Cogmed Working Memory Training®

Claims & Evidence
Complete Version

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Clinical Assessment

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Introduction

Working memory (WM) involves the ability to focus on a task, keep information in mind and to do mental processing of that information. It is a fundamental brain function that underlies most of our conscious mental work. WM is required in order to understand the content while reading and it is the brain's work space when solving a math problem. It's used when following instructions, reading a map or simply carrying on a conversation. It is limited in its capacity and sensitive to distractions. Impairments in WM are often seen in individuals with ADHD, acquired brain injury and many other common conditions resulting in difficulties with concentration and learning. This in turn may lead to behaviour issues, feelings of low self-confidence and social problems. Until earlier this century, it was presumed that WM capacity was a trait that was rather static, so that once adult maturation of the brain was reached, the WM capacity would be fixed. Based on neuroscientific findings indicating plasticity of the areas of the brain that encompass WM capacity, an innovation from the Karolinska Institute in Sweden was born, demonstrating that WM could in fact be trained to enable more and better information processing (1-4). These discoveries were the foundations on which Cogmed Working Memory Training (CWMT) was created.

CWMT has since continued to develop as an evidence-based intervention and great care is taken to ensure that the claims that are made by Cogmed regarding the effects are supported by published research. As of May 2015, there are 55 original research studies examining the effects of CWMT published in peer-reviewed journals. The effects demonstrated in those are the basis for the claims that Cogmed currently makes. This document describes the policy underlying the formation of a Cogmed claim, as well as an elaboration of the evidence supporting each claim.

The importance of WM in everyday life, in learning, and information processing is self-evident, and makes WM training both relevant and compelling to pursue. While WM capacity itself is relatively easy to quantify using standardized laboratory measures, assessing it and related functions in everyday life is much more challenging. The lack of instruments that can quantify a change in the number of WM related failures occurring during a classroom lecture, a phone conversation, a meeting, or a shopping run to name a few examples, is a reality and a boundary within which the evidence base lies. While the technology to track brain activity and function in everyday situations, across large periods of time may be within a theoretically possible grasping point, it is far from the reality of where the academic research field currently operates. Despite this limitation, evidence of benefits related to CWMT in everyday situations is emerging.

Methodological considerations

Control groups

For a study to be able to adequately answer the question of interest it is important to have a control group to which any changes in performance or behaviour can be contrasted. In the case of CWMT this typically includes controlling for test-retest improvements, that is improvements in test performance that occur when the test is repeated. This is controlled for in both studies using active control designs and in studies using a waitlist or passive control, where both the active training group and the comparison group perform the test before and after the intervention period. The design of using an active control group also controls for the time spent with the intervention as well as time spent interacting with researchers or other contact persons. The type of design that is optimal for a study depends on the question(s) being asked. For example, if one wants to compare an intervention with the treatment a person would typically receive, then a treatment as usual, or waitlist control group is valuable. This will answer the question of whether an intervention is a valuable addition to the a person's well being. However, if one wants to answer more specific questions concerning specific components of an intervention, then one needs to have an active control condition where all components except for the one of interest are held the same, or as similar as possible. In initial studies of CWMT, researchers were particularly interested in investigating the adaptive component of training and therefore used a program that was identical to normal CWMT except for the adaptive level algorithm. Since the initial studies were published the effect of adaptive WM training has been well demonstrated and the use of a non-adaptive control is not necessarily optimal for studies investigating other aspects of CWMT.

Inferential statistics

In statistical analyses, one hopes to make inferences about a certain population. Since it is most often impossible to test the whole population of interest, one must draw a smaller study sample that is assumed to reflect this population. However this is not always the case and it is impossible to know whether a sample is or is not reflective of the population as a whole. When a hypothesis is posed in an experiment there are two types of risks for drawing false conclusions that stem from a discrepancy between the sample population included in the study and the larger population of interest. A Type I error (or false positive) means finding an effect that is not actually there in the population as a whole. The probability of making this type of error is usually designated by α. A Type II error (or false negative) means failing to find an effect that is actually there in the population as a whole. The probability of making this type of errors is usually designated by β. The general statistical convention is to allow a maximum α of 5% (risk for a Type I error) and a maximum β of 20% (risk of a Type II error).

Type I error

In the case of intervention studies, the risks associated with drawing false positive conclusions are that interventions that are not actually effective will be deemed as effective, possibly causing people (more research/funding/individuals) to “waste” their time and money with little or no benefit as a result. This is of course of ethical concern and is one of the reasons to why the α level is set rather low (5%). In studies where many independent tests (on independent data sets) are run, the risk of a Type I error increases (for the study as a whole). One can decrease this risk by setting an α level cut-off that is even lower using a method for correcting for multiple comparisons (e.g. Bonferroni correction). However, this is sometimes done also when the tests are not independent, causing the α to be unnecessarily strict and consequently increasing the risk of a Type II error.

Type II error

The consequence of drawing false negative conclusions are equally problematic. In the case of intervention studies, this would imply that a research study concludes that there is no real effect following an intervention, when in fact the intervention is effective in the population as a whole. This could mean that individuals/clinicians/researchers would be discouraged from pursuing the intervention, leading to missed remediation or further exploration of the findings. This is of ethical concern as it may discourage development and further pursuit in effective treatments or interventions, causing the progress within a research field to stagnate. Consequently, it may withhold useful remediation from individuals who would benefit from it.

The statistical power of a study (1-β) which is the probability of finding a true effect, is affected by the study sample size, the effect size and set α level. A study is considered “underpowered” when the sample size is too small considering the expected effect sizes, leaving the study with a low probability of identifying real effects that would be observed in the whole population. Therefore, it is of ethical importance not to overstate the impact of non-significant findings *if the study is underpowered to detect relevant effect sizes*. Thus, one should always consider effect sizes in addition to the statistical significance (α) using for example methods of meta-analyses. While such methodologies have advantages in terms of their rigour, they do not meet demands of summarizing results more swiftly. Due to the quickly evolving literature on CWMT, Cogmed employs a policy to evaluate evidence from studies including a set of criteria for when such evidence is to be considered sufficiently strong for Cogmed to support a claim. These are stated below.

Evaluation of research and formation of claims

General quality of research

For a study to be considered to be of sufficient quality to contribute to formation or revision of a claim, the criteria listed below must be met. These closely match the criteria listed for evaluation of "effectiveness of research based psychotherapies for youth" by Silverman & Hinshaw (2008).

- Reliable and valid outcome measures
- Design that supports the hypothesis
- Statistical methods that support the question being investigated
- Study on recommended population according to Cogmed training manual (excluding studies where majority of sample has severe oppositional disorder, high comorbidity, intellectual disability (IQ <70), severe depression or anxiety).
- Implementation with high fidelity to Cogmed recommendations regarding coaching method, study population, and high quality of training.

Formation of a claim

Randomized controlled trials (RCT) and controlled studies that investigate the effects of CWMT and meet the standards above for quality will be considered when forming a claim.

Criteria for forming a claim are as follow (at least one out of the three must be fulfilled):

- An effect is observed in at least two RCTs.
- An effect is observed in at least three controlled studies.
- An effect is observed in one RCT and in two controlled studies.

Disputable results of effects

Claim criteria: Assuming that the probability of making a Type I vs Type II error is set to the conventional cut-off levels (maximum α of 5% and maximum β of 20%), it is Cogmed policy to revise a claim when a study reporting a statistically significant negative finding with sufficient power and overall quality is replicated twice (also with sufficient power, i.e. 3 well powered studies disputing a claim).

Cogmed Claims

Based on the above criteria and assuming good fidelity to the Cogmed method, Cogmed supports the following claims:

1) CWMT leads to sustained improvements in working memory, from childhood to adulthood, as seen in
   a) preschoolers (6, 16, 41, 42)
   b) children and adolescents (1, 3, 7, 13, 18, 25-27, 33, 34, 36, 45, 52, 53)
   c) adults and old adults (5, 15, 22, 28, 37, 38, 46, 47)
2) CWMT leads to sustained improvements in attention seen in both
   a) subjective measures of attention (3, 11, 14, 18, 26, 38, 31, 47)
   b) and objective measures of attention (5, 6, 15, 22, 25, 28)
3) Improvements in working memory following CWMT are associated with changes in functional brain activity
   a) seen as changes in the neurochemistry (9), functional activity related to working memory (2, 4, 22), and functional connectivity at rest (52)
4) Learning outcomes in reading (13, 35, 45) and math (34, 43, 45) improves for many underperforming students following CWMT
5) In clinical trials, CWMT has been shown to improve attentional problems in many with ADHD (3, 11, 25, 47)
   a) as evident in rating scales (3, 11, 47)
   b) or measured with objective measures (25)
6) Adult Cogmed users report improved functioning in daily life (5, 28, 47)

Elaboration of the evidence underlying each claim

This section discusses each of the claims and highlights specific findings that are especially impactful given the design or methods used in the particular studies.

Claim 1

CWMT leads to sustained improvements in working memory, from childhood to adulthood, as seen in

a) preschoolers (6, 16, 41, 42)
b) children and adolescents (1, 3, 7, 13, 18, 25-27, 33, 34, 36, 45, 50, 52, 53)
c) adults and old adults (5, 15, 22, 28, 37, 38, 46, 47, 49)

The claim that CWMT improves WM is at the very core of the purpose of this training method and is supported by 25 controlled studies and is well substantiated through independent meta-analyses (Melby-Lervåg & Hulme, 2012; Rapport, 2013, Cortese et al, 2015; Spencer-Smith & Klingberg, 2015). This was first demonstrated in the original studies by Klingberg and colleagues (2002 and 2005) which ultimately took this research innovation from the Karolinska Institute (Stockholm, Sweden) to be available commercially. This has since been replicated by independent research groups worldwide in studies of high methodological rigour (blinded, randomized controlled trials) (16, 25-27, 33, 41, 50). The fact that WM is proven to be malleable with practice is a groundbreaking finding, which has caused some resistance and controversy in the academic world of psychological theory in which WM capacity had traditionally been viewed as a fixed trait (Shipstead et al, 2012 and subsequent commentaries). In the 2012 Cogmed Research Meta-analysis, which included all Cogmed studies published at that time, research participants in the standard adaptive Cogmed training group improved an average 26% in visuo-spatial WM and 23% in verbal WM more than the control groups from baseline to post-test on non-trained WM tests (available from the Cogmed website, cogmed.com/research). One published meta-analyses showed that improvements in WM following CWMT were of large effect sizes (d = 1.18 in verbal and $d = 0.86$ in visuo-spatial) (Melby-Lervåg & Hulme, 2013, *Developmental Psychology*). Furthermore, in comparison with other WM training programs, the effects seen after Cogmed were larger than all other interventions. Thus, the research evidence for Cogmed has consistently demonstrated significantly improved WM.

WM assessments

The outcomes that have been used to assess WM have included tasks that are similar to the trained ones for instance Digit span backwards for verbal WM and Block tapping task for visuo-spatial WM, only presented in a different manner (e.g. physical blocks) and using a verbal response to answer (for digit span). This is done in order to minimize the use of task specific strategies that one may have developed during the training. The effects have also been shown on tasks that are more dissimilar to the trained ones, sometimes including a more complex processing operation than simply reproducing or reversing a sequence (7, 8, 16, 31, 43, 46). This ensures that the WM increases seen after training are not entirely task-specific but transfer to tasks that do not allow use of the same strategies as those potentially used during training.

Populations studied

The populations studied with CWMT that have demonstrated improved WM include samples of ADHD (1, 3, 13, 25, 27, 34, 36, 42, 43, 47, 49), brain injury, (5, 15, 26, 37, 38), low WM/ at risk for academic underperformance (7, 18, 33, 41, 50), typically developing/developed (6, 16, 22, 28), children born prematurely (14, 30) and children with intellectual disability (31). Whether the magnitude of WM improvements related to training depends on whether WM was low or in the normal range prior to training is yet unclear (see 20, 45, 24 for examples of this type analysis). The impact of CWMT on daily life, is however likely to be more pronounced if WM deficits are underlying behavioural problems, academic difficulties or other cognitive deficits (see claim 2, 5, and 6 for further discussion).

Sustained effects

The effects on WM after training have been shown to be sustained where follow up assessments have been conducted at 2 to 12 months post intervention (3, 7, 14, 18, 33, 36, 37, 41, 47).

Claim 2

CWMT leads to sustained improvements in attention seen in both
a) subjective measures of attention (3, 11, 14, 18, 26, 38, 47)
b) and objective measures of attention (5, 6, 15, 22, 25, 28)

As previously mentioned, studying attention and WM in the laboratory is generally reliable, but quantifying it in everyday situations is more difficult. The effects of CWMT on attention have been demonstrated on two levels; subjective and objective. The subjective measures consist of questionnaires regarding attention difficulties either directly for the trainee, or for someone close to the trainee (parent or teacher), to rate. This is done prior and post training and is then compared with the equivalent data from a control group (who received either a comparison intervention or no intervention) (3, 11, 14, 18, 26, 38, 47). The objective measures of attention are either laboratory measures of sustained attention (5, 6, 15, 22, 28) or observational data from blinded raters assessing student's abilities to stay on task during an academic performance task (25).

Subjective measures of attention

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, as well as by teacher ratings on Strengths and Difficulties Questionnaire (SDQ), and the DuPaul ADHD-RS-IV (School version). Adult 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) (see Claim 6 for further information).

Objective measures of attention

The laboratory tests of attention that have been used in studies where effects of CWMT has been demonstrated include the Paced Auditory Serial Addition Task (PASAT) (5, 15, 22, 28) in adults and a type of Continuous Performance Task (CPT) (6) in children. The PASAT involves presenting a series of single digit numbers where the two most recent numbers must be summed. It is considered to be a measure of sustained attention. The Auditory Attention test (NEPSY-II) assessing the same ability adapted for children includes presenting auditory cues for the child to respond to certain ones while ignoring others. One study examined attention while the students performed an academic task (RAST) and found that individuals who had trained CWMT, on average had fewer instances of lapses in attention, primarily looking away from the task and playing with an object during the task, compared to an active control group (25). This effect was found when the student's behaviour during this task was rated by assessors that were blind to each student's training condition (Cogmed or control). These effects clearly illustrate how inattention may directly impair academic performance.

Sustained effects

In the meta-analysis reviewing results on ratings of attention from studies investigating the effects of Cogmed (Spencer-Smith & Klingberg, 2015, *PLOS one*), it was concluded that there is a small to moderate effect size (0.47) on ratings of inattention that is in large sustained 2 to 8 months later (0.33).

Claim 3

Improvements in working memory following CWMT are associated with changes in functional brain activity

a. seen as changes in the neurochemistry (9), functional activity related to working memory (2, 4, 22), and functional connectivity at rest (52)

Effects of CWMT on a more fundamental neuronal level have been studied using functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and Magnetoencephalography (MEG). fMRI serves as a proxy for measuring brain activity. It provides a blood- oxygen-dependent

(BOLD) signal, which reflects oxygen levels in the blood. Since an increase in oxygen level is related to increased brain activity, it is assumed that the BOLD signal can be used as a non-invasive measure of brain activity. Studies using fMRI to measure effects of CWMT typically include measuring brain activity of participants in both the active training group and in the control group before and after the training period. This way the researchers can get an objective estimate of how the brain activity has changed after training and to which extent this change is due to completing CWMT. So far three different studies have used this method to investigate changes in brain activity relating to CWMT (2, 4, 22). These studies, including young and older adults have all shown alterations in activity in WM related brain areas following training. These findings show that CWMT influences how the brain processes information in a WM demanding task, and the degree of influence to be directly related to the degree of improvement during CWMT. Thus, the evidence suggests that the improvements seen during CWMT are directly related to changes observed in brain activity.

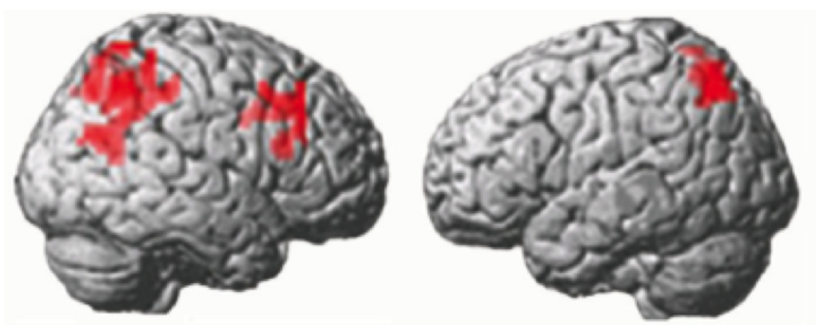

Figure 1. Brain areas demonstrating changed activity following CWMT from the study by Olesen et al. (2).

In 2009 a study by McNab and colleagues (9) was published in the prestigious scientific journal, *Science*. This study demonstrated that CWMT influences the brain's neurochemistry, in particular its dopamine receptors. Using PET to measure the density of dopamine receptors in the brain before and after training, the researchers found that CWMT altered the density of dopamine D1 receptors, again observing a relation between degree of improvement during training and degree of alteration of receptor density. Thus this study demonstrates that CWMT influences fundamental neurochemical properties of the brain. Influence of the dopaminergic system of the brain is of particular relevance for WM and WM training since dopamine is known to be crucial for both WM and attention and is the primary target of psychostimulants used to alleviate symptoms of ADHD.

Another method for measuring brain activity is MEG, a sensitive measure of changes in the magnetic field occurring as a result of the electrical signals that underlie brain activity. Astle and colleagues (52) used this method to measure functional connectivity, that is the way in which different areas of the brain synchronise their activity over time. In this randomized and controlled study (using Cogmed non-adaptive as a control) they demonstrate significant changes in resting-state connectivity following Cogmed training. In addition they demonstrate that the neurophysiological changes were directly related to level of improvements in WM following training. The type of long-range connectivity they investigated has previously been demonstrated to be important for WM and attentional control, and is believed to be crucial for dynamic regulation of ongoing processes. Because measures are taken while children are at rest (not performing a task), the differences observed cannot be explained by differences in strategies, motivation or other task-specific skills.

Claim 4

Learning outcomes in reading (13, 35, 45) and math (34, 43, 45) improves for many underperforming students following CWMT

Immediate and delayed effects

In recent years, academic performance has been measured in an increasing number of studies following CWMT. Some studies have shown significant academic improvements directly following CWMT (13, 35, 43) while others have not seen any effects (7) or not shown statistical significance of the effects (32, 33), compared to a non-adaptive WM training group. However, for those studies including follow up measures, there seems to be a pattern emerging showing *delayed* effects on learning outcomes following CWMT (see Figure 2 and 3). For instance, in the randomized, controlled study by Dunning et al (33), the effect size on reading rate went from non-existent (*d*

= 0.04) directly following training, to medium (*d* = 0.66) at the follow up one year later, compared to controls.

Reading comprehension

Out of the studies investigating the effects of CWMT on reading comprehension, there are three controlled studies that have reported significant effects after training. One randomized, controlled trial (35) that investigated the effects of CWMT training on reading in children aged 10 to 12 with ADHD reported a medium effect (*d* = 0.46) on a reading comprehension test (LOGOS Reading Fluency) directly after training which was retained and slightly increased (*d* = 0.62) at the 8 month follow up. There were also significant effects on a test measuring decoding quality directly after training (*d* = 0.57) which was also maintained 8 months later (*d* = 0.64).

A similar study by Dahlin (13) found effects in a sample of 9 to 12 year old children with attention difficulties and special needs, on a measure of reading comprehension (from the Progress in International Literacy Study, IEA) compared to controls. The magnitude of the effects was large directly after training completion (d = 0.88) and the effects were maintained (d = 0.91) at the 7 month follow up assessment.

One study by Holmes & Gathercole (45) investigated the effects of CWMT as a teacher lead intervention implemented as part of the classroom activities (45). After demonstrating the feasibility of implementing CWMT in the classroom in a first sample, they then let two different samples of children with low academic achievement, in grades five and six train CWMT and followed their academic school progress at the end of the school year. They used the National Standard Assessment Test (SAT) in English (reading, writing, speaking and listening skills) as the outcome and reported a medium to large effect (*d* = 0.67) in the sixth graders (but not the fifth graders) along with significant effects in math performance (see below). The researchers reported that “Children improved in math and English compared with matched control group and out of the training group 84% achieved the national expected levels of attainment in English compared to 72% in the control group.”

One randomized, controlled trial by Foy & Mann (41) has investigated pre-reading markers in a group of children between the ages of four and six at risk for academic underachievement. They reported a medium effect (*d* = 0.51) on a test of phoneme awareness (First Sound Fluency Test, DIBELS Next) 3 months after training completion compared with controls (statistically significant at trend level).

When summarizing the effects from all studies measuring reading comprehension, the improvements seen in reading comprehension has an average effect size of 0.23 immediately after training and an average of 0.36 after 8 months in underachieving children (See Figure 2 for all samples).

A likely explanation to the findings indicating a growth over time is that in those cases where an impaired WM has been limiting performance in reading, effects are apparent in conjunction with the increases in WM capacity. However, for those were WM has not acted as a bottleneck for applying current knowledge to perform, effects may not be evident immediately after training, but may emerge in the months following training as an increase in WM capacity enables more learning opportunities and more efficient practice. This is an explanation that would encompass effects in school-aged children where formal instruction and practice are taking place. It is perhaps less likely to be observed in adults who are not currently learning to read or developing their reading proficiency which may explain the non-effects in the study of adults by Gropper et al. (47).

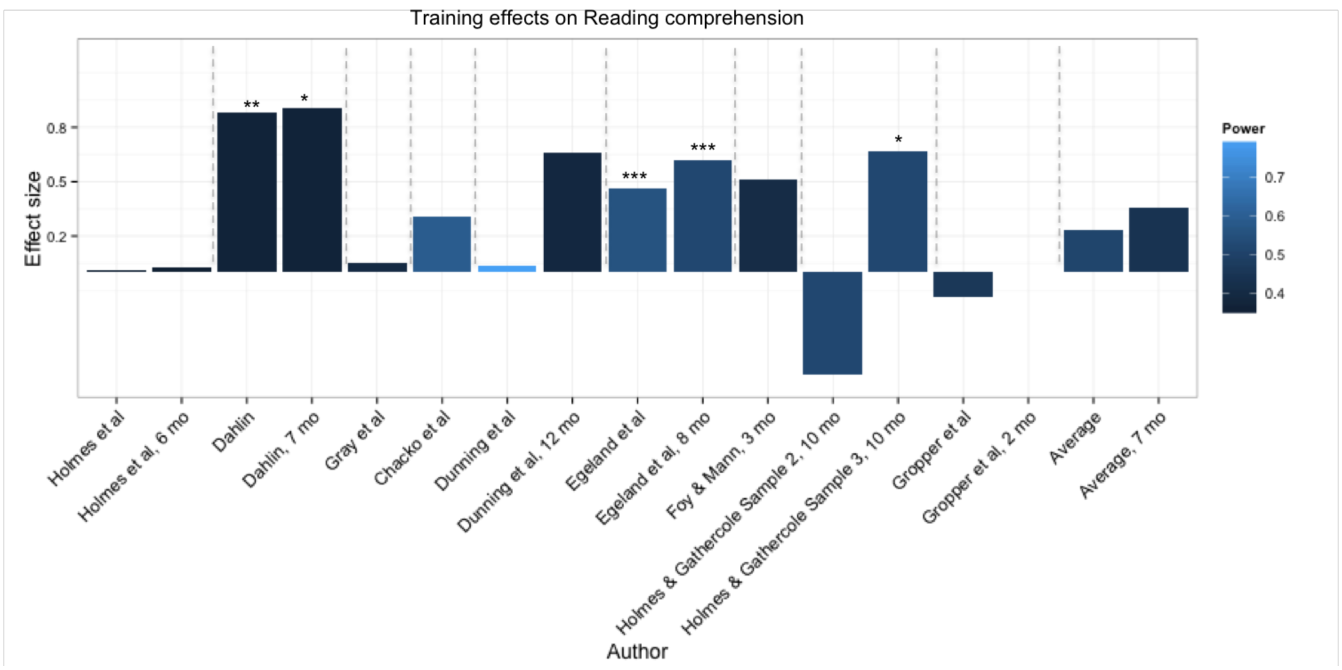

Figure 2. This figure shows the effect sizes on reading comprehension from each study (separated by the dashed lines), for each time point separately and the bars are colour coded according to the statistical power that each study has to detect a medium effect size.

Maths performance

There are three controlled studies that have reported significant effects on math performance after CWMT. In the study by Dahlin (34) from 2013, performance on a test of math concepts (Basic Number Screening Test including grouping, number concepts, serial number patterns, arithmetics, value, division) was compared between controls and Cogmed completers in 9 to 12 year old children with attention deficits and special needs. The effects seen directly after training where in the medium to large magnitude (*d* = 0.69) and these effects were maintained at the 7 month follow up (*d* = 0.65) (see Figure 3). The study also reported a non-significant effect size of *d* = 0.55 on speeded addition directly following training which was partially maintained (*d* = 0.33) at follow up.

The study by Holmes & Gathercole investigated the effects of CWMT as a teacher lead intervention implemented as part of the classroom activities (45). After the two different samples of children with low academic achievement in grades five and six completed their Cogmed training the researchers assessed them and controls at the end of the school year. They used the National Standard Assessment Test (SAT) in math (assessing how to use and apply maths, algebra, shape space, measures and handling data) as the outcome measure. When comparing the academic attainments across the year for the CWMT groups with an age matched sample, the effect sizes for math performance were large and medium (*d* = 1.15 and 0.6, for grade five and six respectively).

One large scale study by Bergman Nutley & Klingberg investigated the training effects on speeded arithmetic performed as part of the Cogmed Progress Indicator (CPI) in Cogmed users during and directly after training and compared them with age-matched controls who only performed the CPI tasks five times over the course of 5-7 weeks (43). The trained sample all had deficits in WM and showed large improvements on the WM tasks with training. The improvements seen on the math task was small to medium (*d* = 0.44) and this improvement was linearly related to the improvements seen on the Following Instructions task. This study did not include a follow up assessment.

One study by Holmes et al. reported significant improvements in math performance six months after Cogmed training completion, however this delayed effect was not compared with a control group and the results are therefore to be considered inconclusive in this regard (7).

Out of the studies that did not find significant effects after training, two studies did not include a follow up assessment (Chacko et al. (32) and Gray et al. (27)) out of which one study was comparing the effects of CWMT on math performance with an intervention targeting math (27).

The studies that did include a follow up measure show an emerging pattern with regards to the direction of the effects over time. The study by Egeland et al. (2013) showed a small effect (d = 0.28) immediately after training that was maintained at follow up, however the study was underpowered to detect small effects (35). Two other studies that included a follow up measure were published by Dunning et al. who reported a small effect size (d = 0.2) for maths reasoning (Wechsler Objective Number Dimensions) immediately after training with a slight increase (d = 0.27) observed at 12 months (33), and Yin et al. (50) who showed a negative effect (-0.29) on numerical operations (Wechsler Individual Achievement Test) directly after training with an increase of 0.4 standard deviations six months post training (50), compared to an active control group.

When summarizing the effects from all studies including outcomes on math performance, improvements in underachieving children are observed immediately after training with an average effect size of 0.18 and an average of 0.44 after 7-9 months (see Figure 3 for effect sizes from all samples).

A likely explanation to these findings indicating a growth in effect over time is that for aspects of maths performance that rely heavily on WM, effects may be apparent immediately when more information can be retained and processed in WM. For learning new skills, these effects will naturally rely both on the math instruction taking place and the ability to learn that new information, where WM plays an important part.

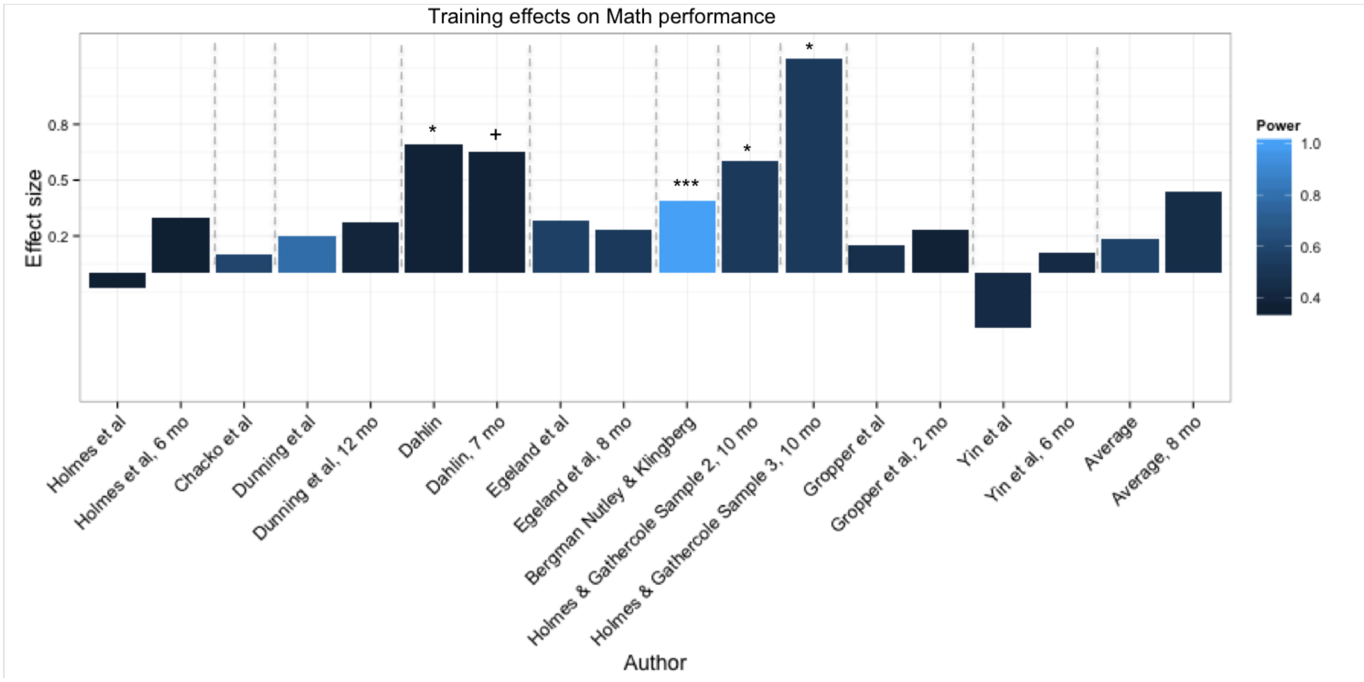

Figure 3. This figure shows the effect sizes on Math performance from each study (separated by the dashed line), for each time point separately and the bars are colour coded according to the statistical power of each study to detect a medium effect size.

Since WM's role in learning is evident, it is of utmost importance to respect the properties of this outcome. Learning is not an absolute state, but a process that occurs over time and if one intends to affect learning one must find a proxy that can be measured over time (e.g. reading comprehension) to demonstrate the change in performance relative to a comparison condition which did not receive the hypothetical impact on learning. Other factors that may be of importance in determining the effects of CWMT on academic performance are the characteristics of the sample (adult vs. child, ADHD vs. other), to which degree they are taking part in learning after the training, the content of that learning and the outcome measures used to assess that learning.

Claim 5

In clinical trials, CWMT has been shown to improve attentional problems in many with ADHD (3, 11, 25, 47)

a) as evident in rating scales (3, 11, 47)
b) or measured with objective measures (25)

WM deficits are commonly observed in patients with ADHD and WM has been suggested to be a core function underlying ADHD symptoms. This has motivated a number of studies to investigate the effects CWMT has on ADHD symptoms overall and inattention in particular. The first large study using Cogmed to be published was by Klingberg and colleagues in 2005 (3). This study included children aged 7-12 who were diagnosed with ADHD. Children with co-morbid diagnoses and/or who were taking psycho-stimulant medication were excluded. Results showed significant improvements in symptoms of inattention as reported by parents of the participants. The improvements following training were found to be significantly greater for the adaptive training group when compared with a non-adaptive control group, and these effects remained significantly greater when measured again 3 months after training had been completed. Positive effects on symptoms of inattention in patients with ADHD has later been replicated in both children and adolescents as rated by parents (11) and in self-ratings in adults (47). In addition, one study has demonstrated reduced symptoms of inattention using an observational design comparing behaviour during an academic-type task in children who trained on the adaptive CWMT with children who trained with the non-adaptive control condition. Following the intervention period, the observers, who were blind to group belonging of each individual participants, rated those who had trained with CWMT as significantly less inattentive compared with the control group. One study on 5-7 year-olds with ADHD reported a significant relation between the improvements on the WM tasks (index improvements) and the reduction of symptoms as rated on two scales by teachers (BRIEF and ADHD-RS), however effects were not evident on a group level in comparison with an active control group (training at level two) (42).

It is important to note that Cogmed does not claim to be a treatment for ADHD, rather Cogmed can be a useful tool to help with some of the symptoms commonly present in ADHD. More research is currently needed to be able to more precisely predict which patients will notice significant improvements in their symptoms. However, the current research literature combined with years of clinical experiences suggest some factors that might influence training success to be co-morbidity, and the degree to which WM deficits influence the ADHD symptoms. For example, two studies that did not find significant effects included samples of ADHD with high co-morbidity. In the case of Chacko et al. (32) a large proportion of participants had co-morbid diagnosis of ODD. Meanwhile the study by Gray and colleagues (27) recruited all participants from a semi-residental school with the following inclusion criteria "coexisting LD/ADHD previously diagnosed in the community, plus severe problems in learning and behavior as well as poor response to the available standards of care and intervention" (27, page 2). Including a high proportion of (or exclusively) participants with co-morbidity make these results difficult to interpret with regards to effects specific to ADHD as any effects observed might be diluted or exaggerated due to the additional diagnoses, and thus these results cannot be generalized to ADHD as one category. It may be noteworthy that even in this heterogeneous and difficult to treat sample, there was a significant relation between the improvements on the WM tasks (index improvement) and the reduction on symptoms rated by parents on inattention and hyperactivity (IOWA Conners rating scale), however, not evident at the group level. These studies could be considered to test the boundaries of the Cogmed method and cannot be considered to inform of the efficacy of CWMT in ADHD in general. More studies are required to address for whom CWMT will lead to relevant improvements and under which conditions training should be performed.

Claim 6

Adult Cogmed users report improved functioning in daily life (5, 28, 47, 49)

There are a number of studies in adults that have reported training related reductions on frequency of self-rated cognitive failures (Cognitive Failure Questionnaire). This has been shown in healthy aging (28), adults with ADHD and learning difficulties (47, 49) and in patients with acquired brain injury (5). Other studies have reported improvements in self-rated general health after 6 months

(15), on the Fatigue Impact Scale (37) and on the Hospital Anxiety and Depression Scale (38) in patients with acquired brain injury. Together this points to improvements in daily functioning that is related to CWMT and that these improvements are of the magnitude that they are noticed by the trainees themselves. For studies including a follow-up measurement, effects were evident also 2 to 6 months after CWMT (15, 28, 37, 38, 47).

Conclusion

The number of research studies investigating the effects seen after completion of the CWMT program are growing each year, with more than 55 peer-reviewed publications as of May 2015. The findings that are repeatedly reported include sustained improvements on WM and attention in both children and adults. Training effects have been reported in children and adults with ADHD, children with learning difficulties, acquired brain injury, hearing impairments, low language abilities, born prematurely, with intellectual disability and in typical samples ranging from preschoolers to older adults. Improved WM capacity is in itself of immense value as it enables more efficient information processing, thus the theoretical link to daily functioning and learning is self-evident. Because formal learning is dependent on information processing in WM, it would seem obvious that better WM would lead to better learning. However, that is for empirical research studies to investigate. Such evidence is starting to emerge, even though this type of research faces many challenges. Assessing learning requires longitudinal approaches, sensitive measures and flawless research design (control groups etc.). These types of studies are both expensive and cumbersome to undertake. While CWMT is the most researched WM program to date (both commercially and non-commercially), more studies are needed to further address more specific effects in daily life, further optimization of the method and further individualization of the training. A substantial body of evidence suggests that CWMT has valuable, relevant impact on people’s lives, and with a growing interest in the method one can anticipate an elevating knowledge base to help impact lives even further. Cogmed has always been and continues to be dedicated to Always Learning.

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