

Cogmed Claims and Evidence V3:

Children completing Cogmed have Improved in Reading & Math

February 9th, 2016

<http://www.cogmed.com/research>

By Charles Shinaver Ph.D.
&
Peter C. Entwistle Ph.D.

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Presenter: Charles Shinaver, Ph.D.
Cognitive Consultant
(888)-748-3828, x110
(800)-627-7271 x 262355
(317)-641-7794
charles.shinaver@Pearson.com

Chat box:

Peter Entwistle, PhD
Cognitive Consultant
(888)-748-3828, x111
(800)-627 7271x262104
202-333-3210
Peter.entwistle@pearson.com



Agenda

- Claims & Caveats to Claims
- Near & Far Transfer
- Overview of Cogmed Research
- Severity of Disorder Continuum
- Salience of Co-morbidity
- Role of WM in Reading Difficulties
- Data Supporting Cogmed's Impact with Reading
- Role of WM with Math Difficulties
- Data Supporting Cogmed's Impact with Math



The claim related to academic achievement:

- 4) *Learning outcomes in reading (13 (Dahlin, 2011), 35 (Egeland, et al, 2013), 45 (Holmes & Gathercole, 2014)) and math (34 (Dahlin, 2013), 43 (Bergman-Nutley & Klingberg, 2014), 45 (Holmes & Gathercole, 2014)) following Cogmed *improves for many underperforming students*.
- 1st time that claims about academic achievement have been made related to Cogmed.
- Evidentiary basis for these claims will be reviewed.



Caveats to claims.

- Take careful note of the language: "following Cogmed *improves for many underperforming students*." *First, this identified underperforming students – not all students or those who are not underperforming. Secondly not all underperforming students.*
- **'Necessary, but not sufficient' caveat:**
 - Increased Working Memory capacity may be **necessary** for academic gains in an area **but it may not be sufficient** in and of itself for such gains.
 - Domain specific skills or knowledge and or other possible bottlenecks that may have to be addressed for a particular student to make gains in a specific area like reading or math.
 - Just because I increase my WM capacity will my German improve if I have never spoken or taken instruction in German language?
 - Since students automatically receive instruction in reading and math we appear to assume that this instruction will remediate deficits. It may and it may not.
 - **Remediation may be necessary to facilitate gains in a particular area.**
 - **Scaffolding is salient.**
 - Non working memory related deficits also impede academic gain in particular areas like dyslexia.
 - Some dyslexics have poor working memory and others who do not.
 - Dyslexics with poor WM may still need an intervention to help with verbal processing.
 - **Other interventions may be necessary.**
 - For those lacking a deficit in WM one would not expect following Cogmed that there would be growth in reading for this subgroup of dyslexics.

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

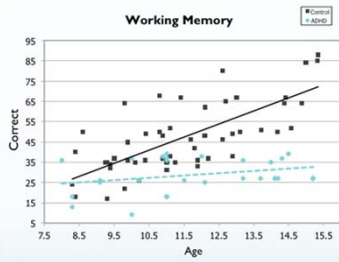
Delegates to different parts of our brain to take action - shifting

Allows us to **block out unnecessary information** – inhibition

Keeps us updated on what's happening – & **focused** on what matters



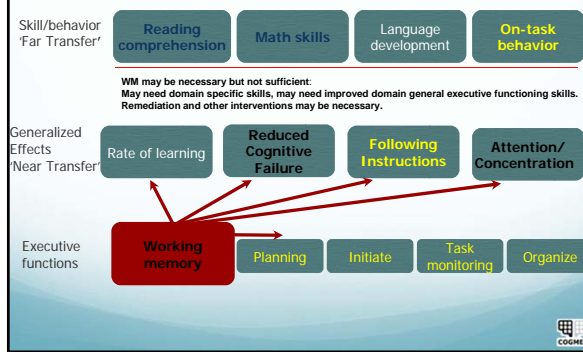
The Development of Working Memory in ADHD. How WSWM became the target for Cogmed.



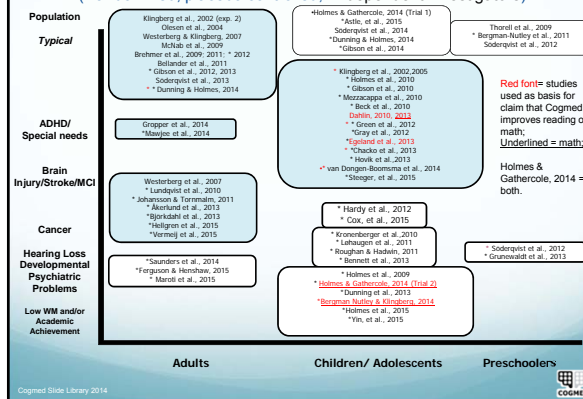
Westerberg et al. (2004). Visuo-spatial working memory: a sensitive measurement of cognitive deficits in ADHD. *Child Neuropsychology* 10 (3) 155-61.



Cogmed: Near & Far Transfer



Over 76 Cogmed published studies cover range of ages & profiles (*randomized, placebo controlled, *independent investigators)



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Severity of Disorder & Co-Morbidity of Cogmed subjects.							
Study	WM deficit	ADHD-I Attention problems	ADHD-C	ADHD-HI	Rx%	LD	ODD/CD
Holmes & Gathercole, 2013 (trial 1) mixed ability	NR	NR	NR	NR	NR	NR	NR
Holmes, et al., 2009	100%	NR*	NR	NR	NR	NR	NR
Dunning, et al., 2013	100%	NR	NR	NR	NR	NR	NR
Benjamin-Nulley & Kingberg, 2014	100%	Mainly Attention problems	Alternative problems/Minor HI	Minor HI	NR	NR	Minor
Holmes & Gathercole, 2013 (trial 2)	NR	NR	NR	NR	NR	100% (Low aca. Perf.)	NR
Dahlin, 2010	NR	33% diag. 60% rated inatt.**	NR	NR	NR	9.5%***	0%
Dahlin, 2013 (not randomized)	-	33% diag. 60% rated inatt.**	22%	NR	NR	22%	0%
Kingberg, et al., 2002	-	NR	100%?	NR	43%	NR	NR
2005 Kingberg, et al., 2005	-	25%	75%	0%	0%	NR	0%
***Howk, et al., 2013	-	0%	100%	0%	69.6%	NR	NA/0%
Green, et al., 2012	-	42%	42%	17%	67%	0%	NR
Van Dongen-Boomsma, et al., 2014	-	7.7%	80.8%	11.5%	0%	NR	3.8%/0%
Beck, et al., 2010	NA	71%	29%	NR	61%	NR	46%
Chacko, et al., 2013	-	34%	66%	0%	27%	NR	50%/9%
Gropper, et al., 2014	-	51%*****	NR	NR	26%	57%	NR
Gray, et al., 2012	-	NR	100%	NR	98%	100% Severe	100%/0%

Comorbidity matters with other treatments including Rx.

1. Meta-analysis of Efficacy of atomoxetine (Strattera) for ADHD (Cheng, et al., 2007). Studies published from 1985 to 2006.
High baseline ADHD symptoms was associated with "greater reduction in ADHD symptoms, whereas **male gender**, **(p=.02)**, **comorbid oppositional defiant disorder (ODD) status** **(p=.01)** and **ADHD hyperactive/impulsive subtype** **(p=.01)** were associated with smaller reductions."
2. Meta-analysis of methylphenidate for adults with ADHD: a Meta-regression analysis (Castells, et al., 2011)
"This study shows that methylphenidate improves ADHD symptoms in adults in a dose-dependent fashion. **The efficacy of methylphenidate appears to be reduced in patients with comorbid SUD.**" **(SUD - Substance abuse disorders).**

Comorbidity matters with Rx treatment.
Comorbidity matters with Cogmed too.

The role of WM in Reading Difficulties.



Reading Disabilities in Children Meta-Analysis

(Kudo, et al., 2015)

This article synthesizes literature that compares the academic, cognitive, and behavioral performance of children with and without reading disabilities (RD).

Forty-eight studies met the criteria for the meta-analysis, yielding 735 effect sizes (ESs) with an overall weighted ES of 0.98.

Small to high ESs in favor of children without RD emerged on measures of **cognition, achievement, and behavior skills**.



Reading Disabilities in Children Meta-Analysis: A Complex Profile of Deficits

(Kudo, et al., 2015)

● Cognition deficits:

- **phonological awareness** [ES = 1.00]
- **rapid naming** [ES = 0.89]
- **verbal working memory** [ES = 0.79]
- **executive processing** [ES = 0.67]
- short-term memory [ES = 0.56]
- visual-spatial memory [ES = 0.48]

Note: Many areas have larger effect sized deficits than WM.

One would expect that these children would need remediation in other salient areas.

IF WM was the only learning bottleneck then immediate gains in reading disabilities might occur post Cogmed.

● academic achievement

- pseudoword reading [ES = 1.85]
- **spelling** [ES = 1.25]
- **math** [ES = 1.20]
- **writing** [ES = 1.20]
- **vocabulary** [ES = 0.83]

This data shows that children with reading disabilities have several areas likely in need of remediation.

behavior skills (ES = 0.80).

Reading Disabilities in Children Meta-Analysis

(Kudo, et al., 2015)

Hierarchical linear modeling indicated that specific cognitive process measures (**verbal working memory, visual-spatial memory, executive processing, and short-term memory**) and intelligence measures (**general and verbal intelligence**) significantly moderated overall group effect size differences.

This data further supports the potentially "leverage" for learning that improved WM potentially provides, but provides the caveats of general and verbal intelligence as moderating outcomes too. This should be considered with Cogmed and with any other salient intervention.

Overall, the results supported the assumption that cognitive deficits in children with RD are persistent. Intervening to ameliorate one of those, WM, is certainly relevant and important.

WM & Language Comprehension Meta-Analysis

(Daneman & Merikle, 1996)

- 77 studies, with 6,179 Ss.
- Association between WM capacity and language comprehension ability to compare the predictive power of the measures of working memory developed by M. Daneman and P. A. Carpenter (see record [1981-22775-001](#)) with the predictive power of other measures of working memory.
- The results of the meta analysis support Daneman and Carpenter's claim that **measures that tap the combined processing and storage capacity of working memory** (e.g., reading span, listening span) **are better predictors of comprehension than are measures that tap only the storage capacity** (e.g., word span, digit span).



WM & Language Comprehension Meta-Analysis

(Daneman & Merikle, 1996)

- Concluded math process plus storage measures of WM are good predictors of comprehension. The superior predictive power of the process plus storage measures is not limited to measures that involve the manipulation of words and sentences.
- So, improving WM has the potential to improve language comprehension.
- Yet, even this may depend upon improved vocabulary.



What about the WISC-V, WM, Reading & Math?

- Is there any research showing working memory to be important with the WISC-V related to reading?
- Is there any data showing a link between the WISC-V and the WIAT-III or K-TEA achievement tests, especially with learning disabled (LD) students?

WISC-V-WIAT-III Typically Developing

- Word Reading
 - VCI and AWMI $R^2=.283$
- Word Reading
 - DS, VC, NSLN, DST $R^2=.333$
 - DS, IN,CO, DST, and NSLN $R^2=.362$
- Pseudoword Decoding
 - WMI, VCI, and NSI $R^2=.242$
- Pseudoword Decoding
 - DS, NSLN, VC, DST $R^2=.284$
 - DS, NSLN, IN,CO, DST $R^2=.362$

WISC-V Abbreviations

- VCI = Verbal Comprehension
- AWMI = Auditory Working Memory Index
- DS = Digit Span
- VC = Vocabulary
- NS = Naming Speed Literacy
- DST = Delayed Symbol Translation
- IN = Information
- CO = Comprehension
- NSI = Naming Speed Index
- FRI = Fluid Reasoning Index
- PSI = Processing Speed Index
- MR = Matrix Reasoning
- AR = Arithmetic
- SI = Similarities
- QRI = Quantitative Reasoning Index
- BD = Block Design
- CD = Coding
- FW = Figure Weights

WISC-V-WIAT-III Typically Developing

- Reading Comprehension
 - VCI, FRI, and AWMI $R^2=.283$
- Reading Comprehension
 - SI, VC, MR, DST $R^2=.310$
 - SI,CO, AR, DST $R^2=.333$
- Total Reading
 - VCI, AWMI, SRI $R^2=.427$
- Total Reading
 - DS, VC, NSLN, SI, DST $R^2=.427$
 - IN,DS, AR, NSLN, SI, CO $R^2=.441$

WISC-V-WIAT-III Typically Developing

- Basic Reading
 - VCI, AWMi, WMI, NSI $R^2=.329$
- Basic Reading
 - VC, DS, NSLN $R^2=.342$
 - IN, DS, NSLN, AR $R^2=.364$
- Oral Reading Fluency
 - VCI, NSI, AWMi $R^2=.302$
- Oral Reading Fluency
 - NSLN, VC, CD, DS, SI, DST $R^2=.268$
 - LNS, NSLN, VC $R^2=.313$

WISC-V-WIAT-III Typically Developing Correlations that relate to math achievement

- Numerical Operations
 - QRI, PSI, AWMi, VCI $R^2=.290$
- Numerical Operations
 - SI, DS, CD, FW, NSQ $R^2=.287$
 - AR, SI, CD $R^2=.309$
- Math Problem Solving
 - QRI, AWMi, VSI $R^2=.397$
- Math Problem Solving
 - DS, DST, FW, CD, BD, VC $R^2=.363$
 - AR, BD, DST, FW, DS $R^2=.434$

WISC-V-WIAT-III Typically Developing

- Total Math
 - VCI, FRI, and AWMi $R^2=.437$
- Total Math
 - DS, CD, FW, DST, SI $R^2=.397$
 - AR, CD, SI, FW, DST, DS $R^2=.448$
- Math Fluency
 - QRI, PSI, AWMi, NSI $R^2=.392$
- Math Fluency
 - CD, DS, NSLQ, FW $R^2=.309$
 - AR, CD, NLS, NSQ $R^2=.427$

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

Study	WM deficit	ADHD-I Attention problems	ADHD-C	ADHD-HI	Rx%	LD	ODD/CD
Dahlin, 2010	NR	33% diag, 60% rated inatt.**	NR	NR	NR	9.5%***	0%

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, 2010)

Table 1 Descriptive statistics and ES (effect sizes) for cognitive and literacy measures in the treatment group and the control groups

Time	Treatment group						Control group						Effect sizes		
	T1		T2		T3		T1		T2		T3			T2-T1	T3-T1
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD			
Psychological measures															
Span board forward	4.54	0.9	5.68	1.0	5.55	1.0	4.20	0.8	4.36	1.0	4.46	1.0	★	0.90	0.74
Span board back	3.96	1.1	5.13	1.4	4.99	1.1	3.90	1.1	4.26	0.8	4.22	0.9	★	0.71	0.62
Digit span forward	4.24	0.7	4.72	0.9	4.63	0.9	4.34	1.0	4.26	0.9	4.46	0.8	★	0.66	0.33
Digit span back	3.02	0.7	3.71	1.0	3.31	1.1	2.97	0.9	3.04	0.7	2.84	0.8	★	0.67	0.46
Stroop time (s)	121.86	34.6	112.39	32.4	103.04	43.0	121.68	27.6	115.08	34.0	107.68	30.8	-	-0.06	-0.16
Raven RCPM	27.23	5.0	29.68	4.7	29.90	4.5	24.80	3.7	26.44	4.2	27.84	4.4	0.26	0.41	-0.11
Literacy measures															
Word decoding	11.74	3.8	12.88	5.4	13.45	5.2	13.67	6.4	12.73	9.4	14.60	7.5	0.37	0.17	-
Orthographical verification	17.14	14.5	19.93	15.1	25.03	15.1	21.80	15.4	26.20	19.7	31.07	24.1	★	0.39	-0.13
Reading comprehension	8.45	3.7	11.50	3.0	11.10	3.1	10.13	5.0	10.27	4.7	10.13	4.7	★	0.88	0.91
WM training measures															
Start scores (T1) and maximum scores (T2)	72.21	12.4	93.41	15.0	-	-	-	-	-	-	-	-	-	-	-


Control group psychological measure = the Klingberg, et al. control group (2005) (n = 25); control group literacy measures = children in small groups in the present study (n = 15); Treatment group (n = 41); Studies = no results completed



Cogmed Training results in improved psychomotor speed & reading. RCT (Same subjects as Hovik, et al., 2013) (Egeland, et al., 2013 – full manuscript linked to Cogmed page)

Study	WM deficit	ADHD-I Attention problems	ADHD-C	ADHD-HI	Rx%	LD	ODD/CD
***Hovik, et al., 2013	-	0%	100%	0%	69.6%	NR	NA/0%


- 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.
- **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.



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

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.



10-12 year old ADHD children make and maintain significant gains in WM for 8 months. RCT (Hovik, et al., 2013 – full manuscript linked to Cogmed page)

Study	WM deficit	ADHD-I Attention problems	ADHD-C	ADHD-HI	Rx%	LD	ODD/CD
***Hovik, et al., 2013	-	0%	100%	0%	69.6%	NR	NA/0%


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



Gain in WM Maintained for 8 months.

(Hovik, et al., 2013)

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.



Teacher-led “whole class” Cogmed

(4) Trial 2:

(Holmes & Gathercole, 2014 – link to full manuscript on Cogmed page)

Study	WM deficit	ADHD-I Attention problems	ADHD-C	ADHD-HI	Rx%	LD	ODD/CD
Holmes & Gathercole, 2013 (trial 2)	NR	NR	NR	NR	NR	100% (Low aca. Perf.)	NR

- 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

(5) Trial 2:

(Holmes & Gathercole, 2014)

- 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

(6) Trial 2:
Sublevel gains in attainment
(Holmes & Gathercole, 2014)

	Year 5			Year 6		
	Trained Group	Comp. group	d	Trained Group	Comp. group	d
English	1.48 (1.56)	2.36 (1.58)	.56	2.00 (1.44)	1.12 (1.20)	.67
Math	1.36 (1.29)	-1.04 (2.88)	1.15	2.12 (1.13)	1.32 (1.55)	.60
	(standard deviation)					



Teacher-led “whole class” Cogmed

(7) Trial 2:
(Holmes & Gathercole, 2014)

- 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.



Role of WM in Math Difficulties



A Meta-Analysis of Mathematics and Working Memory: Moderating Effects of Working Memory Domain, Type of Mathematics Skill, and Sample Characteristics.
(Peng, et al., 2015)

Investigated the relation between mathematics and working memory (WM) and to identify possible moderators of this relation including domains of WM, types of mathematics skills, and sample type.

A meta-analysis of 110 studies with 829 effect sizes found a significant medium correlation of mathematics and WM, $r = .35$, 95% confidence interval [.32, .37].

Moderation analyses indicated that mathematics showed comparable association with verbal WM, numerical WM, and visuospatial WM.

Word-problem solving and whole-number calculations showed the strongest relation with WM whereas geometry showed the weakest relation with WM.

A Meta-Analysis of Mathematics and Working Memory: Moderating Effects of Working Memory Domain, Type of Mathematics Skill, and Sample Characteristics.
(Peng, et al., 2015)

• **INTERESTING FINDING:** The relation between WM and mathematics was stronger **among individuals with mathematics difficulties that are associated with other disorders or cognitive deficits** compared with that among typically developing individuals and individuals with only mathematics difficulties.

• Given other disorders and cognitive deficits this group in which WM has a high correlation to mathematics may need additional remediation and/or interventions.



Another meta-analysis:
Working memory deficits in Math learning difficulties.

(Carmen, 2012).

This study made a "quantitative synthesis of the literature comparing children with Math learning difficulties to average-achieving, age-matched children on measures of working memory in view of Baddeley and Hitch's multi componential working memory model."

Their "meta-analytic investigation drew from the literature a number of 18 studies that matched the inclusion criteria. We hypothesized that all three components of Baddeley and Hitch's model should contribute to the poor Math performance displayed by children with Math learning difficulties, and that this relation varies as a function of age."

They also "hypothesized that children with Math learning difficulties would present more accentuated working memory deficits for numerical material and/or processing."



Working memory deficits in Math learning difficulties: A meta-analysis

(Carmen, 2012).

"Based upon Cohen's criteria, the results indicate a large effect size, in favor of the controls for the relationship between **Math performance and central executive component**, as well as **Math performance and the visual-spatial sketchpad, more accentuated in younger ages.**"

"Only a moderate effect size emerged in the case of **Math performance and the phonological loop (PL).**"

"With respect to numerical versus non-numerical working memory deficits, a large effect size emerged for **numerical central executive measures**, along with a moderate effect size for the PL numerical measures, and a weak effect size for non-numerical PL."

"The results indicate that Math difficulties are attributable to a central executive deficit or delay, more accentuated for **numerical stimuli and/or processing and to a visual-spatial working memory deficit.**"

Given that Cogmed emphasizes visual spatial WM and this was found to account for a larger effect size than PL WM one may posit the possibility that Cogmed may have greater impact upon math than other academic areas. Cogmed has been found to demonstrate a greater effect size on VSWM than PL WM or verbal WM.

A 3rd Meta-Analysis of Math Disabilities: "A Selective Meta-Analysis of the Literature."

(Swanson & Jerman, 2006)

This article synthesizes published literature comparing the cognitive functioning of children who have math disabilities (MD) with that of (a) average-achieving children; (b) children who have reading disabilities (RD); and (c) children who have co-morbid disabilities (MD+RD).

Average achievers outperformed children with MD on measures of verbal problem solving, naming speed, verbal working memory (WM), visual-spatial WM, and long-term memory(LTM).

Children with MD outperformed co-morbid children on measures of literacy, visual-spatial problem solving, LTM, short-term memory (STM) for words, and verbal WM.

Children with MD could be differentiated from children with RD only on naming speed and visual-spatial WM.

Differences in cognitive functioning between children with MD and average achievers were related primarily to verbal WM when the effects of all other variables (e.g., age, IQ, and other domain categories) that were partialled out.

WM training generalizes to Reading Comprehension & Basic Number Skills & lasts 3 years

(Dahlin, 2013 – full manuscript linked to Cogmed page)

Study	WM deficit	ADHD-I Attention problems	ADHD-C	ADHD-HI	Rx%	LD	ODD/CD
Dahlin, 2013 (not randomized)	.	33% diag 60% rated inst.**	22%	NR	NR	22%	0%

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)

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.



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

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



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

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 T2 (treatment effect = $p < .05$, $d = 0.74$) as well as at T3 for the boys (treatment effect = $p < .05$, $d = 0.90$), 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)

Cohen's d Statistics for boys	T2-T1	T3-T1
Span board forward	1.25	1.09
Span board backward	1.05	.83
Digit forward	.57	.54
Digit backward	.87	.36
Raven	.45	.52
Addition	.31	.56
Subtraction	.09	.25
Number skills	.28	.56
Reading comprehension	.67	.76
Word Reading	.22	.35

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 – link to full manuscript on Cogmed page)

Study	WM deficit	ADHD: Attention problems	ADHD-C	ADHD-HI	Rx%	LD	ODD/CD
Bergman-Nutley & Klingberg, 2014	100%	Mainly Inattentive problems	Attentive problems/ minor HI	Minor HI	NR	NR	Minor

n=176 children (treatment group), ages 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.

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)

- **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
- **following instructions:** digitized from classroom analog test developed by Gathercole, et al., (2008), practice trials with one and two items and then begins with first task of 2 items; test concluded when two items at the same level are incorrect, span task)
- **mathematics test: See next slide.**

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)

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.

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)

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 underperformance 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;
 (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)

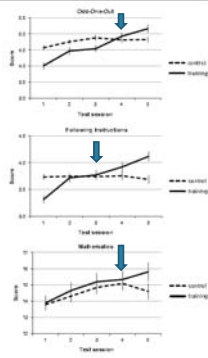
Take note that changes begin to be registered at about 3 or more weeks into training.

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, FI & Math significantly Improved

Fig. 3 Reported scores of the WM transfer tasks for the training and control groups (mean and SEM, SD)



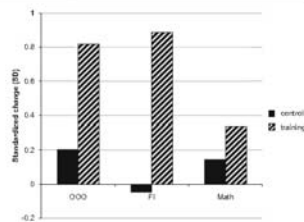
Note when the training group surpasses the control group.

WM

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:

Fig. 2 Standardized change (T5 - T1)/SD_{T1} for the two groups



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)

- Improvements in FI were linear and showed minimal test-retests in the control group.
- In OOO and the math 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).

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)

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 (T5t - T1t) - (T5c - T1c)/SDT2-T1.pooled, and the

EFFECT SIZES:

- 0.60 for OOO,
- 0.69 for FI and
- 0.44 for Math."

New Research?

Is there any newly published research ?
What is the status of ongoing studies?

Working Memory is Associated with Long Term Attainments in Math & Reading

Front. Psychol., 10 November 2015 | <http://dx.doi.org/10.3389/fpsyg.2015.01711>

[Stina Söderqvist](#)* and [Sissela Bergman Nutley](#)

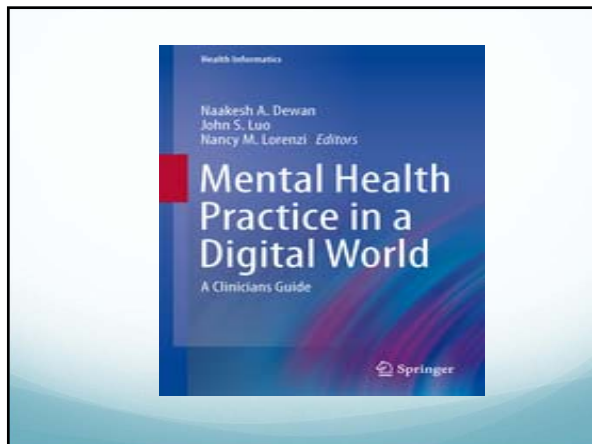
Clinical Research, Pearson Clinical Assessment, Stockholm, Sweden

Training working memory (WM) using computerized programs has been shown to improve functions directly linked to WM such as following instructions and attention. These functions influence academic performance, which leads to the question of whether WM training can transfer to improved academic performance. We followed the academic performance of two age-matched groups during 2 years. As part of the curriculum in grade 4 (age 9–10), all students in one classroom ($n = 20$) completed Cogmed Working Memory Training (CWMT) whereas children in the other classroom ($n = 22$) received education as usual. Performance on nationally standardized tests in math and reading was used as outcome measures at baseline and two years later. At baseline both classes were normal/high performing according to national standards. At grade 6, reading had improved to a significantly greater extent for the training group compared to the control group (medium effect size, Cohen's $d = 0.66$, $p = 0.045$). For math performance the same pattern was observed with a medium effect size (Cohen's $d = 0.58$) reaching statistical trend levels ($p = 0.091$). Moreover, the academic attainments were found to correlate with the degree of improvements during training ($p < 0.053$). This is the first study of long-term (>1 year) effects of WM training on academic performance. We found performance on both reading and math to be positively impacted after completion of CWMT. Since there were no baseline differences between the groups, the results may reflect an influence on learning capacity, with improved WM leading to a boost in students' capacity to learn. This study is also the first to investigate the effects of CWMT on academic performance in typical or high achieving students. The results suggest that WM training can help optimize the academic potential of high performers.

Conclusions

- Reading and Mathematics may both improve following Cogmed. There is some data to suggest this. It is still early. We will need more studies on larger numbers and those are occurring now.
- Cogmed is not sufficient. Training time and coaching are important.
- Reading instruction will be needed for many students. Many children will need help with phonological processing. Many children need to improve their sight word and decoding skills.
- Gaps in Math's skills may exist for many students and remedial instruction may be needed to boost performance in school.
- WM is not the only problem for many LD or ADHD students.
- Some students with ADHD will still benefit from medication.

Many students will show gradual improvement so they will require time to demonstrate the benefit of Cogmed.



Presenter: Charles Shinaver, Ph.D.
Cognitive Consultant
(888) 748-3828, x110
(800)627-7271 x 262355
(317) 641-7794, (317) 379-9083 cell
charles.shinaver@Pearson.com

Presenter:
Peter Entwistle, PhD
Cognitive Consultant
888-748-3828, x111
202-333-3210
Peter.entwistle@pearson.com



Thank you!