvement after training (Westerberg et al., 2007, Lundqvist et al., 2010, Johansson & Tornmalm, 2011).

Figure 3. Rating scale data for children and adults from three clinical practices using Cogmed in Singapore, the Netherlands, and Canada.

	N _{total}	Mean (SD) T1	Mean (SD) T2	SC	%1	N _{improved}	% 2	% 3
Singapore (Inattention)	222	17.01 (6.550)	11.77 (6.240)	0.80	30.81	172	77.48	38.34
Netherlands (Inattention)	500	17.63 (5.010)	11.86 (4.920)	1.15	32.73	438	87.60	37.85
Canada (Inattention)	47	17.70 (6.105)	13.13 (5.918)	0.75	25.82	37	78.72	31.53
Child Summary	769			0.90	29.78	647	81.27	35.91
Singapore (Inattention)	8	22.33 (6.205)	15.62 (8.380)	1.08	30.05	6	75.00	41.94
Netherlands (Inattention)	112	23.96 (5.025)	18.05 (5.143)	1.18	24.67	96	85.71	28.93
Adult Summary (Inattention)	120			1.13	27.36	102	80.36	35.44
Canada (ADHD)	29	28.19 (10.753)	22.77 (10.088)	0.50	19.23	24	82.76	24.60
Canada (CFQ)	29	54.53 (13.903)	44.64 (14.491)	0.71	18.14	22	75.86	27.29

N_{total} = total number of participants in the sample

SC = standardized change, $(\text{mean}_{T2} - \text{mean}_{T1} / \text{SD}_{T1})$

% 1 = average percent improvement for N_{total} on rating scale from baseline to post-test

N_{improved} = number of participants in the sample that significantly improved on rating scale from baseline to post-test

% 2 = percent of N_{total} that significantly improved on rating scale from baseline to post-test, $((N_{\text{improved}} / N_{\text{total}}) * 100)$

% 3 = average percent improvement for N_{improved} on rating scale from baseline to post-test

CONCLUSION

Consistent with the message put forth by Cogmed, as well as the findings from academic research, 80% of Cogmed End-Users improve after training. Further, End-Users improve by 30% on measures of inattentive symptoms. Clinical Evaluations such as those included in this, Part I of the Clinical Evaluations Series, add yet another level of evidence for the claims made by Cogmed. Not only does research support the efficacy of Cogmed at the biochemical, neuro-imaging, neuropsychological, and behavioral levels but, so too does the clinical data which reflects the real world implementation of the Cogmed solution. Always looking to the future, Cogmed thus encourages clinicians using Cogmed in their practices to collect detailed data that will add to the growing body of support for Cogmed and provide them greater information for how the effects of Cogmed manifest in the real world. The statistics reported from the practices in this Clinical Evaluation can be used as a reference point for how many End-Users are expected to improve and by how much their symptoms are expected to decrease.