Cogmed Research Claims & Evidence

Cogmed Working Memory Training™
Pearson Clinical Assessment

Version 1.2

Prepared by:
Kathryn Ralph
Cogmed Research Coordinator
kathryn.ralph@pearson.com
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. In some studies of children with ADHD, increased WM has also shown transfer to executive functions such as attention, inhibition and reasoning. Cogmed studies have investigated the impact of WM training from the most fundamental level of genetics (Brehmer et al., 2009) and biochemical functioning (McNab et al., 2009) to its impact on learning (Holmes et al., 2009) and behavioral expression (Klingberg et al., 2005).

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 working memory 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 researchers who have used Cogmed are also presented here.

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
COGMED

A FORERUNNER IN THE FIELD OF EVIDENCE-BASED COGNITIVE TRAINING

I. What makes Cogmed an evidence-based intervention?

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

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

The utility of Cogmed Working Memory Training can be conveyed through a series of claims linking the Cogmed training protocol to specific improvements in WM capacity for people with and without working memory deficits. Evidence can be presented at varying levels of detail depending on the audience being addressed: broad, synopsis or specific. Broadly, one can provide evidence for each claim by making reference to a Cogmed study published in a peer-reviewed journal that supports the claim. Beyond citing particular training studies, the article abstract is a more detailed source for a synopsis of the evidence for a particular claim. In addition, review articles and summaries of training studies available on the Cogmed website can provide the necessary background. For the most in depth evidence for a Cogmed claim, it is vital to go directly to the text, to read the published Cogmed articles and to take note of particular quotes that directly support each claim.
# Cogmed Working Memory Training™ Published Research

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Claims and Evidence

**EXECUTIVE SUMMARY**

I. WM is key to attention and learning

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

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

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

V. Improved WM generalizes to improvements in daily functioning

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

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

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

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

I. WM is key to attention and learning

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

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

Reference(s): Klingberg, 2010⁴; Holmes et al., 2009²; Holmes et al., 2010³

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

WM can be improved using the adaptive Cogmed program and the prescribed training protocol. Cogmed users train intensively for 30 to 40 minutes, 5 days a week for 5 weeks. It is during this sustained training period that the user engages in 8 out of 12 visuo-spatial and verbal exercises per day that continually adjust in difficulty in accordance with user performance. In a 2011 review of interventions shown to aide executive functions in children, researchers noted that executive functions such as working memory must be continually challenged to see improvements and non-adaptive training does not lead to gains.⁴ This assertion is supported by blinded,
randomized, controlled trials comparing adaptive Cogmed training to both non-adaptive Cogmed training\(^5\) and non-adaptive commercially available video games.\(^6\) Additionally, research with children with cochlear implants\(^7\) and adults with acquired brain injury\(^8\) 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.

Researchers have also demonstrated that WM gains have generalized beyond improvements in task-specific performance by using non-trained assessments of working memory.\(^9\) Non-trained tests measure the underlying ability (i.e., WM) that was trained but with assessments that differ in configuration, presentation, response mode. Thus, adaptive training has led to improvements in WM that cannot be attributed to practice. For example, in a study of children with ADHD by Klingberg et al. in 2005, users who did adaptive training showed a 19\% improvement on a non-practiced visuo-spatial WM task compared to the non-adaptive training group.\(^10\) Importantly, over 20 published training studies that have used the adaptive Cogmed solution and protocol have resulted in improvements in WM capacity post-training.

**Reference(s):** Diamond & Lee, 2011\(^4\); Holmes et al., 2009\(^5\); Thorell et al., 2009\(^6\); Kronenberger et al., 2011\(^7\); Lundqvist et al., 2010\(^8\), Holmes et al., 2009\(^9\); Klingberg et al., 2005\(^10\)

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

Gains in working memory capacity after Cogmed training have been observed in preschool children, school-aged children, adolescents and adults. In 2009, Thorell et al. found that it was possible to train WM and that training effects transferred to non-trained WM tests in 4 and 5 year olds.\(^11\) These findings are supported by improvements in visuo-spatial and verbal WM in a study of pre-school children by Bergman-Nutley et al. (2011).\(^12\)

School-aged children have also shown improvements in WM post-Cogmed training. Klingberg et al. (2002) observed a significant effect of training on the span-board, a non-trained assessment of visuo-spatial WM in children ages 7 to 15 years. In 2005, Klingberg et al. replicated these findings in a group of children, 7 to 12 years of age, with improvements in both verbal WM (digit-span) and visuo-spatial WM (span-board).

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

Adults have also shown improved WM after Cogmed training. In a poster presented at the 2008 meeting of the Cognitive Neuroscience Society, Westerberg and colleagues revealed that adaptive training of both normally 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. Older adults (60 to 70 year olds) who did adaptive training not only improved compared to their age-matched peers who did not train adaptively but also, achieved WM scores comparable to 20-30 year olds who did not train adaptively. Such improvements in WM and attention were also observed by Brehmer et al. in a study of 24 older adults (ages 60 -70 years).\textsuperscript{13}

Reference(s): Thorell et al., 2009\textsuperscript{14}, Bergman-Nutley et al., 2011\textsuperscript{15}, Klingberg et al., 2002, Klingberg et al.,2005, Løhaugen et al., 2010, Brehmer et al., 2011\textsuperscript{13}

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

Improvements after Cogmed have been shown in physiological, neuropsychological and behavioral assessments. Neuroimaging studies using PET and fMRI scans have revealed that improvements in WM capacity post Cogmed are associated with changes in the density of cortical D1 dopamine receptors and decreases in D1 dopamine receptor binding potential, which in turn impacts the transmission of dopaminergic signals.\textsuperscript{14} fMRI has also shown increased activation in the frontal and parietal regions of the brain that support WM function.\textsuperscript{15\&16}

Neuropsychological testing in numerous studies, including a 2005 study of ADHD children by Klingberg et al., have also shown that participants improved in one or more areas after Cogmed including: WM capacity, attention, inhibition, and non-verbal reasoning. Effects were also evident in parental ratings of inattention and hyperactivity/ impulsivity both immediately post Cogmed and at follow-up three months later. 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.\textsuperscript{17} Mezzacappa and Buckner found that teacher ratings of ADHD symptoms decreased by 26% in a sample of 9 children, ages 7 to 12.\textsuperscript{18}

Reference(s): McNab et al., 2009\textsuperscript{14}, Olesen et al., 2004\textsuperscript{15}; Westerberg & Klingberg, 2007\textsuperscript{16}; Klingberg et al., 2005, Beck et al., 2010\textsuperscript{17}, Mezzacappa & Buckner, 2010\textsuperscript{18}

V. Improved WM generalizes to improvements in daily functioning

In addition to laboratory measures of WM and attention, participants also improve on self-reported assessments of daily functioning following WM training. Beyond the gains reported for improved attention and decreased ADHD symptoms (Klingberg et al., 2005; Beck et al., 2010; Mezzcappa & Buckner, 2010; Gibson et al., 2010), Cogmed users have reported decreased
cognitive failures and improved occupational outcomes. In a study by Westerberg et al., 2007, stroke patients who trained with Cogmed not only improved significantly on the span-board (visuo-spatial WM), digit span (verbal WM) and PASAT (WM and attention), but also on the Cognitive Failures Questionnaire (CFQ), a self-report behavioral assessment of cognitive failures. In a 2008 poster, Westerberg et al. also revealed that two groups of normally aging adults, ages 20-30 years and 60-70 years, reported decreased cognitive failures on the CFQ after Cogmed.

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. In another study of brain injured adults, Johansson and Tornmalm (2011) also found decreased report of cognitive failures on the CFQ and improved occupational performance on the COPM.

Reference(s): Klingberg et al., 2005; Beck et al., 2010; Mezzcappa & Buckner, 2010; Gibson et al., 2010; Westerberg et al., 2007; Lundqvist et al., 2010; Johansson & Tornmalm, 2011

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

Researchers have observed training-related gains in working memory that have been sustained for up to 6 months post-intervention. Increases in WM capacity have also transferred to behavioral improvements that have been sustained for up to 6 months. After Cogmed, the type of behavioral improvement is dependent on the population studied and on the core areas of deficit experienced by that population. In one study of hearing impaired children, Kronenberger et al. (2010) observed increased performance on a sentence repetition task at both post-intervention and 6 month follow-up. Maintenance of gains relating to language, sentence perception and speech production may be crucial for hearing impaired children and could have positive impacts on academic and social outcomes as they develop. In 2011 study, Johansson and Tornmalm found that brain injured adults self-reported decreased cognitive failures immediately after training that were maintained at 6 months.

Reference(s): Holmes et al., 2009; Holmes et al., 2010, Kronenberger et al., 2010, Johansson & Tornmalm, 2011
VII. Effects of WM training are specific: WM and its derived functions are improved, but there is no across-the-board-improvement

WM training improves WM capacity. Transfer of training effects have been seen in the improved attention, reasoning, inhibition, academic ability, daily functioning and occupational performance of trained populations. Enhancement of these related systems are not surprising, as they are linked functionally and possibly share common neural networks. It is important to note that Cogmed does not claim to improve all brain functions nor improve systems distinct from WM. For example, Cogmed has been shown to improve WM but not to improve long-term memory in general. Cogmed has been shown to improve functions related to IQ in ADHD groups such as reasoning and attention but, not to improve global scores of IQ that depend on other factors such as experience and knowledge. Even in the sphere of learning, Cogmed has led to improvements on WM-related reading functions such as comprehension but, not orthographic reading that involves understanding letters and spelling.

Reference(s): Westerberg et al., 2007; Holmes et al., 2010; Dahlin, 2011

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

Although improvements in WM have been observed in all ages and various WM profiles, including typically functioning pre-school children (Thorell et al., 2009; Bergman-Nutley, 2011) and adults (Brehmer et al., 2011; Bellander et al., 2011), Cogmed is perhaps most beneficial and yielding of larger real world benefits for WM impaired individuals. However, WM training should not be considered an intervention for only individuals meeting specific diagnostic criteria for a disorder. Instead, Cogmed should be implemented with participants who exhibit constraint in WM. As evidenced in Holmes et al., 2009, children screened for low WM experienced improved WM, instruction following and math ability regardless of whether they had predetermined learning disabilities, ADHD or any other clinical disorder. Similarly, Dahlin (2011) posited that working memory training would be useful for children with reading comprehension problems and attention problems after training 42 school children with “special needs”. For some, WM constraint may not be a co-morbid condition but instead, a limitation that has been present since birth or that has emerged over the normal course of development.

Reference(s): Thorell et al., 2009; Brehmer et al., 2011; Bellander et al., 2011; Holmes et al., 2009; Dahlin, 2011
WHAT CANNOT BE CLAIMED?

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

**ADHD**

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

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

**Learning**

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

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

**Aging**

What evidence is there for improvements in normally aging adults after Cogmed?
It is well established that WM capacity increases with development until about 20 years of age and then begins decline with the normal aging process. Cogmed has been shown to improve WM in younger adults, ages 20 to 30 years, and older adults, ages 60 to 70 years. A study by Westerberg et al. (2008) revealed unsurprisingly 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 not trained, but also improved to levels comparable to that of 20-30 years olds who had not trained.

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.
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.”


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)”.


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).”

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

4. “EFs must be continually challenged to see improvements. Groups assigned to the same program, but without difficult increasing, do not show EF gains.”


5. “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...”


6. “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.”


7. “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.”


8. “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.”


9. “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.”


10. “… 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.”


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

11. “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).”

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


13. “...older adults improved their WM performance through training and there was transfer of gains to non-trained WM tasks tapping sustained attention and episodic memory.”


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

14. “...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...”


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.”

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.”


17. “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.”


18. “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.”

V. Improved WM generalizes to improvements in daily functioning

19. “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.”


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


21. “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.”

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

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


23. 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.”


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


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

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

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


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


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


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

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

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


working memory in children with ADHD. *Applied Cognitive Psychology, 24*(6), 827-836. doi: 10.1002/acp.1589


