How to think about Cogmed
Research Related to ADHD & WM
Deficits
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Agenda

• Visual Spatial Working Memory basis for Cogmed
• Understanding differences between ADHD Inattentive Presentation and Combined Presentation: Comorbidity & Severity
• Cogmed Use Case: WM deficits/ADHD
• Highlights of Several Specific Studies in Response to Criticism in the Literature
What is Working Memory?

A system for temporary storage and manipulation of information, necessary for a wide range of cognitive tasks

- To keep information in your mind for a short period of time (seconds) & use in your thinking
- Processes all stimuli we encounter - updating
- Delegates to different parts of our brain to take action - shifting
- Allows us to block out unnecessary information - inhibition
- Keeps us updated on what’s happening – & focused on what matters

Ikkai & Curtis (2010)

WORKING MEMORY & ATTENTION

The Development of Working Memory in ADHD. How VSWM became the target for Cogmed.
How does ADHD affect learning?
More errors, slower learning, no automaticity.
(Huang-Pollock & Karalunas, 2010)

When a task has a low WM demand
Children with ADHD still make more errors and learn it more slowly.
When a task has a high WM demand
Children with ADHD don’t get to automaticity.

Result of these struggles: A distinct trajectory of less academic achievement.

The ADHD puzzle has not been completely solved.

- Cogmed provides part of the solution.
- Medication may also be part of the solution.
- Your coaching and interventions from your practice or school may provide the rest.

Skills training in an area you can recommend may be needed — What you offer can complement Cogmed = Cogmed +

The goal is to improve from improved WM/attention to better skills, a higher level of functioning and greater success.

The goal is to focus upon solutions. In the case of ADHD it is rare and unexpected that a singular layer of intervention or training will provide a satisfactory or comprehensive solution. Instead one expects layers of training and/or interventions that address specific areas of deficit individualized to a person.

You play an integral role in that process.

Cogmed: Near & Far Transfer

Skill/behavior 'Far Transfer'
Reading comprehension  Math skills  Language development  On-task behavior

Generalized effects 'Near Transfer'
Rate of learning  Reduced Cognitive Failure  Following Instructions  Attention/Concentration

Executive functions
Working memory  Planning  Initiate  Task monitoring  Organize
Cogmed Claims & Evidence
Specific ADHD Samples.
(May, 2015)

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)

http://www.cogmed.com/research “Claims & Evidence”

Cogmed Claims & Evidence
Also Relevant to ADHD.
(May, 2015)

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) Astle, et al., 2015. “Cognitive Training Enhances Intrinsic Brain Connectivity in Childhood”

http://www.cogmed.com/research “Claims & Evidence”

Is Cogmed Efficacious with children: VSWM?

Table 1. Short working/verbal improvements on visuo-spatial WM from published research studies using Cogmed working memory training.

<table>
<thead>
<tr>
<th>Study</th>
<th>Test Measure</th>
<th>Verbal Working Memory</th>
<th>Visuo-Spatial Working Memory</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD</td>
<td>Cogmed</td>
<td>Working Memory</td>
<td>Visuo-Spatial Memory</td>
<td>Effect Size</td>
</tr>
<tr>
<td></td>
<td>VSWM</td>
<td>Working Memory</td>
<td>Visuo-Spatial Memory</td>
<td>Effect Size</td>
</tr>
</tbody>
</table>

Note: In Cogmed Claims & Evidence, Effect Sizes in this doc. & tables to follow have not been calculated to adjust for different sample sizes.
Is Cogmed Efficacious with children: VWM?

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Sample</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Klingberg et al., 2005</td>
<td>RCT, double blinded</td>
<td>ADHD children</td>
</tr>
<tr>
<td>Green et al., 2012</td>
<td>RCT, double blinded</td>
<td>ADHD children</td>
</tr>
<tr>
<td>Beck et al., 2010</td>
<td>Randomized, waitlist control</td>
<td>ADHD children</td>
</tr>
<tr>
<td>Mezzacappa &amp; Buckner, 2010</td>
<td>Pilot</td>
<td>ADHD children</td>
</tr>
<tr>
<td>Gibson et al., 2011</td>
<td>Randomized, active control</td>
<td>ADHD children</td>
</tr>
<tr>
<td>Nolen et al., 2009</td>
<td>Active Control</td>
<td>ADHD children</td>
</tr>
<tr>
<td>Tharald et al., 2009</td>
<td>Randomized, active control</td>
<td>ADHD children</td>
</tr>
<tr>
<td>Grunewald et al.</td>
<td>&quot;Wipe and Switch&quot;</td>
<td>ADHD children</td>
</tr>
</tbody>
</table>

Studies which have found significant differences on a variety of measures of attention.

Note: This does not include studies from 2013-2014.

Does Cogmed generalize to improved attention in children?

- Study Design: Cogmed Claims & Evidence
- Sample: ADHD Children
- Measures: Studies from 2013-2014

Cogmed Claims & Evidence

Relevant to ADHD. FAR TRANSFER. Note ages.

(May, 2015)

4) Learning outcomes in reading (13, 35, 45) and math (24, 43, 45) improves for many underperforming students following CWMT


33% diag. with ADHD, 60% rated inatt, 9.5%*** LD, the rest had learning difficulties.

9-12 years old.


Ages 7-14.


Rationale: Repeated recital of WM trials when difficulty level is not adapted typically leads to faster reaction times but not an increase in WM capacity - no generalization

"Non-adaptive training" (placebo – but perhaps it is actually ‘mini-Cogmed’). The problem is that it sets a rather high bar and reduces differentiating EF:
- 2-3 items per span
- same number of items per trial
- not challenging WM capacity

Adaptive training:
- maintain multiple stimuli simultaneously
- short delays while stimuli held in WM
- unique sequencing order each trial
- difficulty level adapts as function performance
- correct trial: sub-level increase, more difficult span arrangement, more items per span
- incorrect trial: almost right – small decrease, not even close – large decrease
Understanding Differences between ADHD Combined type (ADHD-C) & ADHD Inattentive type (ADHD-I)

Meta-Analysis of Co-Morbidity in ADHD-C vs ADHD-I (Willcutt et al., 2012)

<table>
<thead>
<tr>
<th></th>
<th>ODD</th>
<th>CD</th>
<th>GAD</th>
<th>SAD</th>
<th>MDD</th>
<th>BPD/AB</th>
<th>LD</th>
<th>Speech/Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD-C</td>
<td>51.8%</td>
<td>22.6%</td>
<td>11.3%</td>
<td>13.5%</td>
<td>9.8%</td>
<td>6.9%</td>
<td>24.2%</td>
<td>14.8%</td>
</tr>
<tr>
<td>ADHD-I</td>
<td>24.9%</td>
<td>7.1%</td>
<td>10.4%</td>
<td>8.7%</td>
<td>9.5%</td>
<td>3.2%</td>
<td>29.3%</td>
<td>17.8%</td>
</tr>
</tbody>
</table>

ODD= Oppositional Defiant Disorder, CD= Conduct Disorder, GAD= generalized anxiety disorder, SAD= seasonal affective disorder, MDD= Major depressive disorder, LD= Learning disorder. Data is from Willcutt et al., (2012).

This meta analysis found substantial difference between comorbidity of ADHD-C vs. ADHD-I. This suggests the possibility that ADHD-C may be a more severe form of the disorder. Additionally, most clinicians would agree that trainees with more comorbidity are more difficult to treat, often require multiple treatments of greater intensity and duration.

ADHD is not Synonymous with a Working Memory Deficit (WMD), but there is overlap
(Klingberg, 2012)

- Klingberg describes the work of Susan Gathercole.
- Children with WMD's struggled with math and reading.
- Struggled to follow instructions.
- TEACHER DESCRIPTIONS:
  - "Unfocused."
  - "Not listening to a word I say."
- Yet, teachers did not complain of them having poor memories.
- Gathercole et al., administered rating scales of attention and hyperactivity & impulsivity problems.
- As many as 75% of the children with low working memory had attention problems as shown on the questionnaires.
- A minority had serious difficulties with hyperactivity and impulsiveness.
- Does impulsivity and hyperactivity have more overlap with Oppositional defiant disorder and conduct disorder and as such represent a distinct treatment challenge?

“Children with low working memory and children with ADHD: same or different?”
(Holmes, et al., 2014 (December)

- Supports the notion that ADHD combined type is a more severe disorder than is a WM deficit.
- “ADHD” group was clearly identified as ADHD combined type.
- Children were not on medication during the testing.
- By diagnosis they will have an elevation in impulsivity, hyperactivity and inattention. Data supported this.
- The ADHD combined group is more likely to be more challenging –especially if they were not medicated. This could have an impact upon the results if they were to do Cogmed.
- Common finding that ADHD children respond faster, but make more errors. WM deficit children responded slower is also somewhat expected. This is consistent with sluggish cognitive tempo for the WM deficit group which is a common hypothesis for ADHD inattentive type.
"Children with low working memory and children with ADHD: same or different?" (Holmes, et al., 2014 December)

- The ADHD combined type group was significantly elevated on areas that one could argue are likely to interfere with Cogmed: oppositionality & rule violations compared to the WM group.
- As expected they were elevated on hyperactivity.
- ADHD children had more executive functioning deficits compared to the children identified as WM deficit:
  - Inhibition
  - Shifting
  - Emotional control
  - Behavioral regulation index
  - Monitor
  - Global executive score
- It is important to realize that these additional behavior struggles could have an adverse impact upon doing Cogmed and may adversely affect results one attains from the program.

"Children with low working memory and children with ADHD: same or different?" (Holmes, et al., 2014 December)

- Several significant cognitive differences between the ADHD group and the WM deficit group in favor of the ADHD group in this sample.
- YET, ADHD group were significantly higher functioning in several cognitive areas:
  - performance IQ
  - digit recall
  - rote recall
  - verbal short term memory
  - matrix memory
  - listing recall
  - forward digit recall
  - verbal WM
  - color one out
  - visuo-spatial WM
  - number sequencing time
  - color naming time.
- The fact that with all of these cognitive advantages the ADHD group still performed similarly poorly to the WM deficit group also supports the conclusion that this is a more severely disordered group.
- This should be prominent in mind when considering our clinical, educational and research expectations with combined type ADHD.
- Yet the picture with Cogmed studies is sometimes murky as these groups are sometimes not clearly delineated.

<table>
<thead>
<tr>
<th>Study</th>
<th>WM deficit</th>
<th>ADHD-I</th>
<th>ADHD-C</th>
<th>ADHD-HI</th>
<th>Rx%</th>
<th>LD</th>
<th>ODD/CD</th>
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<tbody>
<tr>
<td>Holmes &amp; Gathercole, 2013 (trial 1)</td>
<td>NR NR NR NR NR NR NR</td>
<td></td>
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<tr>
<td>Holmes, et al., 2009</td>
<td>100% NR* NR NR NR NR NR</td>
<td></td>
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<tr>
<td>Dunning, et al., 2013</td>
<td>100% NR NR NR NR NR NR</td>
<td></td>
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<tr>
<td>Bergman-Nutley &amp; Klingberg, 2014</td>
<td>Mainly Attentive problems</td>
<td>Minor HI</td>
<td>Minor HI</td>
<td>NR NR</td>
<td>Minor</td>
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<tr>
<td>Holmes &amp; Gathercole, 2013 (trial 2)</td>
<td>NR NR NR NR 100% (Low aca. Perf.) NR</td>
<td></td>
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<td>Dahlin, 2010</td>
<td>NR 33% diag. 60% rated inatt.** NR NR NR 9.5%*** 0%</td>
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<td>Klingberg, et al., 2002</td>
<td>100%? NR 43% NR NR</td>
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<tr>
<td>Klingberg, et al., 2005</td>
<td>25% 75% 0% 0% NR 0%</td>
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<td>Hovik, et al., 2013/Egeland . - 0% 100% 0%</td>
<td>69.6% NR NA/0%</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Green, et al., 2012</td>
<td>42% 42% 17% 67% 0% NR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Van Dongen-Boomsma, et al., 2014</td>
<td>- 7.7% 80.8% 11.5% 0% 3.8%/0%</td>
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<td></td>
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<tr>
<td>Beck et al., 2010</td>
<td>NA 71% 29% NR 61% NR 46%</td>
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<tr>
<td>Chacko, et al., 2013</td>
<td>- 34% 66% 0% 27% NR 50%/9% *</td>
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<tr>
<td>Gropper, et al., 2014</td>
<td>- 51%***** NR NR 26% 57% NR</td>
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<tr>
<td>Gray et al., 2012</td>
<td>- NR 100% NR 98% 100% Severe 100%/0%</td>
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</table>

Cogmed & Children with Working Memory Deficits

WM deficit Children: improve math & following instructions after Cogmed

(WM deficit; Holmes, Gathercole, & Dunning, 2009)

Skeptics & respected researchers connecting WM to Achievement scrutinize Cogmed & conclude: “Adaptive training leads to sustained enhancement of poor working memory in children.”

n=42 children, ages 8-11 screened for working memory deficits (at or below the 15th percentile) were randomly assigned to high or low intensity training conditions.

Assessments: Pre- and post-training

- Working memory (verbal STM, verbal WM, visuo-spatial STM and visuo-spatial WM (AWMA; Alloway, 2007)
- IQ (WASI; Wechsler, 1999)
- basic reading ( WORD; Wechsler, 1993)
- mathematical reasoning (WOND; Wechsler, 1996)
- following instructions (classroom analog test) (Gathercole et al., in press)

The Instruction Task

Holmes et al., 2009.

Instruction task (Gathercole et al.): practical, real world assessment of WM capacity in classroom setting

“Touch the yellow pencil and then put the blue ruler in the red folder.” Mimics span method: Increase number of instructions until failure.
Low WM Children improve attention and math up to six months after training

(Holmes et al., 2009)

“…This study provides the first demonstration that these commonplace deficits and associated learning difficulties can be ameliorated, and possibly even overcome, by intensive adaptive training over a relatively short period: just 6 weeks, typically…”

From WM Deficit to Average Range WM

(Holmes, 2009)

- Children with composite scores in excess of 95 (39 percentile) after training calculated.
  - Adaptive: 68%*
  - Non-Adaptive: 25%

Standard Score Gains at the end of training:

- 5 points
  - Adaptive: 91%*
  - Non-adaptive: 40%
  - Adaptive: 77%*
  - Non-adaptive: 15%
  - 15 points
  - Adaptive: 50%*
  - Non-adaptive: 0%

At 6 months follow only for the adaptive group:

- 5 points: 84%
- 10 points: 63%
- 15 points: 32%

Summary

(Holmes et al., 2009)

1. Academic effect was not immediate, it emerged gradually (at 6 months in mathematics reasoning)
2. Following instructions was significantly improved at the end of training & at 6 months.
3. Training took place in school.

Take home: Cogmed improves WM capacity, attention, following instructions and mathematics in school children with low WM.
“Does WM training lead to generalized improvements in children with low working memory? A randomized controlled trial”  
(Dunning, et al., 2013)

- 810 children ages 7-9 given Automated Working Memory Assessment (AWMA), verbal WM (backward digit recall) and VS WM test Mr. X involving recalling a series of locations, interspersed with mental rotation decisions.
- n=94 children at or below the 15th percentile on both WM tests with English as their first language (47 boys, mean age=8 yr, 5 m).
- 3 groups: Adaptive training, non-adaptive training, no intervention.
- 6 weeks of training. Then follow-up assessments.
- Follow up at 12 months: 15 schools in adaptive, 19 in non-adaptive groups.
- Schools randomly assigned to adaptive or non-adaptive training.
- Classroom-based tasks administered: following instructions, rhyme recall, sentence counting (processing), sentence counting (storage).

<table>
<thead>
<tr>
<th>BMI (z)</th>
<th>AWMA</th>
<th>VS-STM</th>
<th>VSTM</th>
<th>WM</th>
<th>VSWM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adap. vs no int.</td>
<td>Adap. vs no int.</td>
<td>Non-ad vs no int.</td>
<td></td>
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<tr>
<td>1</td>
<td>1.32</td>
<td>1.50*</td>
<td>3.66***</td>
<td>2.33*</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>.54</td>
<td>.87</td>
<td>.43</td>
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<tr>
<td>t</td>
<td>.43</td>
<td>2.73**</td>
<td>.43</td>
<td>.67</td>
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<tr>
<td>d</td>
<td>.26</td>
<td>.57</td>
<td>1.87</td>
<td>.36</td>
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<tr>
<td>d</td>
<td>1.72</td>
<td>1.83</td>
<td>2.83**</td>
<td>.59</td>
<td></td>
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<tr>
<td>d</td>
<td>.44</td>
<td>2.67**</td>
<td>.36</td>
<td>.34</td>
<td></td>
</tr>
</tbody>
</table>

*p< .05, **p<.01, ***p<.001.
RCT (4) Impact upon Class-based tasks  
(Dunning, et al, 2013)

<table>
<thead>
<tr>
<th></th>
<th>ADP</th>
<th>Adapted</th>
<th>Non-ad</th>
<th>No int</th>
<th>ADP-ad</th>
<th>Non-ad</th>
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<tbody>
<tr>
<td>Class</td>
<td>1</td>
<td>d</td>
<td>t</td>
<td>d</td>
<td>t</td>
<td>d</td>
</tr>
<tr>
<td>FI</td>
<td>2.59*</td>
<td>.71</td>
<td>1.21</td>
<td>12</td>
<td>1.16</td>
<td>86</td>
</tr>
<tr>
<td>Rhyme recall</td>
<td>.28</td>
<td>.11</td>
<td>1.50</td>
<td>26</td>
<td>.59</td>
<td>14</td>
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<tr>
<td>Sentence counting</td>
<td>.59</td>
<td>.32</td>
<td>1.85</td>
<td>.54</td>
<td>1.22</td>
<td>31</td>
</tr>
<tr>
<td>Sentence counting (processing)</td>
<td>.35</td>
<td>.70</td>
<td>2.37***</td>
<td>1.10</td>
<td>1.44*</td>
<td>.81</td>
</tr>
<tr>
<td>Basic Reading</td>
<td>1.52</td>
<td>.36</td>
<td>2.28*</td>
<td>.82</td>
<td>3.62***</td>
<td>.85</td>
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<tr>
<td>Written Exp.</td>
<td>1.99*</td>
<td>.69</td>
<td>1.62</td>
<td>.57</td>
<td>4</td>
<td>23</td>
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<td>Attention Omissions</td>
<td>.47</td>
<td>.19</td>
<td>2.53*</td>
<td>.32</td>
<td>1.98*</td>
<td>.24</td>
</tr>
</tbody>
</table>

*p<.05, **p<.01, ***p<.001.

● Cogmed 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.
● Adaptively trained children made significantly greater improvements in tests of VS STM & Verbal and Visual Spatial WM than non-adaptively trained or those that received no intervention.
● 1st double-blinded RTC study on this key group of poor learners that meets stringent criteria for intervention research. Results reinforce earlier outcomes with low WM kids (Holmes, et al., 2009).

RCT (5)  
(Dunning, et al, 2013)

● Classroom behaviors did not show sustained improvement at one year.
● At follow up accuracy in sentence counting (processing) corrected the number of words in a sentence did improve.
● Suggested that scaffolding may be required for training to generalize and be effective in new situations (Wilson, 2008).
● The greatest improvements in WM following training were observed in complex span measures strongly associated with children’s academic achievements in literacy and mathematics (Swanson & Siegel, 2001; Alloway, Gathercole, Willis & Adams, 2004). Response to research.
● It is possible that outcome measures lacked sufficient subtlety to detect changes that more process-oriented measures may find.

PRIORITY: Establish whether other training activities can be developed to promote the “application of these enhanced WM skills to less predictable memory-demanding situations in the classroom.”

RCT (6)  
(Dunning, et al, 2013)
n=50 children ages 9-11 - low academic performance from a cohort of 256 Year 5 and 6 children attending middle school in South East England.

Selections based on raw scores in English and math from teacher assessments administered at the end of the previous year.

English assessed reading, writing, speaking and listening skills.

Math assessed the ability to use and apply math, complete tests of number and algebra, shape space and measures and handling data.

N=25 from Year 5 (age 9 years, 5 months, 16 boys) and 25 from year 6 (age 10 years, 6 months, 13 boys).

These children had the lowest teacher assessment scores of their cohorts. They were matched with 50 children based upon age, gender and performance on the teacher assessments from the previous cohorts of children in year 5 and 6.

Teacher-led “whole class” Cogmed
(4) Trial 2:
(Holmes & Gathercole, 2013)

Data are presented separately because year 5 and year 6 have distinct status in the UK state education system. SAT’s are required in year 6 and optional in year 5.

The year 5 group was trained as one group of 25 supervised by the head teacher and a classroom assistant. (Whole class)

Year 6 was trained in two smaller groups (n-13, n-12) supervised by the same staff at the end of the school day.

Teacher-led “whole class” Cogmed
(5) Trial 2:
(Holmes & Gathercole, 2013)

Sublevel gains in attainment
(Holmes & Gathercole, 2013)
Children in Year 5 who completed training made significantly greater gains in math than the comparison group.

Children in Year 6 who completed training made significantly greater gains in English and Math.

Of the trained group at the end of Year 6 84% reached the nationally expected levels of attainment in English at the end of Year 6 compared with 72% of the comparison group.

Academic attainment was not related to baseline attainment.

WM deficit Children: Transfer increased Linearly with amount of training time & Correlated with improvement on trained tasks. WM, FI & Math Improved (Bergman-Nutley & Klingberg, 2014)

<table>
<thead>
<tr>
<th>Study</th>
<th>WM deficit</th>
<th>ADHD-C</th>
<th>ADHD-HI</th>
<th>R%</th>
<th>LD</th>
<th>ODD/CO</th>
</tr>
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<tbody>
<tr>
<td>Bergman-Nutley &amp; Klingberg, 2014</td>
<td>100%</td>
<td>Mainly Attentive problems</td>
<td>Minor HI</td>
<td>NR</td>
<td>NR</td>
<td>Minor</td>
</tr>
</tbody>
</table>

n=176 children (treatment group), aged 7-14, mean age 11.1 years, all had WM deficits, Majority were diagnosed with ADHD, but it was not verified in the study. Based upon the rating scale noted below children had "mainly inattentive problems (score of 16) and minor problems with hyperactivity (score of 8) and ODD (score of 6)."

n=304 Typically developing children, aged 7-15. This group took same transfer tasks at the same weekly intervals for 5 weeks. They did not train.

Assessments: Disruptive Disorder Behavior Checklist, parent ratings, before training

Transfer tests administered once a week for 5 weeks:

**Working memory** ("odd one out") (OOO) identify which shape is the odd one out and remember its location. Based upon the AWMA, 2007

**Mathematics test:** See next slide.

Mathematics test: The mathematics test was a speeded arithmetic test where the participants had to solve mental arithmetic problems (addition and subtraction) with two or three terms and a sum less than 20, excluding duplicate terms and numbers with 0 in them. As many problems as possible were to be answered during 1 min. The scoring was the sum of the correctly answered trials after subtracting the number of mistakes multiplied by 0.33 (so that random performance would give a score of 0). This might be considered a test of math proficiency given the fact that it is a timed test.

Standard training format: trained 5 days/week for 5 weeks.

Compliance was very high with a mean of 24.89 days trained & 88% completed all 5 tests. Training was done during the summer of 2012.
WHY THIS STUDY MATTERS:

WM is impaired in subjects with dyscalculia & it is correlated to math performance in the general population. Performance on WM tests is predictive of future math performance. Math underachievement is associated with academic underachievement and higher risk for unemployment.

"Studies investigating the effects of WM training on mathematics have thus far presented mixed results regarding such transfer (Gray et al., 2012; Dunning, Holmes, & Gathercole, 2013; Holmes & Gathercole, 2013)."

"The inconsistent results of WM training on mathematics could be due to: (1) a true lack of effect or that only certain aspects of mathematics are affected; (2) that effect occurs not directly after training but later, as a result of improved WM capacity in combination with instruction; or (3) that the effect size is small, and the existing studies include too few subjects to detect a significant effect."

WM deficit Children: Transfer increased Linearly with amount of training time & Correlated with improvement on trained tasks. WM, FI & Math Improved (Bergman-Nutley & Klingberg, 2014)

Take note that changes begin to be registered at about 3 or more weeks into training.
As such the role of the coach in supporting the motivation of the trainee is very important.

Realize: "Transfer increased Linearly with amount of training time & Correlated with improvement on trained tasks."

WM deficit Children: Transfer increased Linearly with amount of training time & Correlated with improvement on trained tasks. WM, FI & Math Improved (Bergman-Nutley & Klingberg, 2014)

T5-T1 showed the biggest difference between groups seen here:
WM deficit Children: Transfer increased Linearly with amount of training time & Correlated with improvement on trained tasks, WM, FI & Math Improved
(Bergman-Harley & Klingberg, 2014).

- Improvements in FI were linear and showed minimal test-retests in the control group.
- In OOO and the mat test there were test-retests effects in the control group at T2 and T3 after which they leveled off.
- With all 3 measures the maximal difference between training and control group was seen in the final testing (T5).

EFFECT SIZES:
- The effect for WM (OOO) was medium to strong (d=.67)
- The effect size for FI was strong (d=.90)
- The effect size for math was small (d=.20).

- When effect size was calculated with age-normalized scores, the effect size (Cohen’s delta) for math was medium (d=.39).

- "An alternative way to calculate the effect sizes is analyzing the change in mean scores relative to the standard deviation of the change (T5 - T1) - (T5c - T1c)/SDT5-T1,pooled, and the

EFFECT SIZES:
- 0.60 for OOO,
- 0.99 for FI and
- 0.44 for Math.”

Cogmed & ADHD

Research discovery:
Working memory can be improved!, RCT (Klingberg et al., 2002)

Training of working memory in children with ADHD.
Randomized, controlled, double-blind trial (RCT)

Assessed:
- Trained visual spatial working memory.
- Non-trained working memory: Span Board.
- Selective Attention: Stroop Task.
- Non-verbal reasoning/general intelligence: Raven’s matrices.
- Reaction Time: Choice Reaction time test.
- Inhibition/impulsivity: Head movements.

Experiment 1: n=7, 6 boys, 1 girl; between ages 7 and 15. Experiment 2: n=4 healthy adult males ages: 23, 29, 20, 22.
Double blind, placebo controlled, randomized.
RCT Summary
(Klingberg et al., 2002)

Take home: Effects of Cogmed generalize to non-practiced tasks. Children with ADHD improve on neuropsychological evaluations after WM training.

1. 1st published research on WM training
2. Children with ADHD improved on neuropsychological tests (span board, Stroop test, Ravens progressive matrices)
3. Head movements reduced.
4. Samples of kids with ADHD (7) and healthy adults (4)
5. Limitations: Small sample size, the lack of behavioral measures, and no long-term follow-up

Larger study confirms that Cogmed helps kids with ADHD, RCT
(Klingberg et al., 2005)

- Validation and expansion of the Klingberg et al., 2002 study, with multisite format, 3-month follow up and rating scale data.
- Randomized, controlled, double-blind trial, RCT
- n=53, ages 7-12, without Rx.
- Compliance (>20 training days) met by 44 subjects (22 tx, 22 control). Of those 42 evaluated at 3 months follow up.

Results for Klingberg 2005 RCT study.

MAIN OUTCOME MEASURE:
Span-board task - Visual Spatial Working memory (VSWM):
Effect Size - ES=.93, follow up ES=.92 (99%)

SECONDARY OUTCOME MEASURES:
- Verbal working memory (VWM): Digit span from WISC-III ES=.59, ES=.57
- Response inhibition: Stroop Interference task, ES=.54, ES=.35
- Nonverbal reasoning ability Raven's Colored Progressive Matrices. ES=.45, ES=.30
- Motor activity: Infrared camera recording # of head movements in 15 minutes of performing a detection task. Not replicated.
- ADHD:
DSM-IV 18 items were used as a rating scale. Conners Raging Scale for Parents & teachers.
- Parent ratings: Significant improvement on inattention & hyperactivity/impulsivity for both post treatment and follow up.
- Teacher ratings: No change.
**RCT, Summary**

*Klingberg et al., 2005*

**Take home:** Replication and validation of Klingberg et al., 2002. Cogmed can improve WM capacity in children with ADHD. Included use of rating scales, 3 month follow up and no medication.

Results remain after 3 months, effects on parent ratings - blinded (attention and impulse control), effects on neuropsychological tests (span board - VSWM, digit span VWM, Raven’s & Stroop – faster and more accurate) & Shows improvement on complex problem solving.

Does not show significant effects on teacher ratings or head movement.

**NOTE:** Inter-rater correlations between parents and teachers are often low (Swanson, et al, 2001), a twofold difference in the effect sizes from parents and teachers reported in other studies (Wolraich et al., 2001).

---

**Impact of training and medication (Rx) on WM of children with ADHD**

*(Holmes et al., 2010)*

Compared Cogmed and pharmacological intervention (Rx) on the WM of children with ADHD, who had been diagnosed for at least 6 months with no co-morbid disorders indicated.

Single test-retest, design (teachers did not want off Rx whole grading period)

Assessed 4 aspects of WM (verbal and visuo-spatial STM & verbal and visuo-spatial WM) in 25 children ages 8 -11 years with clinical diagnosis of ADHD for 6 months or longer and receiving quick release stimulant medication (e.g. Methylphenidate).

- T1 = Off medication, pre-training. 12 subtests of AWMA & IQ (WASI; Weschler, 1999)
- T2 = On medication, pre-training. 8 WM tasks from AWMA & IQ
- T3 = On medication, post-training. 8 WM tasks from AWMA & IQ
- T4 = On medication, 6 month follow-up. 4 WM tasks from AWMA & IQ

---

**Impact of training and medication on WM of children with ADHD**

*(Holmes et al., 2010)*

![Graph showing impact of training and medication on WM of children with ADHD](image)

*Slides courtesy of Dr. Joni Holmes*
ADHD children achieve significant gains on four WM tests post-intervention

"...By far the most dramatic gains in WM function were observed with WM training. Significant and substantial improvements were found in all assessed aspects of WM, in each case lifting the group from a level below average to one within the average range of scores for children of their age..."
Summary

- Significant but distinctive gains in working memory in children with ADHD, no IQ effect.
- Pharmacological intervention, (Rx)
  - Significant gains in visuo-spatial, but not verbal aspects of WM reflects predominant influence of medication on right hemisphere structures associated with visuo-spatial WM (Bedard et al., 2004)
- Possible that the impact of medication on working memory deficits associated with poor academic progress will also be restricted in scope
- Behavioural intervention
  - Significant gains in non-trained working memory tasks, which extended across all four aspects of working memory (low-average to average range) for up to 6 months.

Take home: Children with ADHD show up to 6 months lasting effect of Cogmed WM training. Wider effect on executive functioning than stimulant medication alone.

WM Training Generalizes to Improve Off-task Behavior in Children w/ ADHD, RCT

(Green, et al., 2012)

- n=26, 18 males, 8 females. Ages 7 – 14 years old. ADHD. Randomized, double-blind, placebo controlled design, RCT. Ecologically valid laboratory measure of ADHD associated behaviors.
- ADHD-C: 42%, ADHD-I: 42%, ADHD-HI: 17%
- Rx: 67%
- 25 sessions of training
- Restricted Academic Situations Task (RAST) observational system assessed off-task behavior during the completion of an academic task.
- Found significant reductions in off-task ADHD-associated behavior on the RAST system and improvement on WM tests. Also improvement on WMI on WISC-IV (VWM).
- No significant differences between groups in improvement on parent rating scales. Data suggest WM training may provide a mechanism for indirectly altering academic performance in children with ADHD.

Off-task Behavior was measured with the RAST, RCT

(Green, et al., 2012)

- Measured at 30 second intervals.
- Videotaped through 1 way mirror.
- Off-task is the category of the highest rate of behavior that occurred.
- Sharp decline in "looks away" behavior.

Child told to complete academic worksheets for 15 minutes.

Work 1 grade below current.
Also decline in “Plays with object”, RCT  
(Green, et al., 2012)

10-12 year old ADHD children make and maintain significant gains in WM for 8 months. RCT  
(Hovik, et al., 2013)

<table>
<thead>
<tr>
<th>Study</th>
<th>WM ARTICLE</th>
<th>ADDH</th>
<th>ADHD-C</th>
<th>ADHD-H</th>
<th>Rx%</th>
<th>LD</th>
<th>GOSC</th>
<th>ID</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
<td>69.6% N</td>
<td>NR</td>
<td>NA</td>
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RCT results: Systematic training resulted in long term gains (8 months).
Evidence for both domain-general and domain-specific models.

n=67; children 100% with combined type ADHD ages 10-12.
Note: 41 Rx stimulant (MPH) + 5 atomoxetine (Strattera) + 1 Risperidone. = 70% on Rx

Design: Randomized, Placebo controlled Trial, RCT.
Treatment vs. treatment as usual. 8 month follow up. Control group received special education treatment as usual & health care follow up.

MEASURES: 6 measures of each form of WM, divided into auditory WM, visual WM, and Manipulation WM

RESULTS: All treatment subjects significantly improved on all measures of WM. Improved significantly more on Visual WM than auditory WM. Manipulation WM gain remained after controlling for increase in simple storage.
Gains were found in both domain general and domain specific areas.

Cogmed Training results in improved psychomotor speed & reading. RCT (Same subjects as Hovik, et al., 2013)  
(Egeland, et al., 2013)

• N=67 children diagnosed with ICD-10 hyperkinetic Disorder=100% ADHD-Combined type, randomly selected into a control group or training group. 70% on Rx, RCT. Control group received special education treatment as usual & health care follow up. Ages 10-12.
• Exclusion criteria: 1. IQ below 70. 2. Comorbid diagnosis of Pervasive Developmental disorders, Tourette’s disorder, evidence of psychosis or Bipolar disorder and Conduct disorder.
• Measures: Battery of NP tests, measures of mathematics and reading skills.
• Results: Psychomotor or processing speed improved. Reading improved. Reading was improved in both speed and quality of text reading and word decoding quality improved.

Normalization before Cogmed:
• No differences between groups regarding medications were found.
• The majority of subjects performed in the normal range on Rx on the CCP-II before Cogmed.
• On Rating scales teachers rated them in the normal range and parents rated them in the highly symptomatic range.
• Children referred for medications may be more impaired.
• They hypothesized that children who have optimized their behavior due to Rx may show less treatment effect.
• Suggestion: Control for medication.
WM training in young children with ADHD, RCT trial
(van Dongen-Boomsma et al., 2014)

<table>
<thead>
<tr>
<th>Study</th>
<th>WM training</th>
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<tbody>
<tr>
<td>n=18 treatment, 16 control, average age 6.5 tx, 6.6 control. All boys. None medicated.</td>
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Average age 6.5 used JM. Would better effects been found with RM?

Cogmed group made significant gains in VWM with an effect size of .93. Yet the gain was lost after statistical correction for multiple testing. Given a large effect size one wonders whether the sample size was large enough to detect actual group differences. JM has only VWM tasks so a gain in VWM is a transferred effect.

AGE RANGE ISSUE: Age ranges are not strictly applied to Cogmed. So close to 7 years old they could have done Cogmed RM and would have had substantially more time on task. RM has more tasks and has VWM tasks - JM does not. RM would have resulted in greater time on task. One wonders how this would have affected transfer.

HIGHLIGHTS THE CLINICIAN-MEDIATOR ROLE: Deciding whether to use RM instead of JM is a rather important decision because it could increase the intensity of the training and quite likely the impact.

Support for longer training argument: Index improvement significantly contributed to the ADHD-RS and Behavior Rating Inventor of Executive Function both rated by the teacher, but revealed no significant group differences.

WM training effects on reading in ADHD or inattentive Children with learning problems (2)
(Dahlin, 2010)

Population: special needs children; ages 9 – 12 years
N = 57 (n = 42 in treatment group and n = 15 in control group [special needs class])
Diagnosed with ADHD or inattention and with co-morbidity of learning problems.

Design: Active control, Randomized, Blinded, Test-retest
T1 = Baseline, T2 = 5-6 week follow up, T3 = 6-7 month follow up
Treatment group improved significantly on outcome measures:
1) Visuo-spatial and verbal WM (Span Board; WAIS-NI & Digit Span; WISC III) (T2)
2) Reading comprehension (Reading narrative texts & answering questions) (T2 & T3)
WM training effects on reading in ADHD or inattentive Children with learning problems (Dahlin, 2010)

Examined the relationship between working memory and reading achievement in 57 school children with special needs.

Special needs: 33% had ADHD diagnosis, 60% rated inattentive by teachers & general learning problems

Significantly improved untrained working memory tasks, nonverbal problem solving & reading comprehension. Effect size for reading comprehension was d=.91, it was substantial.

Take home: Children with attention with special education needs and attention problems improved significantly on untrained working memory tasks, nonverbal problems solving and reading comprehension within the treatment group.

WM training effects on reading in ADHD or inattentive Children with learning problems (3) (Dahlin, 2013)

<table>
<thead>
<tr>
<th>Study</th>
<th>WM and Basic Skills</th>
<th>WM and Basic Skills</th>
<th>WM and Basic Skills</th>
<th>WM and Basic Skills</th>
<th>WM and Basic Skills</th>
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<tbody>
<tr>
<td>WM</td>
<td>WM &amp; Basic Skills</td>
<td>WM &amp; Basic Skills</td>
<td>WM &amp; Basic Skills</td>
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<td>WM &amp; Basic Skills</td>
<td>WM &amp; Basic Skills</td>
<td>WM &amp; Basic Skills</td>
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</tbody>
</table>

Study II: Dahlin (2013) found that WM and basic number skills were highly related. The performance of boys in the treatment group improved more than boys in the control group on basic number tests at both post-tests.

Study III: Basic skills assessed three years later (T4) are reported. Gains in reading comprehension, V/SWM, V/S-STM, central executive WM maintained at 3 years.
Study II: n=27 students. (18 treatment (9 with ADHD), 9 control (4 with ADHD). Some had dyslexia.

Psychologists interviewed the parents of students in the treatment group for 30-40 minutes to ensure they did have attention difficulties.

Parents completed ODD ratings.

Assessments by teachers and psychologists from each school formed the basis for participation in the study.

Basic number skills:

Addition & Subtraction verification tasks: In two minutes, the student determines whether equations have been calculated correctly.

Basic Number screening test (BNST) (Gillham & Hesse, 2001): 30 different tasks in mathematics, including the four basic arithmetic operations, grouping and completing series

Study II: BNST was significant at T2 (post-Cogmed) but not T3 (6-7 months post-Cogmed) for the tx group.

NOTE: Girls were few in number and performed significantly poorer than boys on several tests so analyses were only repeated for boys.

The re-analysis showed significant improvement in the BNST at T3 (treatment effect \( p < .05, d = 0.74 \)) as well as at T3 for the boys (treatment effect \( p < .05, d = 0.85 \)), but not in addition or subtraction.

The experimental group's results from the different test sessions were compared using Cohen's d. The effect on WM tests Span board was high (forward, \( d = 1.05 \), backwards, \( d = 0.93 \)).

The conclusion drawn is that mathematics and WM are related. Boys aged 9 to 12 years seem to benefit from WM training by improving their performance on both the WM-test and the mathematics test (BNST).

WM training generalizes to Reading Comprehension & Basic Number Skills & lasts 3 years (Dahlin, 2013)

Study III: n=27 students. It was decided to ask 2/3 of the control group (n=10) and twice as many from the treatment group (n=20) to complete the reading and mathematics measures once again at 3 years follow up. This resulted in a control group of 9 students (3 female) and 2 with ADHD and 18 (3 female (4 with ADHD) in the treatment group. Financial limits prevented follow up with all 57 students.

3 students lost: 1 boy due to ODD. 1 girl due to low IQ. One boy in control group did Cogmed between T2 and T3 so he was removed.

Effect size notes: “An effect size (\( d \)) of 1.0 for a subject indicates an increase of 1 SD (standard deviation). According to Hattie (2009), this signifies an increase equivalent to two to three years of development and a performance increase of approximately 60%. An effect size of 0.8 signifies an increase of approximately 30%, or 9 months.”

WM training generalizes to Reading Comprehension & Basic Number Skills & lasts 3 years (Dahlin, 2013)
Study II VSWM: Significant at T2 (directly after training) & T3 (6-7 months after training).

Reading Comprehension: Entire experimental group significantly improved at T2, T3 and T4 (3 years follow up) in reading comprehension.

Among boys: At T4: Significant improvements in VSWM (Span board backwards), VS-STM (Span board forward), Significant improvements in Central executive WM: Attention: DSM-IV, Questions 1-9 – rated by parents and teachers. Significant improvement effect sizes on Reading comprehension (1.08) and basic number skills in boys, subtraction (.94), basic number test (.75). Also, reading comprehension and number skills were related to WM measures.

ADHD or not? No difference was found in training effect whether with or without the diagnosis.

WM training generalizes to Reading Comprehension & Basic Number Skills & lasts 3 years (Dahlin, 2013)

<table>
<thead>
<tr>
<th>Cohen's d Statistics for boys</th>
<th>T2-T1</th>
<th>T3-T1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Span board forward</td>
<td>1.25</td>
<td>1.09</td>
</tr>
<tr>
<td>Span board backward</td>
<td>1.05</td>
<td>0.83</td>
</tr>
<tr>
<td>Digit forward</td>
<td>.57</td>
<td>.54</td>
</tr>
<tr>
<td>Digit backward</td>
<td>.67</td>
<td>.36</td>
</tr>
<tr>
<td>Raven</td>
<td>.45</td>
<td>.92</td>
</tr>
<tr>
<td>Addition</td>
<td>.31</td>
<td>.36</td>
</tr>
<tr>
<td>Subtraction</td>
<td>.09</td>
<td>.35</td>
</tr>
<tr>
<td>Number skills</td>
<td>.28</td>
<td>.36</td>
</tr>
<tr>
<td>Reading comprehension</td>
<td>.67</td>
<td>.76</td>
</tr>
<tr>
<td>Word Reading</td>
<td>.22</td>
<td>.35</td>
</tr>
</tbody>
</table>

WM training generalizes to Reading Comprehension & Basic Number Skills & lasts 3 years (Dahlin, 2013)

Cogmed WM training for Children with ADHD & Notable Co-morbidity (Beck et al., 2010)

<table>
<thead>
<tr>
<th>Body</th>
<th>WM skills</th>
<th>ADHD symptoms</th>
<th>LD</th>
<th>LD</th>
<th>WD</th>
<th>WD</th>
<th>WD</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>52</td>
<td>71%</td>
<td>29%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WM training lead to improvements on parent and teacher rating of ADHD symptoms?

Population: ADHD children and adolescents, ages 7 -17, 61% on stimulant medication

N = 52 (n = 27 in treatment group and n = 24 in waitlist control)

Design: Randomized, Waitlist control. Screened for WM constraint with BRIEF (WM scale) or at least 6 inattentive symptoms (DSM-IV-TR) and P-ChIPS for ADHD

T1 = Baseline, T2 = 1 month post intervention, T3 = 4 month follow up

Treatment groups improve significantly over waitlist control on rating scales:

1) Conner's Parent Scale (T2 & T3);
2) BRIEF Parent Form (T2 & T3)

Take home: WM training associated with reduced parent report of inattentive behavior and ADHD symptoms at 1 month and 4 months after training. No significant difference in teacher ratings (Conner's Teaching Scale & BRIEF:Teacher Form)
Cogmed effective with ADHD with substantial Co-morbid disorders

(Beck et al., 2010)

52 children met DSM IV criteria for ADHD, combined (29%), Predominantly Inattentive type (71%) with many had co-occurring disorders (63%).

Co-occurring disorders:
Conduct disorder or Oppositional defiant disorder - 46%
Anxiety disorder - 39%
Mood disorder - 8%
One co-morbid disorder - 29%
Two co-morbid disorders - 17%
Three or more co-morbid disorders - 17%
Taking Stimulant (Rx) medications - 61%

Moderate to strong effect sizes for parent ratings of ADHD symptoms after Cogmed

(Beck et al., 2010)

<table>
<thead>
<tr>
<th></th>
<th>Results</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD Index</td>
<td>74.74</td>
<td>93.22</td>
</tr>
<tr>
<td>Cognitive Problems/Inattention</td>
<td>87.02</td>
<td>92.76</td>
</tr>
<tr>
<td>Hyperactivity</td>
<td>87.25</td>
<td>92.66</td>
</tr>
<tr>
<td>Oppositional</td>
<td>87.02</td>
<td>92.66</td>
</tr>
<tr>
<td>BAS I Inattentive Scale</td>
<td>8.22</td>
<td>9.31</td>
</tr>
</tbody>
</table>

Conners’ Parent Scales:

- ADHD Index: 37% significant, 33.3% reliable change.
- Cognitive problems/inattention: 48% significant, 25.9% reliable change
- Hyperactivity and on the DSM-IV Inattentive scale: 51.9% sig., 22.2% reliable change.

Teacher ratings on the Conners’ did not show significant improvement.

BRIEF (Behavior Rating Inventor of Executive Function):

Parents rated children in the experimental group as significantly improved on:
- Metacognitive index, working memory, initiate, and Plan/organize

Follow up: Parent-rated ADHD symptoms were still significantly lower, monitoring and metacognitive index on the BRIEF approached significance.

Teachers rated the experimental group as significantly improved on the Initiate scale of the BRIEF.

Take home: Parent reports of executive functioning and ADHD symptoms can be improved by intense and prolonged training even when subjects have co-morbid diagnoses.
Cogmed Training resulted in significantly greater verbal and nonverbal working memory storage, but (Chacko, et al., 2013)

<table>
<thead>
<tr>
<th>Study</th>
<th>WM accrue</th>
<th>ADHD-C</th>
<th>ADHD-H</th>
<th>Rx%</th>
<th>LD</th>
<th>CADD C.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chacko, et al., (2013)</td>
<td>27%</td>
<td>59%</td>
<td>9%</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Note: The comparison condition used here was essentially the same as Klingberg, et al., 2002,2005, Holmes et al., 2009; Dunning et al., 2013; Green et al., 2012)

Conclusion appears excessive: “When a more rigorous comparison condition is utilized, CWMt demonstrates effects on certain aspects of working memory in children with ADHD; however CWMt does not appear to foster treatment generalization to other domains of functioning. As such, CWMt should not be considered a viable treatment for children with ADHD.”

Upon close scrutiny this study opens a number of questions:
1. With a sample of predominantly hyperactive-impulsive and/or combined type ADHD children in contrast to a sample of predominantly inattentive ADHD children is Cogmed as effective?
2. Would medication play an additive role with this population as it did with Holmes, et al., 2010?
3. How does co-morbidity factor into expectations for treatment outcome? (ODD, CD and one LD or several LDs)? Are there implications for neuroplasticity?
4. How does SES factor into expectations for treatment outcome?

Consider the level of co-morbidity and the type of ADHD in Chacko, et al., (2013)

Compare Beck et al. (2010) with Chacko:
1. ADHD-C vs ADHD-I: Beck et al., (2010) 29% of their sample were combined ADHD, while 71% were predominantly inattentive type. Chacko, et al. Had 66% combined type ADHD and 34% inattentive ADHD.
2. Comorbidity: Similarly, Beck had 46% with co-morbid Conduct disorder or Oppositional defiant disorder-46%, while Chacko had 50% ODD, 9% CD for 59% total.
4. Rx: Beck et al., had 61% taking medications (Rx)- 61%, Chacko, et al., had 29% taking Rx.
5. Transfer effects: Beck et al., 2010 had transfer effects to BRIEF parent ratings of Parents rated children in the experimental group as significantly improved on: Metacognitive index, working memory, initiate, and Plan/organize. Reductions in ADHD symptoms & teacher ratings of improved initiate on the BRIEF. Chacko et al., 2013 found Cogmed resulted in significantly greater verbal and nonverbal WM storage.

Cogmed with College Students with ADHD/LD (Gropper, et al., 2014)

<table>
<thead>
<tr>
<th>Study</th>
<th>WM accrue</th>
<th>ADHD-C</th>
<th>ADHD-H</th>
<th>Rx%</th>
<th>LD</th>
<th>CADD C.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gropper, et al., (2014)</td>
<td>51%*****</td>
<td>NA</td>
<td>NA</td>
<td>26%</td>
<td>57%</td>
<td>NA</td>
</tr>
</tbody>
</table>

DESIGN: Wait list control. Not blinded (Cannot claim causality.)

n=62, college students, ages 19-54.

Registered with student services with a confirmed diagnosed of ADHD & LD

BESD Binomial Effect Size Display (BESD) calculation was used to compare changes in effect size of WM capacity.

CFQ: Cognitive Failure Questionnaire was used at a measure of generalization but is also considered a measure of “ecological effects”.

n=62, 7 to 11 year olds. 78% males. Mean age=8.4. RCT

Cogmed training showed significantly greater verbal and nonverbal WM storage, but not in storage and manipulation.

Note: The comparison condition used here was essentially the same as Klingberg, et al., 2002,2005, Holmes et al., 2009; Dunning et al., 2013; Green et al., 2012)
ADHD in College: ADHD/LD in college are a unique subgroup. One the one hand, they are likely to have missed substantial skill development over their academic career. As such, expecting academic achievement to improve would be quite challenging. On the other hand as ADHD/LD who made it to college they are doing comparatively well. So they would be both relatively high-achieving and possibly to have gaps in their development.

Expectations: Improving "learning capacity" after expected years of lagging behind would be an optimistic outcome. Then academic skill remediation with scaffolding would be expected to have a notably greater impact.

RESULTS: Cogmed resulted in significantly improved VWM (WAIS), VSWM - (CONTAB). Gains maintained at 2 month follow up. Also, self-reported fewer ADHD symptoms (ADHD Self Report Scale) and fewer cognitive failures post program. At 2 months they continued to report fewer cognitive failures.

Using Binomial Effect size display (BESD) 47% difference between groups, BESD 28% reduction of symptoms, cognitive failure questionnaire 25% reduction.

Index scores predicted WM improvement on CONTAB, ASRS, CFQ. In other words students cannot just go through the motions.

BETTER EFFORT = BETTER RESULTS

ADHD/LD College Students Self-reported changes post Cogmed suggest ecological improvements. (Gropper, 2014)

THE STUDENTS CONCLUSIONS (Ecological effects):
Majority noticed an improvement in recalling verbal information (e.g. phone numbers, appointments, names).

Improvement in verbal memory allowed students to learn and retain information from lectures and books without rereading over and over again.

Several students reported that they could better sustain attention and feel alert for longer periods of time.

Some reported that they did NOT improve in time management or organizational skills, but there were not substantial changes in these areas. Here the argument for scaffolding makes sense.

Overall the feedback was positive.

However, the authors conclude that a causal link between Cogmed and these changes cannot be assumed.
The study by Gray et al., 2012 was the most severely debilitated group of ADHD-C/ODD/LD Children to do Cogmed.

**UNUSUALLY SEVERE SUBJECTS:**

- Residential school required both ADHD/LD along with severe problems in behavior and learning as rated by both parents and teachers.
- They had to have had a poor response to both medication treatment and special education treatment.
- They had to have failed previous interventions.
- Oppositional Defiant Disorder (ODD): All were at or above the 90th percentile on ODD as rated by both parents and teachers.
- Learning disabilities: Severe learning disabilities were severe with all academic scores more than two standard deviations below the mean (WRAT-4) at baseline.
- Design Challenge: the comparison group was receiving a math intervention that the control group did not get.

The notion that the Cogmed group would exceed them in improving in math seems highly unlikely.

**DESIGN:** RCT, control group received math training. All students were in a residential treatment facility in which they received: Complicating factor was that both groups were in a school with intensive remedial school along with psychopharmacological treatment resulted in gains for both groups of children. This included attention, reading, math and behavior.

**RESULTS:** Cogmed training resulted in significant but small gains on verbal (Etau=.13) and visuo-spatial WM (Etau=.08) but not on teacher or parents behavioral ratings or academics compared to group training on math tasks. On a subset of WM criterion measures upon which this group improved significantly compared to the control which was a math-training group.

- Sample size: n=60, (52 male, 6 female), ages 12 to 17, average age=14.2 (control) and average age of control=14.4 (Peer groups)

Gray et al. (2012) studied a group of treatment resistant adolescents with combined severe LD and ADHD, as well as majority of children (57 - 77%) falling below 16th percentile for WM.

**Key Finding:** They found that “those who showed the most improvement on the WM training tasks at school were rated as less inattentive/hyperactive at home by parents.”

Greater progress within the program resulted in greater improvement on inattentive/hyperactive by parents.

This theme has arisen in other studies that there is a trend toward greater increases on the training index or the training task results in better results. A trend like this was seen with the preschoolers in the van-Dongen-Broosomma et al. study.

Similarly, the training index significantly contributed to an ADHD rating scale and the BRIEF by the teacher, but there were not significant group differences.

**Dosing hypothesis:**

One wonders whether subjects needed more training time to accomplish greater gains. A possible explanation for these findings is that longer and more intensive training may be required to ameliorate severe difficulties in WM (Gray, et al., 2013). This is a matter of dosing which in other areas of computerized cognitive training has been explored in more depth.
Recently published studies on ADHD & Cogmed that will be included in next Month’s webinar.

ADHD 2015 Child Neuropsychology Combined cognitive and parent training Steeger et al. Link to Abstract

ADHD 2014 Journal of Attention Disorders Working Memory Training in ADHD: Controlling for Regulation and Expectancy Mawjee et al. Link to Abstract

Innovations and the issue of the Pipeline of research: State of Ongoing Cogmed Research Collaborations

<table>
<thead>
<tr>
<th>Category</th>
<th>Child</th>
<th>Adult/Adolescent</th>
<th>Type</th>
<th>#</th>
</tr>
</thead>
<tbody>
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<td>Typical WM (11)</td>
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<td>7</td>
<td>Placebo</td>
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<td>ADHD (13)</td>
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<td>Comparison</td>
<td>20</td>
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<td>Exposure (12)</td>
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<td>10</td>
<td>Waitlist</td>
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<td>Cancer (18)</td>
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<td>3</td>
<td>Passive</td>
<td>4</td>
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<td>Development (9)</td>
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<td>Single Case</td>
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<tr>
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<tr>
<td>Total</td>
<td>52</td>
<td>46</td>
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</table>

- 23 include imaging
- 58 include Behavioral Ratings
- 26 include Reading Measures
- 30 include Math Measures

Does this chart affect which populations to whom you might provide Cogmed?

Cogmed Claims:
- Working memory is key to attention, executive function
- Working memory can be improved by training, using right tool/protocol
- Working memory can be improved at all age levels
- The improvement can be tracked by on four levels: FMRI/PET, Neuro-psych testing, rating scales, and real life behavior
- Improved working memory generalizes to behavioral improvement
- The behavioral improvement is sustained, at least six months
- The effects of WM training are specific: WM and its derived functions are improved, but there is no across-the-board-improvement
- Training effects are pronounced in populations with a WM deficit, but effects not constrained to ADHD
Completed Cogmed studies of ADHD Children & Adolescents

<table>
<thead>
<tr>
<th>Completed</th>
<th>Location/Institution</th>
<th>Children</th>
<th>ADHD</th>
<th>Description</th>
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<td>Neuropsychological and virtual classroom intervention for children with learning and attention problems: The effectiveness of working memory training</td>
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</tbody>
</table>

Ongoing Studies on Cogmed ADHD Children(1)

1. Ongoing | Prague Psychiatric Center & Prague Children's Hospital | Children | 2 different types of working memory training: Auditory-verbal working memory and visual working memory, in healthy children and children with ADHD |
2. Ongoing | University of Tampere Center of Excellence in Child Development | Children | Working memory training in children with ADHD, RCT, and pilot study |
3. Ongoing | University of Maastricht | Children | Effects of working memory training for children with ADHD, RCT, and pilot study |
4. Ongoing | University of Paris Ouest Nanterre La Défense | Children | Working memory training in children with ADHD, RCT, and pilot study |
5. Ongoing | Universidad Nacional de San Martin | Children | WM training in a Latin American social context |
6. Ongoing | University of California, Davis | Children | A comparison between parent training & Cogmed WM training for academic readiness and parent-child relationships in ADHD children |
7. Ongoing | University of Alabama at Birmingham | Children | WM training for children with ADHD/Anxiety: A study of children with co-morbid ADHD and anxiety using Cogmed and EEG |
8. Ongoing | The Bascule Beernink | Children | WM training for clinically referred school age children with ADHD: better performance in the classroom? |
9. Ongoing | Ohio State University | Children | A blinded active placebo controlled trial of WM training for children and adolescents with ADHD, reading comprehension problems, and executive function difficulties |
10. Ongoing | Hamad Hospital School Health Specialist Clinic | Children | Prevalence and management of ADHD among Qatari students |
11. Ongoing | George Washington University | Children | Effectiveness of Cogmed WM training in ADHD children with ADHD |

Ongoing Studies on Cogmed ADHD Children(2)

1. Ongoing | Children & Adolescents | Children | 2 different types of working memory training: Auditory-verbal working memory and visual working memory, in healthy children and children with ADHD |
2. Ongoing | University of Western Ontario | Children | Working memory training in children with ADHD, RCT, and pilot study |
3. Ongoing | University of Maastricht | Children | Effects of working memory training for children with ADHD, RCT, and pilot study |
4. Ongoing | University of Paris Ouest Nanterre La Défense | Children | Working memory training in children with ADHD, RCT, and pilot study |
5. Ongoing | Universidad Nacional de San Martin | Children | WM training in a Latin American social context |
6. Ongoing | University of California, Davis | Children | A comparison between parent training & Cogmed WM training for academic readiness and parent-child relationships in ADHD children |
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11. Ongoing | George Washington University | Children | Effectiveness of Cogmed WM training in ADHD children with ADHD |
Completed Cogmed studies of ADHD Adults

<table>
<thead>
<tr>
<th>Study</th>
<th>Institution</th>
<th>PI</th>
<th>Population</th>
<th>Topic</th>
<th>Program</th>
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</thead>
<tbody>
<tr>
<td>Completed</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

NOTE: The argument for how to address the issue of whether Cogmed “works” with ADHD by organizing data based upon severity of disorder is in a chapter we recently published.


This chapter puts into the larger perspective computerized cognitive training in the areas in which it has been most applied clinically: Schizophrenia, Traumatic Brain Injury & ADHD.

It is in this chapter where the “severity of disorder” argument is made.


Ongoing Studies on Cogmed ADHD Adults

<table>
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<tr>
<th>Study</th>
<th>Institution</th>
<th>PI</th>
<th>Population</th>
<th>Topic</th>
<th>Program</th>
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<tbody>
<tr>
<td>Ongoing</td>
<td></td>
<td></td>
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</tbody>
</table>

Responding to Criticism:

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Thank you!