COGMED CLAIMS & EVIDENCE

Cogmed Working Memory Training

Pearson

Clinical Assessment

Version 2.0

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TABLE OF CONTENTS

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 following training. Average improvements on non-trained tasks of WM 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). Studies have investigated the impact of Cogmed Working Memory Training from the most fundamental level of genetics (Brehmer et al., 2009; Bellander et al., 2011; Söderqvist et al., 2011, 2013), biochemical functioning (McNab et al., 2009), neuronal activity (Olesen et al., 2004; Westerberg & Klingberg, 2007; Brehmer et al., 2011) to its effect on learning (Dahlin, 2011, 2013; Holmes et al., 2009, 2013) and every day functioning (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 Cohrane criteria for highest level of acceptance for an intervention.

"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, M.D., Ph.D.

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.

In order to convey the close relationship between the Cogmed program and it's 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

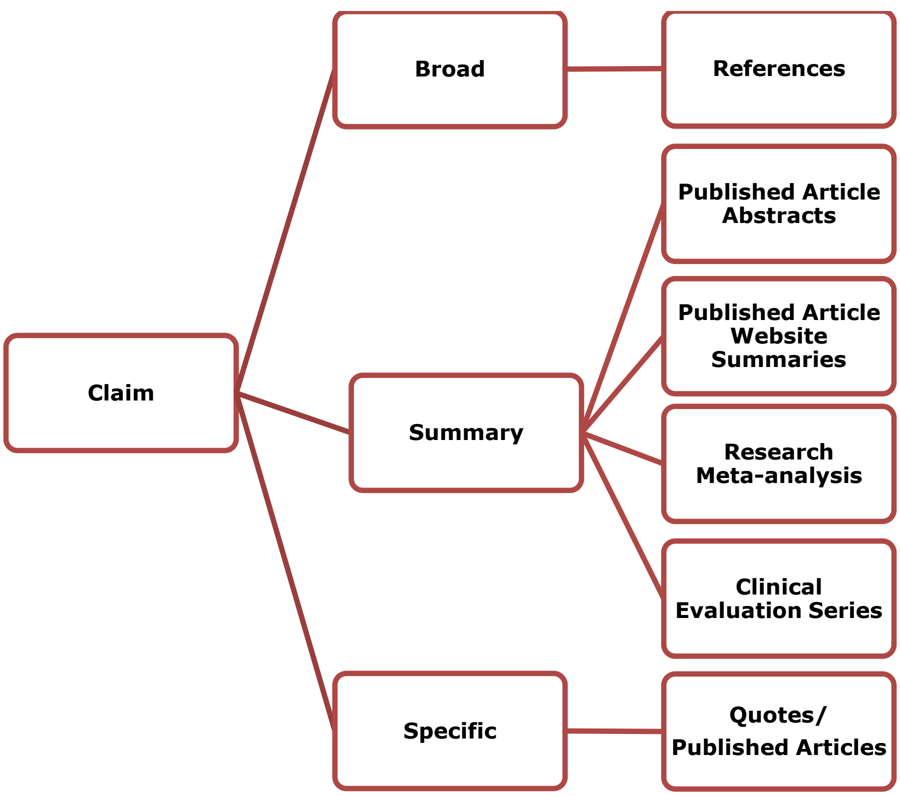
The efficacy of Cogmed has been demonstrated through a credible body of scientific work. First emerging as a research discovery at the Karolinska Institute in Stockholm, Sweden, the effect of Cogmed on WM has since been investigated by independent researchers at world-renowned institutions. Through these studies, evidence has been gathered about WM and related executive functions with findings published in leading peer-reviewed scientific journals and presented at professional conferences. The presence of the Cogmed method in peer-reviewed journals ensures that experts have assessed the results from these 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 Cogmed research in academia, where findings are typically gleaned within the tightly controlled and highly structured research setting, there is strong evidence that WM training impacts the individual in the "real world". Beyond the lab, Cogmed is used by a range of licensed professionals including clinical psychologists and psychiatrists, as well as educators. Since 2006, over 600 clinical practices and 125 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 tens of thousands of End-Users. Thus, while the research literature surrounding WM training continues to improve, to evolve, and to be challenged, the data from clinical and school settings demonstrates Cogmed to be 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 method 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, summary, or specific. Broadly, one can make *reference* to a study using Cogmed from a peer-reviewed, published journal that supports a specific Cogmed claim. Beyond citing particular training studies, the article *abstract* provides a more detailed synopsis of the research supporting a claim. *Review articles* and *summaries* of training studies, that are linked to or 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 (Appendix A)* provides the average percent change and effect size values observed post-training and based solely on information available in the published texts. Further, the *Clinical Evaluation Series (Appendix B and C)* 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 read the published Cogmed articles and thus the text that directly support each claim *(Appendix D).*



COGMED CLAIMS AND EVIDENCE

EXECUTIVE SUMMARY

I. Working memory (WM) is key to attention and learning

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

III. Training related effects have been shown on three levels of assessment: brain imaging, neuropsychological tests, and behavioral rating scales

IV. Training effects have been observed in all age ranges after Cogmed

V. Improvements in WM after Cogmed have generalized to reduced cognitive failures in daily life

VI. Gains in WM and behavioral outcomes are sustained over the long term

VII. WM is commonly impaired in individuals with ADHD

VIII. Groups with ADHD have demonstrated gains in WM capacity post Cogmed training

IX. Improvements in symptoms of inattention have been shown after Cogmed training in groups with ADHD and other clinical diagnoses using behavioral rating scales (e.g. the inattention subscale from DSM-IV)

The evidence for these claims is taken directly from 43 published peer-reviewed Cogmed Working Memory Training studies, book chapters, review articles, clinical evaluations, and meta-analysis that are publicly available for individual review and that are summarized on the Cogmed website

Cogmed Working Memory Training Published Research Table

Population	Year	Publication	Title	Author
ADHD	2014	Journal of Attention Disorders	Working memory training in college students with ADHD or LD	Gropper et al.
ADHD	2013	PLoS ONE	RCT of working memory training in ADHD: Long-term near-transfer effects	Hovik et al.
ADHD	2013	Journal of Education and Learning	Working memory training and the effect on mathematical achievement in children with attention deficits and special needs	Dahlin
ADHD	2013	Journal of Child Psychology and Psychiatry	A randomized clinical trial of Cogmed Working Memory Training in school-age children with ADHD: A replication in a diverse sample using a control condition	Chacko et al.
ADHD	2013	PLoS ONE	Few effects of far transfer of working memory training in ADHD: A randomized controlled trial	Egeland, et al.
ADHD	2013	Child Neuropsychology	Recall initiation strategies must be controlled in training studies that use immediate free recall tasks to measure the components of working memory capacity across time	Gibson et al.
ADHD	2012	Neurotherapeutics	Will working memory training generalize to improve off-task behavior in children with Attention-Deficit/Hyperactivity Disorder?	Green et al.
ADHD	2012	Journal of Child Psychology and Psychiatry	Effects of a computerized working memory training program on working memory, attention, and academics in adolescents with severe LD and comorbid ADHD; a randomized controlled trial	Gray et al.
ADHD	2011	Child Neuropsychology	Component analysis of verbal versus spatial working memory training in adolescents with ADHD: A randomized, controlled trial	Gibson et al.
ADHD	2011	Reading and Writing	Effects of working memory training on reading in children with special needs	Dahlin
ADHD	2010	Applied Cognitive Psychology	Impacts of training and medication on working memory on ADHD Children	Holmes et al.
ADHD	2010	Journal of Clinical Child & Adolescent Psychology	A controlled trial of working memory training for children and adolescents with ADHD	Beck et al.
ADHD	2010	School Mental Health	Working memory training for children with attention problems	Mezzacappa et al.
ADHD	2005	JAACAP	Computerized training of working memory of children with ADHD	Klingberg et al.

ADHD	2002	J. of Clinical & Experimental Neuropsychology	Training of working memory in children with ADHD	Klingberg et al.
Brain Injury	2013	Brain Injury	Can computerized working memory training improve impaired working memory, cognition and psychological health?	Åkerlund et al.
Brain Injury	2013	Brain Injury	A randomized study of computerized working memory training and effects on functioning in everyday life for patients with brain injury.	Björkdahl et al.
Brain Injury	2013	Psycho-Oncology	Working memory training in survivors of pediatric cancer: A randomized pilot study	Hardy et al.
Brain Injury	2012	Scandinavian Journal of Occupational Therapy	Working memory training for patients with acquired brain injury: effects in daily life	Johansson & Tornmalm
Brain Injury	2010	Brain Injury	Computerized training of working memory in a group of patients suffering from acquired brain injury	Lundqvist et al.
Brain Injury	2007	Brain Injury	Computerized working memory training after stroke – a pilot study	Westerberg et al.
Classroom Behavior/Low WM	2013	Educational Psychology	Taking working memory training from the laboratory into schools	Holmes & Gathercole
Classroom Behavior/Low WM	2013	Developmental Psychology	Does working memory training lead to generalized improvements in children with low working memory? A randomized controlled trial	Dunning et al.
Classroom Behavior/Low WM	2009	Developmental Science	Training leads to sustained enhancement of poor working memory in children	Holmes et al.
Classroom Behavior/SEBD	2011	Learning and Individual Differences	The impact of working memory training in young people with social, emotional and behavioral difficulties	Roughan & Hadwin
Down Syndrome	2013	American Journal on Intellectual and Developmental Disabilities	Computerized memory training leads to sustained improvement in visuo-spatial short term memory skills in children with Down syndrome	Bennett et al.
Hearing	2011	Journal of Speech, Language, and Hearing Research	Working memory training for children with cochlear implants: A pilot study	Kronenberger et al.
Low IQ	2012	Frontiers in Human Neuroscience	Computerized training of non-verbal reasoning and working memory in children with intellectual disability	Söderqvist et al.
Preterm	2013	Pediatrics	Working memory training improves cognitive function in VLBW preschoolers	Grunewaldt et al.

Preterm	2010	The Journal of Pediatrics	Computerized working memory training improves function in adolescents born at extremely low birth weight	Løhaugen et al.
Typical	2013	Journal of Cognitive Neuroscience	Polymorphisms in the dopamine receptor 2 gene region influence improvements during working memory training in children and adolescents.	Söderqvist et al.
Typical	2013	Memory & Cognition	Exploration of an adaptive training regimen that can target the secondary memory component of working memory capacity	Gibson et al.
Typical	2012	Frontiers in Human Neuroscience	Working-memory training in younger and older adults: Training gains, transfer and maintenance	Brehmer et al.
Typical	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.
Typical	2011	NeuroImage	Neural correlates of training-related working-memory gains in old age	Brehmer et al.
Typical	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.
Typical	2011	Neuropsychologia	Preliminary evidence that allelic variation in the LMX1A gene influences training related working memory improvement	Bellander et al.
Typical	2011	Developmental Psychology	Dopamine, working memory, and training induced plasticity: Implications for developmental research	Söderqvist et al.
Typical	2009	Developmental Science	Training and transfer effects of executive functions in preschoolers	Thorell et al.
Typical	2009	Science	Changes in cortical D1 receptor binding after cognitive training	McNab et al.
Typical	2009	Neuroscience Letters	Working memory plasticity modulated by dopamine transporter genotype	Brehmer et al.
Typical	2007	Physiology and Behavior	Changes in cortical activity after training of working memory – a single-subject analysis	Westerberg & Klingberg
Typical	2004	Nature Neuroscience	Increased prefrontal and parietal activity after training of working memory	Olesen et al.

CLAIMS AND EVIDENCE

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

I. Working memory (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)(Klingberg et al., 2010).[1]

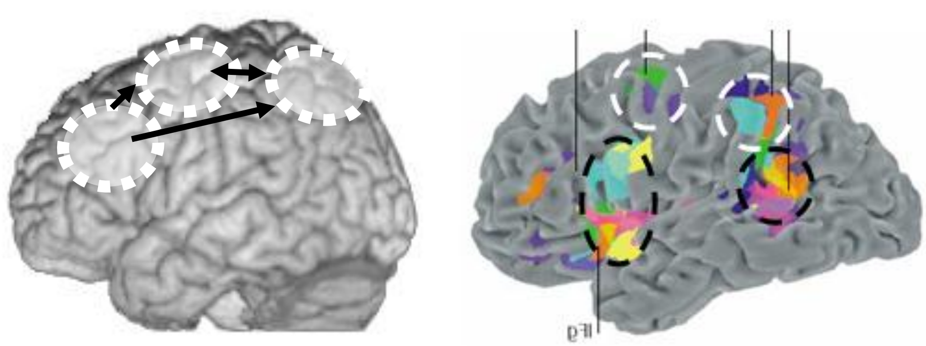


Figure 1. The image of the brain on the left includes ringed areas that are activated during WM tasks. The image of the brain on the right shows areas, represented by black circles, that lie on the border between the parietal lobe and the temporal lobe and which used for stimulus-driven attention. The areas for controlled attention, represented by the white circles, are in the parietal lobe and superior part of the frontal lobe. The areas responsible for controlled attention overlap with those areas that are used during working memory tasks (Corbetta & Shulman, 2002; Curtis & D'Esposito, 2003).

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 (Holmes et al., 2009).[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 more easily 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 (Holmes et al., 2010).[3]

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

WM can be improved using Cogmed, an adaptive cognitive training program, and a sustained and intense training protocol. Historically and in the bulk of Cogmed research, Cogmed End-Users have trained intensively for 30 to 40 minutes, 5 days a week for 5 weeks[1]. It is during this sustained training period that the End-User engages in 8 out of 11 visuo-spatial and verbal exercises per day (Cogmed RM and Cogmed QM) that continually adjust in difficultly 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 tasks that differ from those practiced on during training.

Adaptive WM Training

A hallmark of Cogmed Working Memory 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 that non-adaptive training does not lead to gains (Diamond & Lee, 2011).[4] This assertion is supported by blinded, randomized, controlled trials comparing adaptive Cogmed training to both non-adaptive (placebo) Cogmed training (Chacko et al., 2013; Dunning et al., 2013; Green et al., 2012; Holmes et al., 2009; Klingberg et al., 2002, 2005)[5] and non-adaptive commercially available video games (Thorell et al., 2009).[6]Additionally, research with children with cochlear implants (Kronenberger et al., 2011)[7] and adults with acquired brain injury (Lundqvist et al., 2010)[8] 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.

[1] In 2013, Cogmed released a new feature to the program called "variable protocol", which allows End-User to train for 25, 35, or 50 minutes per day for 3, 4, or 5 days per week. The duration of these new protocols ranges from 5 to 10 weeks. The 50 minutes per day/5 days per week protocol is the "standard" time frame for training and validated in the extant literature.

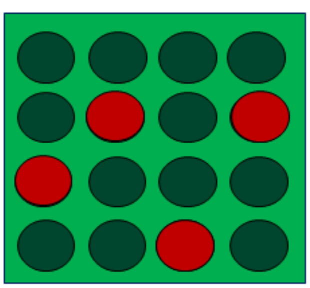
Sustained and Intense WM Training

Not only is adaptivity crucial but also, training must be sustained and intense. Stemming from findings of brain plasticity studies in primates, in order for training to have an observable impact on the brain it needs to be intense in terms of session and number of days trained, repetitive, and progressively more difficult as the End-User improves in performance (Klingberg, 2008).[9] To ensure that End-Users comply with the rigorous training plan, a Cogmed Coach provides regular support and feedback to each End-User. 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 active 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.[10] 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

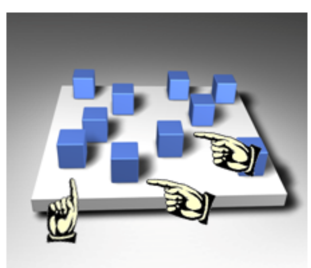
Properly assessing the impact of adaptive, supported, and intense WM training is also essential for demonstrating that WM is improved after Cogmed. Researchers have shown that WM gains have generalized beyond improvements in task-specific performance by using non-trained assessments of WM (Holmes et al., 2009).[11] 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.

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

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

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.[12] Furthermore, over 35 additional published studies using the adaptive Cogmed solution and protocol have resulted in improvements on non-trained tasks of WM (See Table 1). In the 2012 Cogmed Research Meta-analysis, which included all Cogmed studies published at that time and from which effect sizes could be extracted or calculated, 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 (Appendix A). Average effect sizes were 0.98 and 0.77 for visuo-spatial and verbal WM respectively. A more recent analysis by Spencer-Smith and Klingberg (submitted), which included only controlled studies, replicated the results of the Cogmed analysis reporting a 0.93 effect size for visuo-spatial WM on non-trained tasks. Thus, the research evidence for Cogmed, an adaptive, intense, computerized cognitive training program, has consistently demonstrated significantly improved WM.

III. Training related effects have been shown on three levels of assessment: brain imaging, neuropsychological tests, and behavioral rating scales

The impact of Cogmed Working Memory Training has been shown at on three levels of assessment: brain imaging, neuropsychological tests, and behavioral 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 (McNab et al., 2009).[13]

Cogmed Working Memory Training is also associated with changed brain activity in WM associated areas. However, results are conflicting with studies showing both increases and decreases in brain activity and, as discussed in Brehmer et al. (2011), the relationship between activation changes and performance after cognitive intervention is still an open issue[14]. Research with fMRI on healthy adults has shown increased activation in the frontal and parietal regions that are typically associated with WM function (Olesen et al., 2004; Westerberg & Klingberg, 2007).[15 & 16] Differently, research by Brehmer et al. (2011) including an older sample revealed that Cogmed training led to decreased activity 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.[17]

Beyond imaging data, neuropsychological testing in almost all studies using Cogmed have shown that participants demonstrate near transfer to non- trained tests of WM (See Table 1). 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 at., 2012). In a study of children with social, emotional, and behavioral problems, Roughan and Hadwin (2011) found that after Cogmed training, participants 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.[18]

The positive effect of training has been observed on improvements on parental ratings of inattention including the DSM-IV Parent Rating Scale, DuPaul ADHD-RS-IV, Brief Inventory of Executive Function (BRIEF), Disruptive Behavior Rating Scale (DBRS), and Conner's Parent Rating Scale, 3rd Edition. End-Users have also reported significant decreases in their own symptoms and improvements in daily life using the DSM-IV Adult Rating Scale, Cognitive Failures Questionnaire (CFQ), and the Canadian Occupational Performance Measure (COPM). For more detail on rating scale outcomes see Claims V and IX.

IV. Training effects have been observed in all age ranges after Cogmed

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.[19] These findings are supported by significant improvements in visuo-spatial WM in a study of typical preschool children (Bergman Nutley et al., 2011)[20], as well as improved auditory attention, phonological processing, visual and verbal memory and learning, and sentence repetition in preschoolers born at very low birth weight (Grunewaldt et al., 2013).

School-aged children and adolescents 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 with ADHD, 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 with ADHD 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).[21] 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 training 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. Importantly, gains in WM are not isolated to children and adolescents in the above noted ADHD and preterm samples, but also to children from a variety of clinical and non-clinical groups including cancer (Hardy et al., 2013), low WM (Holmes et al., 2009; Dunning et al., 2013), and low acheivement (Holmes & Gathercole, 2013).

Both young and older 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.[22]

It is also important to note that adults with clinical conditions such as ADHD have also demonstrated positive training effects post-Cogmed. In 2014, Gropper et al. investigated the impact of training on college students, ages 19 to 52 years, with combined ADHD and learning disabilities (LD). Not only did participants improve on measures of visuo-spatial and verbal WM at post-test and at two month follow up, but they also reported significantly decreased ADHD symptoms at post-test and decreased cognitive failures (Cognitive Failures Questionnaire) at both post-test and follow up.

V. Improvements in WM after Cogmed have generalized to reduced cognitive failures in daily life

Beyond measures of WM and attention, participants also improve on self-reported assessments of daily functioning following WM training. 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.[23] Significant improvements on measure of WM and the CFQ were replicated with adult college students with comorbid ADHD and learning disabilities (Gropper et al., 2014) and a sample of typically functioning younger and older adults (Brehmer et al., 2012), where younger and older adults who trained adaptively reported less memory complaints that their age-matched peers who trained with the placebo (non-adaptive training).[24] More recent research with acquired brain injury patients also revealed significant improvements on the Barrow Neurological Institute Screen for Higher Cerebral Functions (BNIS) immediately post Cogmed training and 8 months later (Åkerlund et al., 2013).

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.[25] 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.[26]

VI. Gains in WM and behavioral outcomes are sustained over the long term

In studies that have included a long term follow up, increases in WM capacity and improved behavior have been observed from two months to one year post-training (See Table 1). More recent research and clinical evidence has shown gains in WM sustained for up to 12 months post-training. Dunning et al. (2013) demonstrated in a randomized, placebo controlled study that school-aged children with low WM who trained with Cogmed maintained improvements in verbal WM on the Automated Working Memory Assessment, as well as on an classroom based task of WM ability (sentence counting) at one year follow up.[27] Improved behavior (as measured by rating scales) have also been observed over the long term in ADHD (Beck et al., 2010, Gropper et al., 2014, Klingberg et al., 2005), brain injured (Johansson & Tornmalm, 2012; Lundqvist et al., 2010), and typically functioning groups (Brehmer et al., 2012).

12 Month Follow Up	6 to 8 Month Follow Up	2 to 5 Month Follow Up	Post-test Only
Dunning et al., 2013 * Holmes & Gathercole, 2013 * Söderqvist et al., 2014	Hovik et al., 2013 * Dahlin, 2011 * Dahlin, 2013 * Egeland, et al.,2013 Holmes et al, 2010 * Holmes et al., 2009 * Johansson & Tornmalm, 2012 **+** Kronenberger et al., 2011 Løhaugen et al., 2010 *	Åkerlund et al., 2013 * Beck et al., 2010 * + Bennett et al.,2013 * + Björkdahl et al., 2013* + Brehmer et al., 2012 * + Gropper et al., 2014 * + Hardy et al.., 2012 * Klingberg et al., 2005 * + Lundqvist et al., 2010* + Roughan & Hadwin, 2011 *	Bellander et al., 2011 * Bergman Nutley et al., 2011 * Brehmer et al., 2009 * Brehmer et al., 2011 * Chacko et al., 2013* Gibson et al., 2011* + Gibson et al., 2012 * Gibson et al., 2013 * Gibson et al., 2013 * Gray et al., 2012* Green et al., 2012 * + Grunewaldt et al., 2013* Klingberg et al., 2002* McNab et al., 2009 * Mezzacappa et al., 2010 * + Olesen et al., 2004 * Söderqvist et al., 2011 Söderqvist et al., 2014 Thorell et al., 2009 * Westerberg & Klingberg, 2007 * Westerberg et al., 2007 * +

Table 1. Peer-reviewed, published Cogmed training studies arranged by length of follow up testing conducted.
* represents studies where WM gains emerged, were maintained, or increased at the last follow up time-point and
+ represents studies where improvements on behavioral rating scales emerged, were maintained, or increased at the last follow up time-point.

The long term maintenance of WM gains has also been observed in the clinical setting. The Cogmed Clinical Evaluation Part II presents data collected on 70 children with attention problems. The analysis revealed that the children improved on the WM tasks of the WISC-IV (spatial span forwards and backwards, digit span forwards and backwards, and letter number sequencing) by an average 36% at post-training. At 6 months, the average retention of these gains was 78% compared to post-test. At one year, the average retention of these gains was 67% compared to post-test. Gains post Cogmed were also found for adults in the Clinical Evaluation Series Part II data. Forty-five adults with attention problems improved on the WM tasks from the WAIS-IV (spatial span forwards and backwards, digit span forwards and backwards, and letter number sequencing) by an average 26% at post-training. At 6 months, 91% of the gains were maintained and at 12 months adults but further improved their scores from post-test by an addition 17% (i.e. 117% retention) (Appendix C).

Children improved significantly on parent rated behavior of ADHD symptoms after training (Disruptive Behaviors Rating Scale – Parent Version (DBRS-P), Barkley & Murphy, 2006) in the Clinical Evaluation Series Part II. Compared with pre-training scores, children improved on the Inattention sub-scale score by 33% at post-test, 42% at 6 months, and 40% at 12 months. Significant improvements on the WM, Plan/Organize, Monitor, Inhibit, & Shift sub-scales of the Behavioral Ratings Inventory of Executive Functions (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000) were observed at post-training with an additional improvement of 59% at 12 months. Adults also significantly improved and maintained gains on their self-ratings of inattention (DSM-IV Adult Self Report Scale) and cognitive failures in daily life (Cognitive Failures Questionnaire) at one year follow up (Appendix C).

VII.WM is commonly impaired in individuals with ADHD

Research has shown that WM is commonly impaired in individuals with ADHD (Hervey et al., 2004; Martinussen et al., 2005 [28 & 29]; Martinussen & Tannock, 2006; Willcutt et al., 2005) and underlies other complex executive functions and behavioral symptoms such as inattention, which are often observed in ADHD (Rapport et al., 2001). In 2004, Westerberg et al. compared the visuo-spatial WM of a group of children with ADHD to an age-matched typically functioning control group. The researchers found that not only did children with ADHD have lower WM but also, that the gap between them and their typically functioning peers increased with age (See Figure 3).

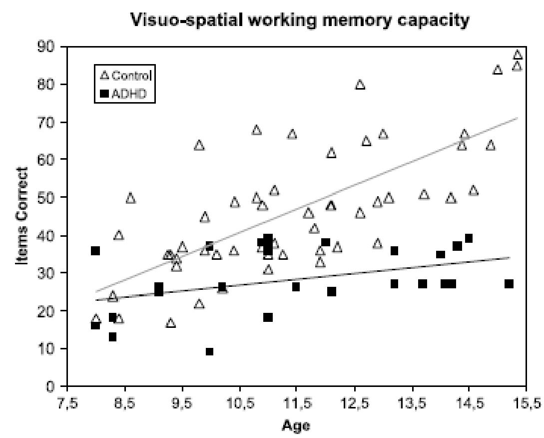


Figure 3. Working memory scores for all participants, N = 80. ADHD participants are represented by black squares. Typically functioning participants are represented by white triangles. Linear regression lines are presented for each group.

Westerberg et al. (2004) summarize the relationship between ADHD and WM in stating:

> There is substantial research done on the neurophysiological substrates that underlie WM function and these substrates, of which the prefrontal cortex seems to be the most important, coincide with those known to be affected in ADHD. It is also well known that WM functioning is dependent on dopamine (Williams & Goldman-Rakic, 1995), which is consistent with the association of ADHD with atypical dopaminergic transmission (Cook et al., 1995). In addition, drugs such as methylphenidate and amphetamine, known to ameliorate the symptoms in ADHD, facilitate dopaminergic transmission (Volkow et al., 1995), and also improve WM (Luciana, Depue, Arbisi, & Leon, 1992; Tannock, Ickowicz, & Schachar, 1995).

Data collected by Holmes et al. and Alloway et al. sheds light on the extent of WM deficits in children with ADHD. After assessing 83 children with ADHD to determine their WM profile, the researchers found that although verbal short term memory (STM) was relatively intact, 38.6% had deficits in visuo-spatial STM, 50.6% had impairments in verbal WM, and 63.9% had poor visuo-spatial WM (Holmes et al., 2010)[30]. In another study by Rappaport et al. (2013), it is estimated that 81% of children with ADHD have deficits in the "working" component of WM (e.g. the central executive)[31]. These findings are consistent with other investigations implicating the attentional control aspect of working memory (central executive), which orchestrates the manipulation of information, as being more impaired in ADHD groups than the storage components of WM (sometimes called short-term memory)(Kofler et al., 2010)[32].

VIII. Groups with ADHD have demonstrated gains in WM capacity post Cogmed training

Over 30% of the published Cogmed research focuses on children and adolescents with ADHD. With the exception of Egeland et al. (2013), which discusses solely far-transfer, all of the remaining papers reveal that participants with ADHD improve on measures of WM after Cogmed training (See Table 2). Increases in WM have been observed across research designs of varying rigor including gold standard randomized, placebo controlled studies (Chacko et al., 2013; Green et al., 2012; Klingberg et al., 2002, 2005) and waitlist controlled studies (Beck et al., 2010; Dahlin, 2011, 2013; Gropper et al., 2014; Hovik et al., 2013). Further, improvements have been found on tasks involving both storage and manipulation, including single-tests of WM, such as the span board or digit span (Chacko et al., 2013, Dahlin, 2011, 2013; Gibson et al., 2011; Gray et al., 2013; Gropper et al., 2014; Holmes et al., 2010; Mezzacappa & Buckner, 2011), multiple tasks grouped to form composite measures (Green et al., 2012; Gropper et al., 2014; Hovik et al., 2013; Klingberg et al., 2002, 2005) and parent ratings of WM related behaviors (Beck et al., 2010). Combined the results from these studies demonstrate that WM, an impaired function in ADHD, can be improved in groups with attention problems[33].

Author	Control Type	WM Measure	ES (d) Post-test	ES (d) Follow Up
Beck et al., 2010	Waitlist	BRIEF – Parent Rating Scale (Working Memory Subscale)	0.85	0.94
Chacko et al., 2013	Placebo	Visuo-spatial (AWMA - Dot Matrix)	1.17	-
		Verbal (AWMA - Digit Recall)	0.28	-
Dahlin, 2011, 2013	Waitlist	Visuo-spatial (WAIS-NI - Span Board Forward; Span Board Backward)	1.19; 0.92	1.05; 0.93

		Verbal (WISC-III – Digit Span Forward; Digit Span Backward)	0.59; 0.79	0.48; 0.34
Egeland et al., 2013	Waitlist	-	-	-
Gibson et al., 2011	Comparison	Spatial and Verbal Immediate Free Recall	-	-
Gray et al., 2012	Comparison	Visuo-spatial (CANTAB – Spatial Span)	Partial eta^2 = 0.08 (small to medium)	-
		Verbal (WISC-IV - Digit Span Backward)	Partial eta^2 = 0.13 (medium)	-
Green et al., 2012	Placebo	Verbal (WISC-IV - WMI)	0.81	-
Gropper et al., 2014	Waitlist	Visuo-spatial (CANTAB – Spatial Span Forward)	Partial eta^2 = 0.22 (medium to large)	Partial eta^2 = 0.243 (medium to large)
		Verbal* (WAIS-IV – Digit Span Forward, Backward and Sequencing)	n.s.	Partial eta^2 = 0.083 (small to medium)
Holmes et al., 2010	None	Visuo-spatial and Verbal (AWMA Full Battery)	-	-
Hovik et al., 2013	Waitlist	Visuo-spatial*(Leiter-R – Visual Span Forward and Backward)	0.67	1.11
		Verbal * (WISC-IV – Digit Span Forward Backward)	0.66	0.47
		Verbal * (Letter Number Sequencing and Sentence Span)	0.27	0.73
Klingberg et al., 2002	Placebo	Visuo-spatial* (Span Board Forward and Backward)	0.13	-
		Verbal* (Digit Span Forward and Backward)	-	-
Klingberg et al., 2005	Placebo	Visuo-spatial* (WAIS-RNI - Span Board Forward and Backward)	0.79	0.81
		Verbal* (WISC-III - Digit Span Forward and Backward)	0.59	0.62
Mezzacappa & Buckner, 2011	Single-Case Design	Verbal (WISC-IV – Digit Span Backward)	0.93	-

Table 2. All Cogmed Working Memory Training studies demonstrate improved WM, except for Egeland et al., 2013, which measured solely far-transfer effects. * Represents a composite measure of WM and n.s. signifies that there was no significant difference between treatment and control groups at the testing point. Dashes mark studies that did not report effect sizes or did not include WM measures. All effect sizes are reported as Cohen's d unless otherwise indicated.

IX. Improvements in symptoms of inattention have been shown after Cogmed training in groups with ADHD and other clinical diagnoses using behavioral rating scales (e.g. the inattention subscale from DSM-IV)

The effect of training has been observed on improved parental ratings of inattention in ADHD children 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-up[34] 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.[35] Gibson et al. (2011) and Gropper al. (2014) also documented improvements on behavioral rating scales in child and adult ADHD groups.

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), which although not a rating scale is 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 in the real world.

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. These results are consistent with the Clinical Evaluation Series Part II, where children improved on the Inattention score of the Disruptie Behaviors Rating Scale by 33% at post-test, 42% at 6 months, and 40% at 12 months.

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 (Appendix B). Thus, it has been documented in both research and clinical evidence that Cogmed improves inattentive symptoms in ADHD groups as measured by rating scale and other observational measures.

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 (Beck et al., 2010; Green et al., 2012; Gropper et al., 2014; Klingberg et al. 2002; 2005; Mezzacappa & Buckner, 2010)

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 in ADHD groups.

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 (Dahlin, 2013; Holmes et al., 2009), as well improved English and math scores in low achievers (Holmes & Gathercole, 2013). However, more evidence in 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 may take time to manifest as improved learning on academic assessments.

Does Cogmed increase an End-Users IQ test scores?
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 (crystalized intelligence). It is possible that WM training positively impacts scores on IQ tests for some individuals, but Cogmed does not claim to improve IQ or to be a cure for persons with disabilities associated with low IQ.

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 to 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.

Claims Cogmed Does Not Make

- Cogmed is a cure for organic brain disease, ADHD, or any other clinical disorder.
- Cogmed is a replacement for medication.
- Cogmed is intended only for people with a diagnosed disorder.
- Cogmed impacts all individuals equally.
- Cogmed results in higher scores on IQ tests.
- Cogmed improves inhibitory, reasoning or long term memory functions.
- Training gains from Cogmed will last forever.
- Cogmed will definitely result in a student getting better grades in school.

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APPENDIX A:

COGMED PUBLISHED RESEARCH META-ANALYSIS 1.4

COGMED CLAIMS AND STATISTICAL SUPPORT

Cogmed Working Memory Training in 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.

I. Working memory (WM) is key to attention and learning

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

III. Training related effects have been shown on three levels of assessment: brain imaging, neuropsychological tests, and behavioral rating scales

IV. Training effects have been observed in all age ranges after Cogmed

V. Improvements in WM after Cogmed have generalized to reduced cognitive failures in daily life

VI. Gains in WM and behavioral outcomes are sustained over the long term

VII. WM is commonly impaired in individuals with ADHD

VIII. Groups with ADHD have demonstrated gains on measures of WM post Cogmed training

IX. Improvements in symptoms of inattention have been shown after Cogmed in groups with ADHD and other clinical populations using behavioral rating scales (e.g., DSM-IV)

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.

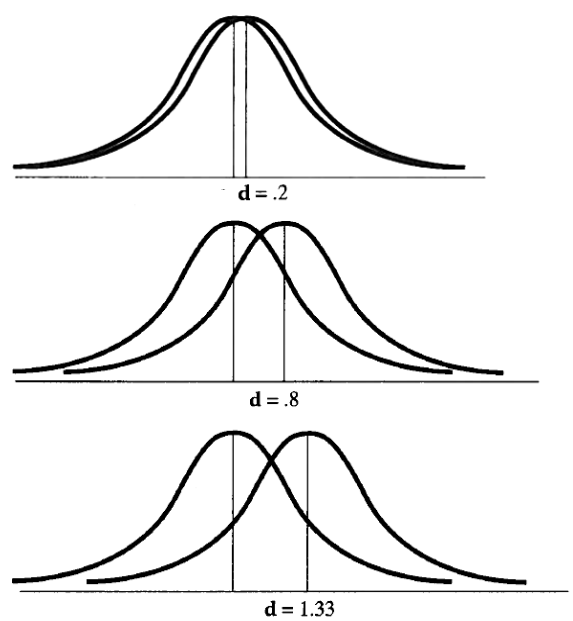


Figure 1. Overlap of group improvement on the Corsi Block test at post-intervention as a function of effect size

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

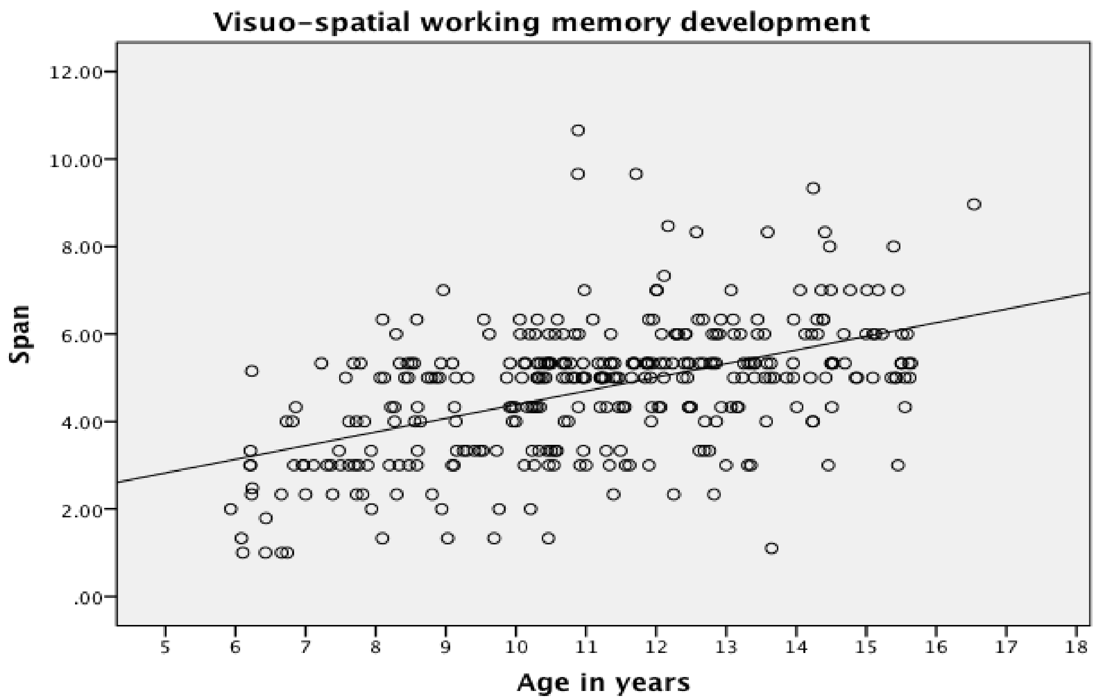


Figure 1 illustrates performance on a visuo-spatial working memory task for a typically developing sample of Swedish children with data collected by Cogmed Systems during the fall of 2011, n=375 (Females: n=196, Males: n=179).

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).

$$D = \frac{\bar{X}_T - \bar{X}_C}{S_{Pooled\ (Pre)}}$$

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 adult self-report of inattention, ADHD symptoms, and cognitive failures. 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 (i.e., 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%.

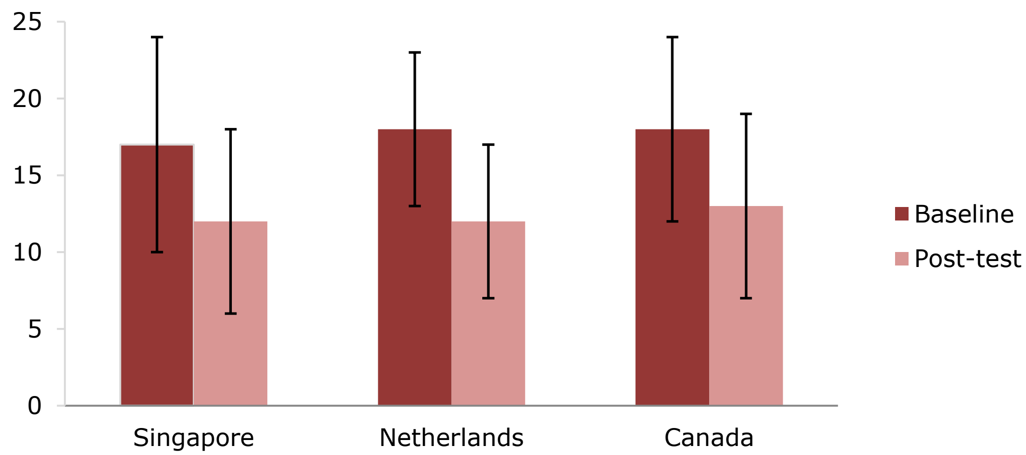
Netherlands

- 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.

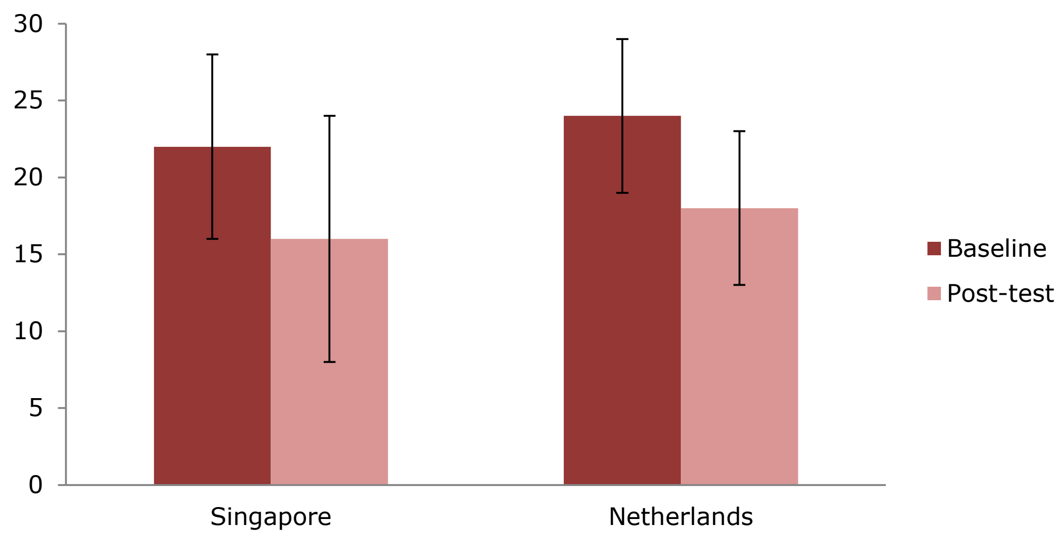
Singapore

- 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, (mean $_{T2}$ – mean $_{T1}$ / 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, (($N_{improved}$/ N_{total})*100)
% 3 = average percent improvement for $N_{improved}$ on rating scale from baseline to post-test

APPENDIX C

COGMED CLINICAL EVALUATION SERIES PART II

INTRODUCTION

Cogmed Working Memory Training is implemented and supported by a network of professionals in school and healthcare settings 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. 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. Clinical Evaluation Series Part I, presented 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, the analysis focused on parent ratings of inattentive symptoms in children, as well as adult self-report of inattention, ADHD symptoms, and cognitive failures. Interestingly, the results from each of the practices were quite consistent: 80% of children and adults that trained with Cogmed experienced improvement at post-test and there was a 30% improvement in inattentive symptoms. The findings of Clinical Evaluation Series Part I fill a gap in the limited body of published research investigating behavioral effects from Cogmed Working Memory Training and provide further support for meaningful effects from the intervention.

Another question still unanswered in the literature is of the longevity of the effects seen after Cogmed. Because of the practical and financial obstacles that a long-term follow-up study demands, such attempts have been rare. In order to encourage such academic research to take place in a controlled design, it is important to provide and highlight the existing clinical data with this regard. This document, Clinical Evaluation Series Part II, focuses on the long-term effects seen after Cogmed for children and adults in the clinical practice. The data includes performance on neuropsychological tests, as well as behavioral ratings that were collected by practitioners with vast experience of Cogmed implementation in the clinical setting, as led by Dr. Roberta Tsukahara in the clinic ADD Austin (Austin, Texas, USA).

UNDERSTANDING THE STATISTICS

Cogmed Clinical Evaluations are intended to reflect the real-world implementation of Cogmed Working Memory Training and therefore do not include control groups. Statistically significant improvements on neuropsychological tests and rating scales for children and adults from pre-training to post-, 6, and 12 month follow up were determined by calculating a comparable scoring unit between all of the measurements and types of assessments called a standardized change (SC) score. The SC score is calculated by taking the group mean assessment score at post training – group mean assessment score at pre-training divided by the standard deviation of the group mean score at pre-training assessment. For each of the other time points, the follow up point was used instead of the post-training score.

- ✓ Percent "improvers" represents the share of the sample that significantly improved on the assessment.
- ✓ Percent improvement is based on the change in the group of Cogmed End-Users on the outcome measure between baseline and post-test.
- ✓ Percent retention is based on the amount of training gain at post-test that has been maintained at 6 and 12 months post-training. Retention over 100% represents not just full maintenance of gains at post-test but further gains (i.e., improvements or reduction in symptoms).

CHILDREN

A heterogeneous sample of children with working memory impairments (mainly ADHD) completed the standard protocol (5 days per week for 5 weeks) of Cogmed Working Memory Training. Children in the sample included males and females that were between 8 and 14 (mean 11.26) years and trained for just under 25 days. Seventy children took part in pre- and post-training assessment, with 27 and 16 returning for 6 and 12 month follow up testing respectively (See Table 1).

Sample Size (N)					Mean (SD)	
Females	**Males**	**Post-Training**	**6 month Follow Up**	**12 month Follow Up**	**Age**	**Training days**
29	41	70	27	16	11.26 (2.93)	24.93 (0.35)

Table 1. Frequencies of the child participants by gender, as well as frequencies of the total sample at different data collection time points. The mean age and mean number of trained days are also reported.

ASSESSMENT

Children were assessed with the Spatial Span Forwards and Backwards, Digit Span Forwards and Backwards, and Letter Number Sequencing from the Wechsler Intelligence Scale for Children, 4th Edition(WISC-IV; Wechsler, 2003). The Spatial Span Forwards and Digit Span Backwards are tasks that are almost identical to those practiced on during training and thus, participant improvement is to be expected. The Spatial Span Backwards and Digit Span Forwards tasks represent near transfer tasks. Thus, they are similar but not exactly the same as those practiced on during training and participant improvement is to be expected. Letter Number Sequencing is not similar to any trained task and improvement therefore represents generalization of training to another task requiring working memory**.**

Children were also assessed with the Test of Variables of Attention (TOVA; Greenberg, 2007), a continuous performance test that measures attention and impulse control. The data reported to Cogmed for this Clinical Evaluation included the ADHD Total Score, as well as Response Time Variability, Commission Errors (impulse control), and Omission Errors (inattention).

- The TOVA ADHD Total Score is a comparison of the End-User's response to typical TOVA responses for an ADHD group. A score of -1.80 or less (more negative) fits the profile of an ADHD sample. A score of more than -1.80 (more positive) does not fit an ADHD profile.

- Response Time Variability accounts for 80% of the variance on the TOVA and measures the variability in the subject's reaction time for accurate responses (i.e., the consistency of their speed in responding correctly to stimuli). Regarding Response Time Variability the TOVA Clinical Manual states: "Individuals with ADHD tend to be inconsistent—they may be able to perform within normal limits for a while, but they "lose it" much sooner than others" (Leark et al., 2007).

- Commission Errors measure impulsivity and/or dis-inhibition and occur when the participant fails to inhibit responding and incorrectly responds to a non-target (i.e., they press the button after a non-target is presented).

- Omission Errors measure inattention and occur when the subject does not respond to the designated target (i.e., the subject omits pressing the button when a target appears or is sounded).

Improvement on the TOVA should therefore include a more positive ADHD Total Score, as well as decreased Response Time Variability, Commission Errors, and Omission Errors.

Behavioral changes were assessed with rating scales answered by the children's parents with regards to observed problems with attention and impulsivity using all scales of the Behavioral Ratings Inventory of Executive Function – Parent Rating Scale (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000) and the Disruptive Behavior Rating Scale-Parent Version (DBRS-PV; Barkley & Murphy, 2006). The BRIEF is an 86-item questionnaire of executive functions developed for parents and teachers of school-age children (5 to 18 years). The DBRS in an 18-item measure with Inattention and Hyperactivity/Impulsivity subscales used to collect parent rated frequency of ADHD behaviors from 0 (never or rarely) to 3 (very often). See Table 2 for assessments.

Battery	Subscales
Wechsler Intelligence Scale for Children, 4th Edition (WISC-IV; Wechsler, 2003)	Spatial Span Forward and Backward, Digit Span Forward and Backward, Letter Number Sequencing
Test of Variables of Attention (TOVA; Greenberg, 2007)	ADHD score, Response Time Variability, Omission, Commission
Disruptive Behaviors Rating Scale –Parent Version (DBRS-PV, Barkley & Murphy, 2006)	ADHD Total Score, Inattention, Hyperactivity/Impulsivity
Behavioral Ratings Inventory of Executive Function – Parent Rating Scale (BRIEF, Gioia, Isquith, Guy, & Kenworthy, 2000)	Working Memory, Plan/Organize, Monitor, Inhibit, Shift, Emotional Control, Initiate, Organization of Materials Metacognition Index , Behavioral Regulation Index, and Global Executive Composite

Table 2. Assessment batteries and subscales administered at pre- and post-training, as well as 6 and 12 month follow up for children.

RESULTS

Working Memory: On average, 67% of child End-Users improved significantly on the working memory measures by 36% at post-training (see Supplementary Information for more detail).

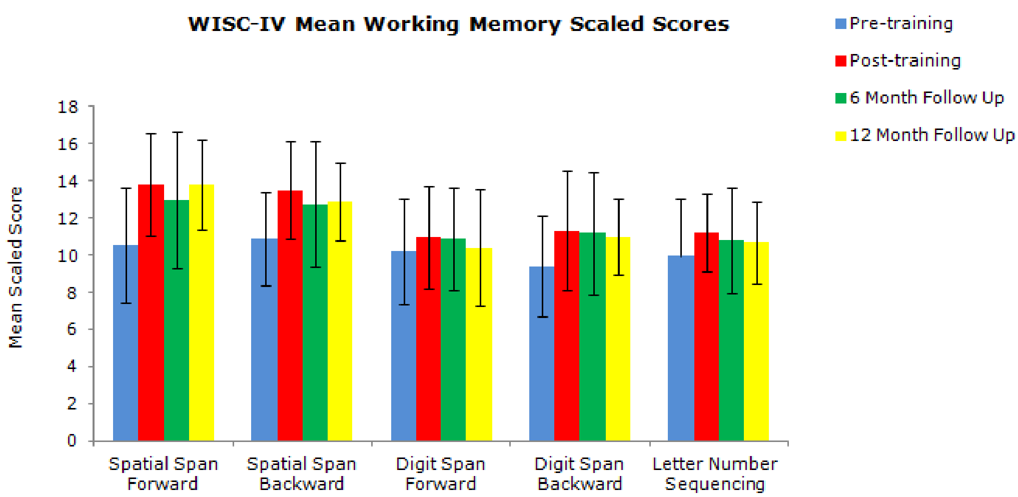


Figure 1. Mean scaled scores for the WISC-IV subscales completed by children directly after training, as well as 6 and 12 months later. Higher scores represent improvement on the working memory measures. Error bars represent standard deviations.

When tested again at 6 and 12 months post training, children largely retained the gains observed at post-test. In evaluating the durability of the training effect on working memory measures, there was an average 78% retention of effect at 6 month follow up and 67% retention of effect at 12 month follow up compared to the results observed at post-training. See Table 3 for retention statistics.

	N Post –training	N 6 Month Follow Up	6 Month Retention	N 12 Month Follow Up	12 Month Retention
Spatial Span Forward	67	26	**74%**	16	**100%**
Spatial Span Backward	67	27	**71%**	16	**76%**
Digit Span Forward	66	26	**89%**	15	**26%**
Digit Span Backward	67	28	**91%**	14	**82%**
Letter Number Sequencing	70	28	**67%**	16	**59%**
Average			**78%**		**67%**

Table 3. The percentage of the retained effects on the WISC-IV sub-scales at the 6 and 12 month follow up sessions compared with the effects seen directly after the training (post) for children.

Attention: At post-test, the share of children that improved on the ADHD Total and Response Variability Time Scores was 65% and 62% respectively. At 6 month follow up, an average 73% of the effect (improvement on the TOVA ADHD and Response Variability) was retained from post-test. At 12 month follow up, not only were all of the gains maintained compared to post-test but, there were an additional 50% improvement on the ADHD Total Score and Response Time Variability Scores (150% retention). Importantly, 52% of children who fit an ADHD profile on the TOVA ADHD Total score prior to training no longer met that profile after training. Over 70% of participants decreased the number of Commission and Omission Errors made at post-test and over 80% of the children tested at 1 year follow also showed decreased errors. The average number of Commission and Omission Errors significantly decreased not just at post-test but continued to either decrease or stay at post-test levels at 6 and 12 months.

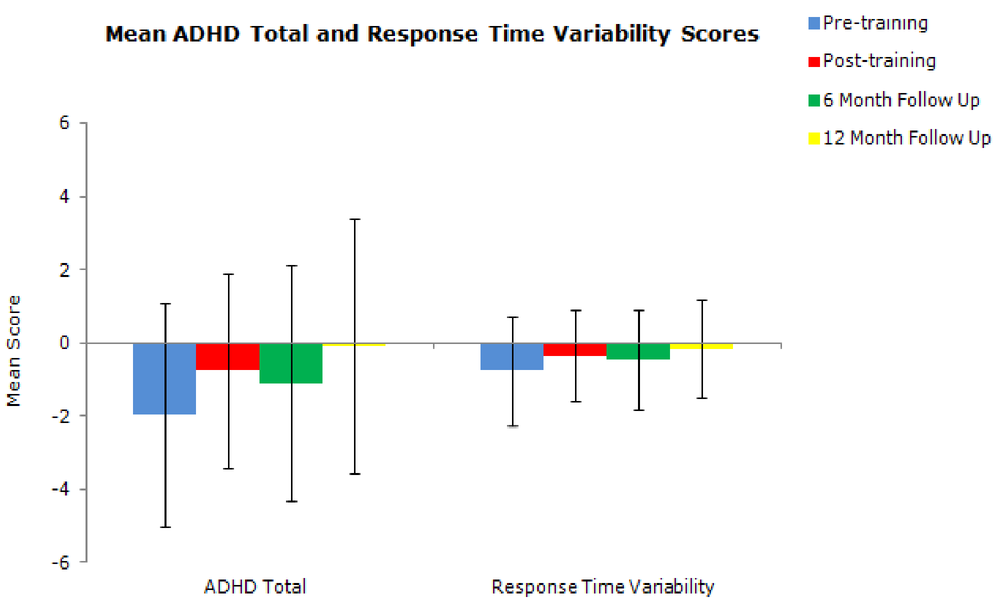


Figure 2. The mean pre-, post-, 6 and 12 month follow up ADHD Total and Response Time Variability scores for children that participated in Cogmed Working Memory Training.

Parent Rated Behavior: The majority of children (between 77% and 80%) improved significantly on the ADHD Total and Inattention scores on the Disruptive Behaviors Rating Scale (DBRS) at all time points compared to pre-training, with less children improving on the Hyperactivity/Impulsivity scale.

	ADHD Total			**Inattention**			**Hyperactivity/Impulsivity**		
	Post-training	6-months	12-months	Post-training	6-months	12-months	Post-training	6-months	12-months
% of Improvers (number)	80% (56)	81% (22)	81% (13)	77% (54)	70% (19)	88% (14)	14% (10)	10% (3)	13% (2)
% Retention		117%	152%		125%	165%		131%	150%
% of Non-Improvers (number)	20% (14)	19% (5)	19% (3)	23% (16)	30% (8)	12% (2)	86% (60)	90% (26)	87% (13)

Table 4. The percent and corresponding number of children that improved on the ADHD Total, Inattention, and Hyperactivity/Impulsivity scores at post-training, 6 month follow up, and 12 month follow up, as well as the percent and number of children that did not improve. For the group that improved, the amount of gains retained at 6 and 12 month follow up are reported, with values larger than 100% representing increased improvement (i.e., decreased disruptive behavior) compared to post-test.

Children had significantly less problems on the ADHD Total Score, as well as Inattention, and Hyperactivity/Impulsivity Behaviors subscales on the DBRS at all of the time points, as tested with a paired samples t-test compared to pre-training ratings (all *t*-scores > 2.3 and all *p*-values < 0.05) (See Figure 2). Noteabley, children improved on the Inattention score by 33% at post-test, 42% at 6 months, and 40% at 12 months. There was a trend towards significance for the Conduct Behaviors subscale (p = 0.076) at post-test but no significant difference at 6 and 12 month follow up. Children significantly improved on the ODD Behaviors subscale at post-training and 6 month follow up, but gains were not maintained at 12 months.

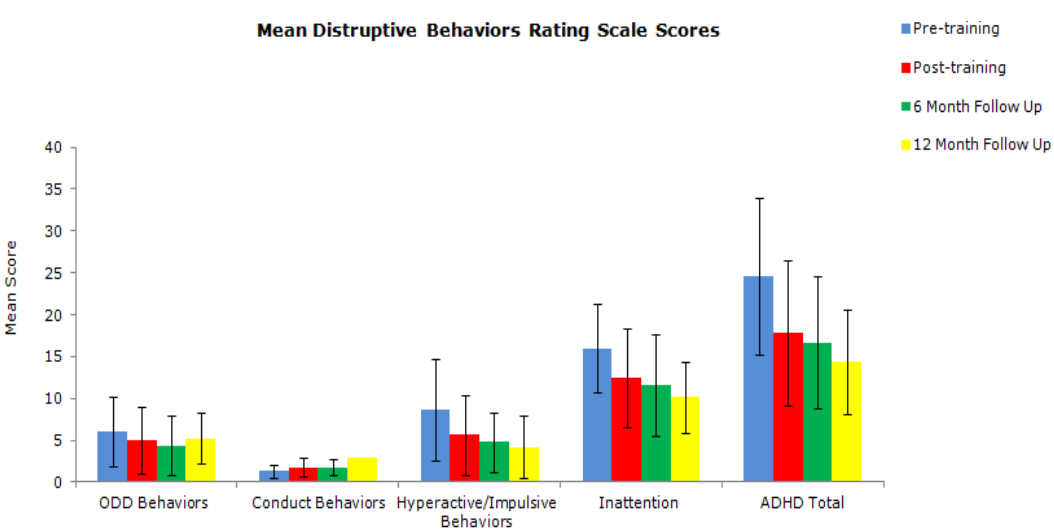


Figure 3. Mean scores for children on all subscales on the DBRS. High scores represent a greater frequency of disruptive behaviors. Significant improvements ($p < 0.05$) were observed for all measures at all the time points except for the Conduct Behaviors subscale at 6 and 12 months and the ODD subscale at 12 months. Error bars represent standard deviations.

Children retained all of the gains reported at post-test on the ADHD Total, Inattention, and Hyperactive/Impulsive Behaviors scores. At 6 months children had improved an additional 25% on the Inattention score compared to post-test and an additional 65% at 12 months compared to post-test. See Table 4 for retention percentages.

For the Behavioral Ratings Inventory of Executive Function (BRIEF), ratings showed significantly improved behavior on the subscales of Working Memory, Plan/Organize, Monitor, Inhibit, and Shift and the composite scales: Behavioral Regulation Index, Metacognition Index and Global Executive Composite (all t-scores > 2.26 and p-values < 0.05)) at all time points compared with pre-test scores. Scores on Emotional Control and Organization of Materials were significant at post-test and 6 month follow up and the Initiate scale was significant only at post-test. See Figure 4 for the mean scores for all of the time points on the BRIEF subscales.

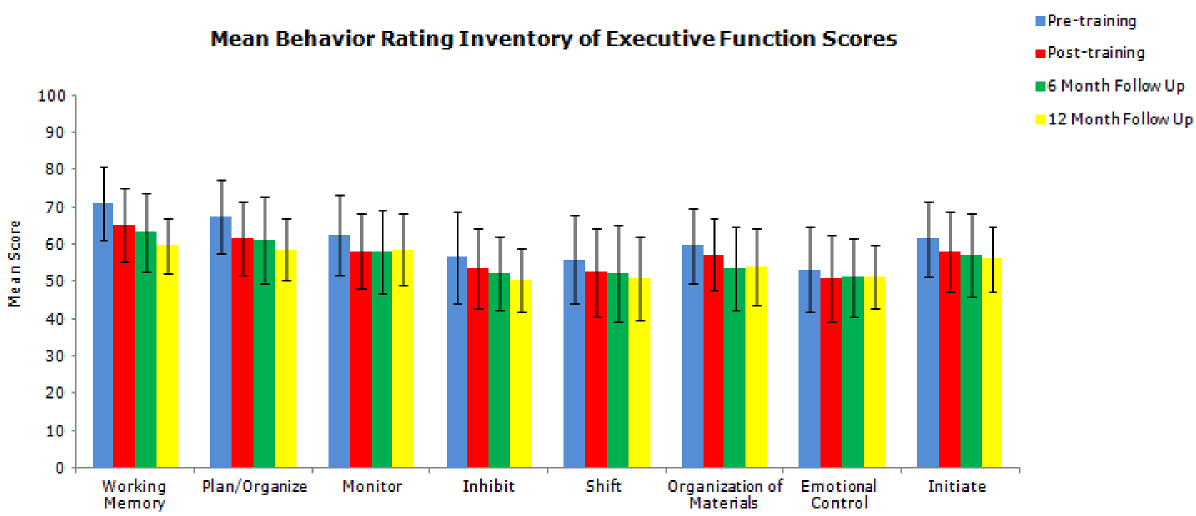


Figure 4. Mean scores on BRIEF subscales as answered by the parents of the children after working memory training. Error bars represent standard deviations.

The share of children in the sample that improved on the BRIEF Working Memory subscale was 64% at post-test, 78% at 6-month follow up, and 100% for the 16 returning participants at one year follow up. See Supplementary Information for the share of participant improvement on the remaining subscales.
Children retained all of the gains reported at post-test on the of Working Memory, Plan/Organize, Monitor, Inhibit, and Shift subscales. On average, children improved an additional 34% at 6 month follow up (134% retention) and an additional 59 % at 12 month follow up (159% retention) compared with post-test. See Table 5 for retention.

	N Post –training	N 6 month Follow Up	6 month Retention	N 12 month Follow Up	12 month Retention
Working Memory	70	27	**131%**	16	**192%**
Plan/Organize	68	27	**110%**	16	**155%**
Monitor	70	27	**103%**	16	**91%**
Inhibit	70	27	**142%**	16	**211%**
Shift	69	27	**107%**	16	**146%**
Organization of Materials	69	29	**261%**	16	**231%**
Emotional Control	70	27	**93%**	16	**83%**
Initiate	70	27	**125%**	16	**159%**
Average			**134%**		**159%**

Table 5. The percentage of the effects on parent rated behavior at the follow up sessions compared with the effects seen directly after the training (post) for children.

ADULTS

A heterogeneous sample of adults with working memory impairments (mainly ADHD) completed the standard protocol (5 days per week for 5 weeks) of Cogmed Working Memory Training. Adults in the sample included males and females aged 51 to 21 (mean = 36.02) years and trained for just under 25 days. Forty-five participants took part in pre- and post-training assessment, with 20 and 15 returning for 6 and 12 month follow up testing respectively (See Table 6).

Sample Size (N)					**Mean (SD)**	
Females	**Males**	**Post-Training**	**6 month Follow Up**	**12 month Follow Up**	**Age**	**Training days**
20	25	45	20	15	36.02 (14.90)	24.93 (0.34)

Table 6. Frequencies of the adult participants at pre-test by gender, as well as frequencies of the total sample at different data collection time points. The mean age and mean number of trained days are also reported.

ASSESSMENT

Adults were assessed with the Spatial Span Forwards and Backwards, Digit Span Forwards and Backwards, and Letter Number Sequencing from the Wechsler Adults Intelligence Scale, 4th Edition (WAIS-IV, 2008). The Spatial Span Forwards and Digit Span Backwards are tasks that are almost identical to those practiced on during training and thus, participant improvement is to be expected. The Spatial Span Backwards and Digit Span Forwards tasks represent near transfer tasks, as they are similar but not exactly the same as those practiced on during training. Letter Number Sequencing is not similar to any trained task and improvement therefore represents transfer or generalization of training to another task requiring working memory. This evaluation reports the longest spans achieved on the WAIS-IV subscales for adults.

Battery	Subscales
Wechsler Adults Intelligence Scale, 4th Edition (WAIS-IV, 2008)	Longest Spatial Span Forward and Backward, Longest Digit Span Forward and Backward, Longest Letter Number Sequencing
Test of Variables of Attention (TOVA)	ADHD score, Response Time Variability, Omission, Commission
Cognitive Failures Questionnaire (CFQ; (Broadbent, Cooper, fitzgerald, & Parks, 1982)	Summary Score
Training Evaluation (DSM-IV Attention)	Attention Summary Score

Table 7. Assessment batteries and subscales conducted at pre- and post-training, as well as 6 and 12 month follow up for adults.

Adults were also assessed with the Test of Variables of Attention (TOVA), a continuous performance test that measures attention and impulse control processes. The raw data reported to Cogmed for this Clinical Evaluation included the ADHD Total Score as well as the Response Time Variability, Commission Errors (impulse control), and Omission Errors (inattention). See above description of the TOVA test.

Behavioral changes post-training were assessed with a Training Evaluation and the Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, fitzgerald, & Parks, 1982). The Training Evaluation is an 18-item measure adapted from the DSM-IV Attention-Deficit/Hyperactivity Disorder Symptom Rating Scale. Participants rated the frequency of just their inattentive behaviors (9-items) on a scale of 0 (never) to 4 (very often), with the highest possible score of 36 representing frequent attention problems. The CFQ is a 25-item self-report scale rating cognitive failures in daily life. Participants rated the frequency of cognitive failures on a scale of 0 (never) to 4 (very often), with the highest possible score of 100 representing frequent failures. See Table 7 for assessments.

RESULTS

Working Memory: On average, 61% of adult End-Users improved significantly on the working memory measures by 26% at post-training (See Supplementary Information for more detail).

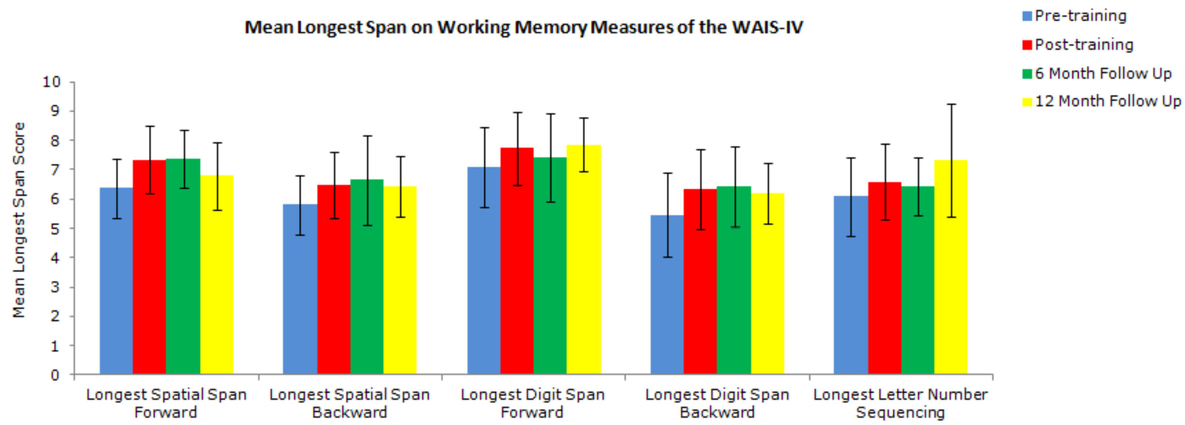


Figure 5. Mean longest span on working memory measures of the WAIS-IV completed by adults directly after training, as well as 6 and 12 months later. Error bars represent standard deviations.

When tested again at 6 and 12 months post training, adults either maintained or improved further the gains observed at post-test. In evaluating the durability of the training effect on working memory measures, there was an average 117% retention of effect at 6 month follow up and 91% retention of effect at 12 month follow up compared to the results observed at post-training. See Table 8 for retention statistics.

	N Post-Training	N 6 Month Follow Up	6 Month Retention	N 12 Month Follow Up	12 Month Retention
Longest Spatial Span Forward	40	21	**103%**	15	**44%**
Longest Spatial Span Backward	40	20	**122%**	14	**90%**
Longest Digit Span Forward	42	21	**52%**	15	**120%**
Longest Digit Span Backward	42	21	**111%**	15	**85%**
Longest Letter Number Sequencing	42	21	**67%**	15	**247%**
Average			**91%**		**117%**

Table 8. The percentage of the effects on the working memory tests that are still evident at the follow up sessions compared with the effects seen directly after the training (post) for adults.

Attention: At post-test, 60% and 64% of participants improved significantly over their pre-test scores on the ADHD Total and Response Time Variability Scores respectively. The improvement on the ADHD Total Score and Response Variability at 6 and 12 month follow-up compared to post-test showed that gains were not only maintained but continued to increase. However, these findings may be reflective of outliers and should be interpreted with caution, with statistics showing over 300% retention. Based on the data, 56% of adults who fit an ADHD profile on the TOVA ADHD Total score prior to training no longer met that profile after training. Over 70% of adults decreased the number of Commission and Omission Errors made at post-test and over 80% of the adults tested at one year follow up also showed decreased errors. The average number of Commission and Omission Errors significantly decreased not just at post-test but continued to either decrease or stay at post-test levels at 6 and 12 months.

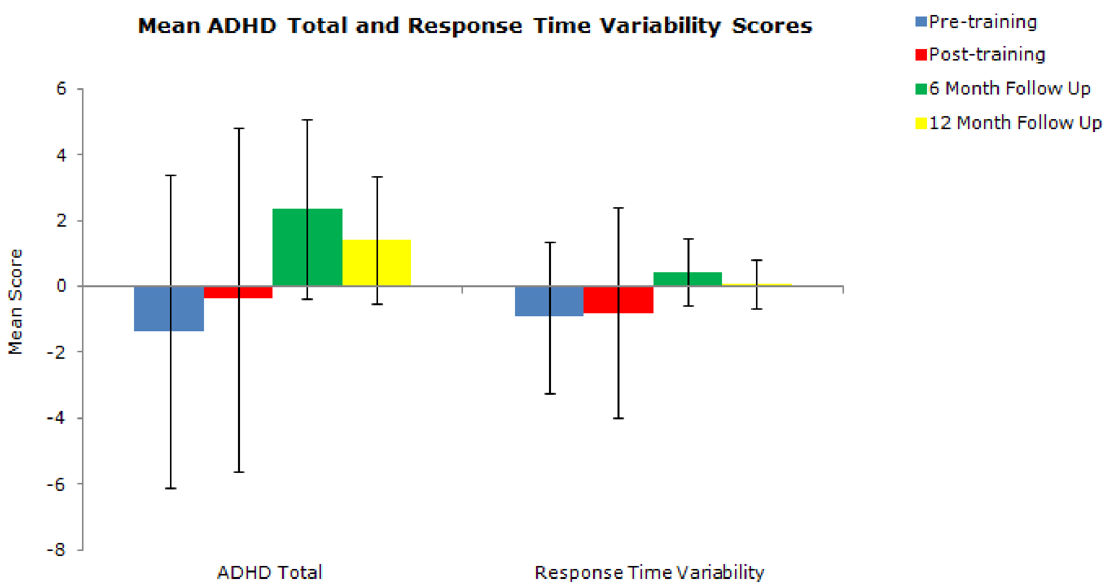


Figure 6. The mean pre-, post-, 6 and 12 month follow up ADHD Total and Response Time Variability Scores for adults that participated in Cogmed Working Memory Training.

Self-Rated Behavior: The share of improvers at post assessment was 86% for the CFQ and 82% for the DSM-IV Inattention scale. The behavioral effects reported by the adults in the sample showed significant improvement for all of the time points on both rating scales (t-scores > 5.73 and p-values < 0.001). The retention of the effects compared to post-test for the CFQ at 6 months was 125% and 100% at 6 and 12 months respectively, with corresponding numbers for the DSM-IV Inattention scale of 127% and 109%. Thus, the improvements on self-reported cognitive failures in daily life and inattentive symptoms post training were either fully maintained or increased at 1 year post Cogmed.

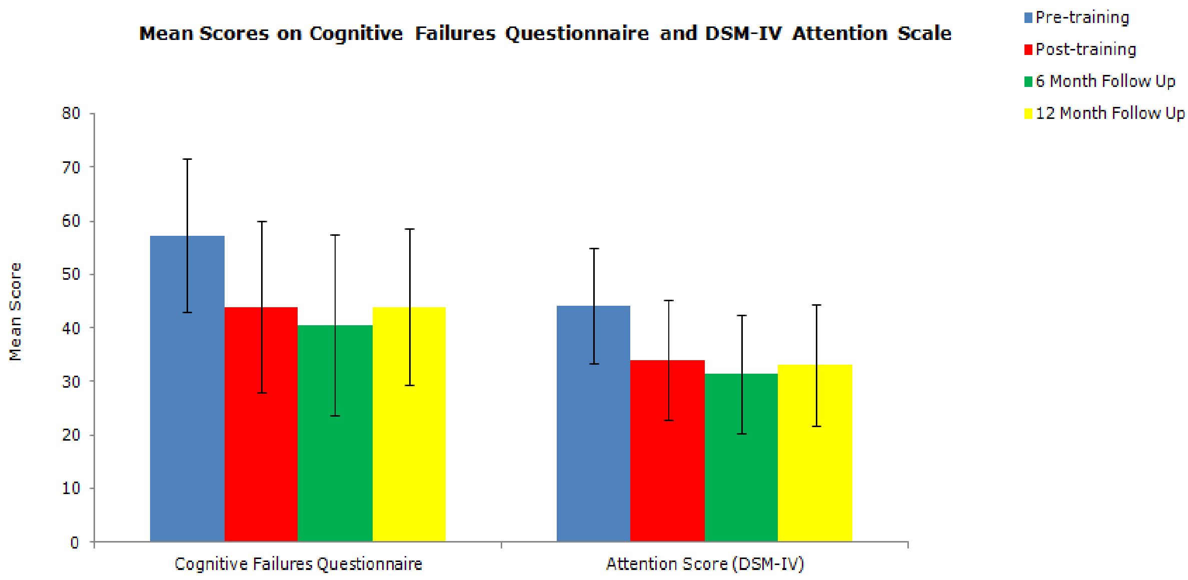


Figure 7. Mean scores for the CFQ and DSM-IV Inattention scale as answered by the adults after Cogmed Working Memory Training. All time points showed significant improvement compared to pre-training ratings. Error bars represent standard deviations.

DISCUSSION

The main findings from this data show that the effects from Cogmed Working Memory Training are largely retained or even further increased at 6 and 12 month follow up. The same pattern can be seen in both children and adults. The majority of the participants in this report had working memory impairments and sought help at the ADD Austin clinic for their difficulties. The sample thus represents a heterogeneous set of individuals with clinically relevant problems that have completed Cogmed in a clinical setting with all of the real world challenges that apply. The data are of great relevance in filling the gap between academic research, often done in quite restricted settings, and the many success stories often reported by clinical patients. Since clinicians collected this data on real End-Users for a full year after completion of the training, no control group data was collected, and the results must thus be interpreted in light of this.

For children, there would be an expected increase in working memory capacity and perhaps also improvement of behavioral problems due to natural development and maturation. The lack of a control group thus makes the retention of the training effects impossible to tease out from the natural development on these abilities and the results are likely a combination of the two. For the adults however, no such increase would be expected and the retention of the effects is likely to be due to the training.

The pattern of results for children and adults was similar, with the tests more similar to the trained ones showing large effects directly after the training. On average the participants in both groups improved by 31% on the working memory tasks from either the WISC-IV or WAIS-IV. These findings are remarkably consistent with a recent data analysis of 2,498 Cogmed End-Users from clinical practices in North America, showing an average improvement of 30% on the Cogmed Progress Indicator working memory task (adapted from the Odd One Out of the Automated Working Memory Assessment (AWMA; Alloway, 2007)). The retention of effects was on average 78% for children and 91% for adults at 6 month follow up and 67% and 117% respectively one year post-training. The effects for the adult sample may imply that the improvements in fact increase with time and may reflect that the new capacity levels of working memory can enable more advanced cognitive activity, possibly strengthening the improvements further.

Results from the TOVA test implied that both children and adults demonstrated decreased behaviors associated with attention deficits (increased ADHD Total Score), including greater consistency in responding to correct stimuli (decreased Response Time Variability), greater inhibition in preventing responses to incorrect stimuli (decreased Commission Error), and increased attention in responding to correct stimuli (decreased Omission Error). The retention of effects at 6 and 12 month follow up was for both groups either the same or larger than at post-test, although outliers may have inflated the extent of additional improvement.

Both children and adults also improved on behavioral ratings after training. Notably, children improved at post-test on parent-rated inattention on the DBRS by 33%. This finding is consistent with the average 30% improvement of 769 children on the DSM-IV Inattention Scale in Clinical Evaluation Series Part I. Not only were effects on behavior found at post-training, but these gains were also largely retained or even increased with time for both children and adults. This again could imply that a portion of the effects from Cogmed Working Memory Training take some time to appear as behavior may be more sluggish to change. Overall, children improved over their inattention scores by an average 21% at 6 months and by 58% at 1 year. Adults improved their self-rated inattention by an additional average 26% at 6 months and 5% at 1 year. On the Cognitive Failures Questionnaire (CFQ), 86% of adults reported a 23% decrease in cognitive failure in everyday life. This is quite consistent with 76% of the adult Canadian sample reporting a 27% decrease on the CFQ in the Clinical Evaluation Series Part I. Further, 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). Because the ratings by parents and the self-reported effects by trained adults were obviously not blinded to the intervention, it is likely that there is an expectation effect possibly inflating the results to a certain degree. However, this effect should not be larger at follow up than immediately post training and does thus not explain the observed pattern.

These results show that on both objective neuropsychological tests and on behavioral rating scales, there is evidence of retained or even increased effects up to one year post completion of Cogmed Working Memory Training. Despite the lack of a control group, expected developmental effects cannot explain this pattern in adults, as it may in children. These findings are very promising and should encourage researchers and clinicians to collect more data and follow up trainees for longer periods in order to get the full picture of the training effects seen after Cogmed.

SUPPLEMENTARY INFORMATION

Data Analysis: The data were analyzed separately for children (< age of 18) and adults. There was a share of participants that returned for either a 6 month follow up or a 12 month follow up assessment or both. In order to investigate if there was a selection bias in the 12 month returnees (e.g. Only the most successful trainees returned for a follow up), the immediate training results from the follow up samples were compared with the results from the ones that did not return, showing no significant difference between them immediately after training. Regression analyses were run for each test to see if the returning sample improved significantly differently from the entire sample, directly after training (post session). The post-score was set as the dependent variable and the following variables were set as the independent: group (no follow up vs. Follow up who were assessed at 12 months), age, sex, days trained, pre-training scores. The results indicated that the End-Users returning for the 12 month follow up session did not differ significantly from the end-users only being assessed directly after training (all *Betas* between -0.11 and 0.07, and all p-values > 0.1).Therefore, the results from the follow up sessions were presented together with the sample that was tested at pre- and post- sessions only.

Working Memory Data (Children):

	Spatial Span Forward			**Spatial Span Backwards**		
	Post-training	6- months	12-months	Post-training	6- months	12-months
Improvers	82% (55)	73% (19)	81% (13)	75% (50)	74% (20)	75% (12)
Percentage Improvement	41%	40%	32%	39%	30%	29%
Non-Improvers	18% (12)	27% (7)	19% (3)	25% (17)	35% (7)	25% (4)

	Digit Span Forward			**Digit Span Backwards**		
	Post-training	6- months	12-months	Post-training	6- months	12-months
Improvers	56% (34)	54% (13)	60% (9)	63% (39)	62% (16)	86% (12)
Percentage Improvement	26%	32%	39%	42%	50%	50%
Non-Improvers	44% (27)	46% (11)	40% (6)	37% (23)	38% (10)	14% (2)

	Letter Number Sequencing		
	Post-training	6- months	12-months
Improvers	59% (41)	56% (15)	40% (6)
Percentage Improvement	31%	43%	27%
Non-Improvers	41% (28)	44% (12)	60 % (9)

Behavioral Rating Scales (Children):

	Working Memory			Plan/Organize			Monitor		
	Post-training	6-months	12-months	Post-training	6-months	12-months	Post-training	6-months	12-months
% of Improvers (number)	64% (45)	78% (21)	100% (16)	18% (12)	15% (4)	6% (1)	23% (16)	22% (6)	19% (3)
% Non-Improvers (number)	36% (25)	22% (6)	0% (0)	82% (56)	85% (23)	94% (15)	77% (54)	78% (21)	81% (13)

	Inhibit			Shift			Emotional Control		
	Post-training	6-months	12-months	Post-training	6-months	12-months	Post-training	6-months	12-months
% of Improvers (number)	27% (19)	19% (5)	25% (4)	30% (21)	22% (6)	25% (4)	70% (49)	68% (19)	63% (10)
% Non-Improvers (number)	73% (51)	81% (22)	75% (16)	70% (48)	78% (21)	75% (12)	30% (21)	32% (9)	37% (6)

	Organization of Materials			Initiate		
	Post-training	6-months	12-months	Post-training	6-months	12-months
% of Improvers (number)	75% (52)	86% (24)	67% (10)	30% (21)	70% (19)	75% (12)
% Non-Improvers (number)	25% (17)	14% (4)	33% (5)	70% (49)	30% (8)	25% (4)

Working Memory Data (Adults):

	Spatial Span Forward			Spatial Span Backwards		
	Post-training	6- months	12-months	Post-training	6- months	12-months
Improvers	59% (23)	74% (14)	60% (9)	56% (22)	61% (11)	64% (9)
Percentage Improvement	26%	25%	24%	29%	30%	32%
Non-Improvers	41% (16)	26% (5)	40% (6)	44% (17)	39% (7)	36% (5)

	Digit Span Forward			Digit Span Backwards		
	Post-training	6- months	12-months	Post-training	6- months	12-months
Improvers	56% (23)	40% (8)	53% (8)	66% (27)	70% (14)	67% (10)
Percentage Improvement	21%	20%	25%	32%	43%	32%
Non-Improvers	44% (18)	60% (12)	47% (7)	34% (14)	30% (6)	33% (5)

	Letter Number Sequencing		
	Post-training	6- months	12-months
Improvers	66% (27)	50% (10)	53% (8)
Percentage Improvement	22%	31%	31%
Non-Improvers	34% (14)	50% (10)	47% (7)

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APPENDIX D

QUOTES THAT SUPPORT COGMED CLAIMS

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 trianing 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 difficult 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] "Learning strategies for recall seems to be of no benefit for any information other than that for which the strategy is being learned. However, rather than learning strategies, the method used in studies of brain plasticity, particularly in primates, was repetitive skill learning. To have an observable effect on the brain, the training had to be of sufficient intensity, in terms of both sessions per day and number of days, as well as repetitive and daily; further, the task had to be of sufficient difficulty, the degree of which is manipulable through automatic methods of adaptation that make the task harder as soon as the performer improves. These principles could also be applicable to working memory training."

Reference: Klingberg, T. (2008). The overflowing brain: Information overload and the limits of working memory. New York, NY: Oxford University Press.

[10] "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., & Rönnberg, J.(2010). Computerized working memory training in a group of patients suffering from acquired brain injury. *Brain Injury*, *24*(10), 1173- 1183.

[11] "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

[12] "… 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., 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.

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

[13] "…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., 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

[14] "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

[15] "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.

[16] "…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

[17] "…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

[18] "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

[19] "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

[20] "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; Klilngberg 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

[21] "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

[22] "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 othre 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

[23] "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

[24] "…both younger and older adults receiving adaptive training showed larger performance gains in a test mesauring 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

[25] "Structured and intense computerized WM training improves subjects' cognitive funcitoing as mesured 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., & Rönnberg, J.(2010). Computerized working memory training in a group of patients suffering from acquired brain injury. *Brain Injury*, *24*(10), 1173- 1183.

[26] "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. Gains in WM and behavioral outcomes are sustained over the long term

[27] "In this RCT, adaptive WM training significantly boosted performance on untrained WM tasks in children with low WM. This enhancement was substantial in magnitude and was partially sustained for 12 months. Children who completed adaptive training made significantly greater improvements in tests of visuo-spatial STM and verbal and visuo-spatial WM than either children who completed a non-adaptive version of training or those who received no intervention. "

Reference: Dunning, D.L., Holmes, J. & Gathercole, S.E. (2013). Does working memory training lead to generalized improvements in children with low working memory? A randomized controlled trial. *Developmental Science*, *16*(6), 915 -925. doi: 10.1111/desc.12068

VII.WM is commonly impaired in individuals with ADHD

[28] "WM processes have been implicated in theoretical models of attention deficit/hyperactivity disorder (ADHD) (Barkley, 1997; Rapport et al., 2001). This is not surprising given that converging data from neuropsychological and neuroimaging studies implicate frontostriatocerebellar dysfunctions in ADHD (Castellanos et al., 2002; Durston, 2003; Giedd et al., 2001). Finally, given the clinical efficacy of stimulant medications in treating ADHD, catecholamine dysregulation has been implicated in the etiology of ADHD (Biederman and Faraone, 2002; Levy and Swanson, 2001). Hence, children with ADHD may exhibit WM deficits because of dysfunction to frontostriatocerebellar brain circuits and/or because of dopaminergic dysregulation (Levyand Swanson, 2001)."

Reference: Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children Attention –Deficit/Hyperactivity Disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *44*(4), 377-384.

[29] "Children with ADHD exhibit moderate to large impairments in WM, with the magnitude of the impairment varying according to the modality of the WM task. Large impairments were evident in both the spatial storage and spatial CE domains, whereas more modest deficits were found in verbal storage and verbal CE domains."

Reference: Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children Attention –Deficit/Hyperactivity Disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *44*(4), 377-384.

[30] "Children with ADHD perform poorly on tests of visuo-spatial STM…and both verbal and visuo-spatial working memory tasks…Their verbal STM appears to be relatively preserved, suggesting that verbal storage problems are not fundamental features of the disorder…Our own data from a sample of 83 children age 8-11 years with a clinical diagnosis of combined type ADHD concur with this pattern of impairment. We found that whilst verbal STM was relatively intact in this sample, visuo-spatial STM scores were in the low average range with substantial deficits in verbal and visuo-spatial working memory…Of the total sample, 19.8% had impairments in verbal STM, which is close to the level of 16% that we would expect in a

normal population. However, 38.6% had deficits in visuo-spatial STM, over half had impairments in verbal working memory (50.6%) and 63.9% had very poor visuo-spatial working memory."

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 Developmental Disorders and Interventions, Volume 39* (pp. 1- 43). Burlington: Academic Press.

[31] "Collectively, ADHD-related central executive deficits appear to be a particularly promising target for intervention given (a) large magnitude effect size estimates (ES = 2.01 to 2.05; Kasper et al., 2012) indicating that at least 81% of children with ADHD have deficits in the working component of working memory, and (b) the strong association between central executive deficits and ADHD-related impairments in core behavioral symptoms and learning/educational outcomes (Burgess et al., 2010;Rapport et al., 2008, 2009)."

Reference: Rapport, M.D., Orban, S.A., Kofler, M.J., & Friedman, L.M. (2013). Do programs designed to train working memory, other executive functions, and attention benefit children with ADHD? A meta-analytic review of cognitive, academic, and behavioral outcomes. *Clinical Psychology Review*, *33*(8):1237-1252. doi: 10.1016/j.cpr.2013.08.005

[32] . "Converging evidence indicates that children with ADHD are impaired in all three components of working memory, with the largest deficits found in the domain-general central executive (CE) system, followed by visuo-spatial (VS) storage/rehearsal and then phonological (PH) storage/rehearsal subsystems (i.e., deficits in CE > VS > PH; Martinussen et al., 2005; Rapport et al., 2008)."

Reference: Kofler, M.J., Rapport, M.D., Bolden, J., Sarver, D.E., & Raiker, J.S. (2010). ADHD and working memory: The impact of central executive deficits and exceeding storage/rehearsal capacity on observed inattentive behavior. *Journal of Abnormal Child Psychology*, *38*, 149-161. doi: 10.1007/s10802-009-9357-6

VIII. Groups with ADHD have demonstrated gains in WM capacity post Cogmed training

[33] "…there is solid evidence that Cogmed working memory training improves working memory capacity as well as top-down attention, measured both with cognitive tasks and estimates of attention in everyday life. Changes in both working memory and attentive behavior are relevant for children in the classroom situation independent of any theoretical disputes about the true nature of working memory capacity."

Reference: Klingberg, T. (2012). Is working memory capacity fixed? *Journal of Applied Research in Memory and Cognition*, *1*(3), 194-196. doi: 10.1016/j.jarmac.2012.06.003

IX. Improvements in symptoms of inattention have been shown after Cogmed training in groups with ADHD and other clinical diagnoses using behavioral rating scales (e.g. the inattention subscale from DSM-IV)

[34] 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.

[35] 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