

Working memory: A cognitive system that supports learning?

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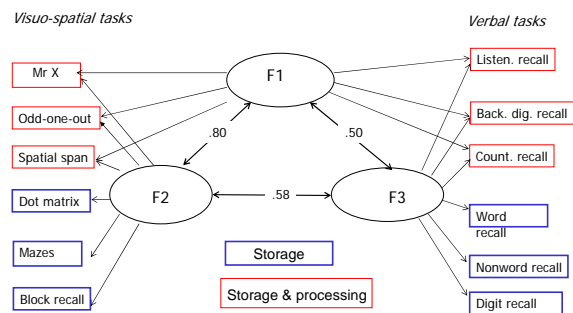
Working memory: key features

- Capacity to hold material in mind and manipulate as necessary for brief period: mental workspace
- Multiple interacting cognitive and neural subsystems
- Limited in capacity
- Catastrophic loss
- Relatively impervious to environmental factors

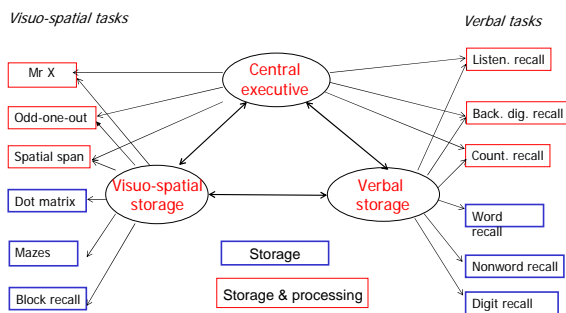
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Working memory: key features

- Capacity to hold material in mind and manipulate as necessary for brief period: mental workspace
- Multiple interacting cognitive and neural subsystems
- Limited in capacity
- Catastrophic loss
- Relatively impervious to environmental factors, highly heritable

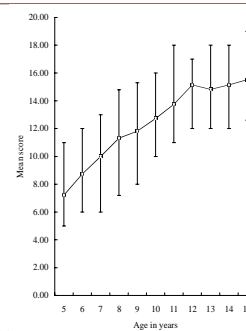
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Development of working memory

- Working memory ability increases steadily with age between 4 and 14 years
- Substantial differences in working memory ability between children of the same age

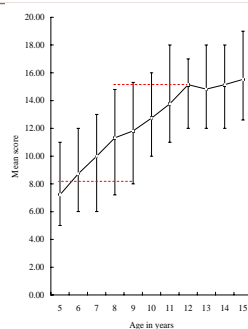
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Mean scores on listening recall test from WMTB-C as a function of age, with 10th & 90th centiles



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Mean scores on listening recall test from WMTB-C as a function of age, with 10th & 90th centiles



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Working memory deficits present in many developmental disorders

Deficits in working memory in:

- Dyslexia
- Specific Language Impairment
- ADHD
- Developmental Coordination Disorder
- Genetic disorders, e.g., Down syndrome
- Hypertension

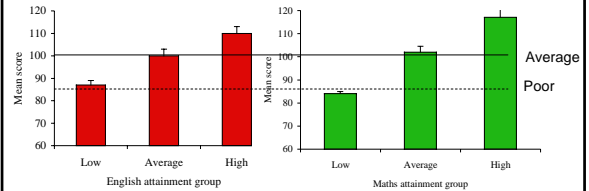
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Why is working memory important?

Poor working memory is a risk factor for learning difficulties that:

- i) warrants detection in its own right, and
- ii) requires, and benefits from, intervention

Gathercole et al. (2004): Mean working memory scores as a function of English and maths KS2 attainment groups, data from 11-year olds



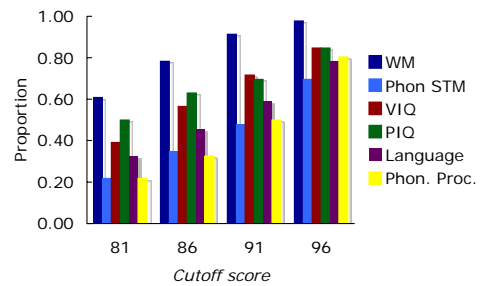
Working memory as a specific predictor of learning difficulties

Gathercole, Alloway, Adams & Willis (2006)

46 children aged 7 to 11 years identified as having SEN in reading, confirmed by our assessments.

Assessed: IQ, maths, language, verbal working memory, verbal STM, phonological awareness

Proportions of children failing to reach cutoff scores



Multiple regression: dependent variable reading score

Predictor	stand. β
Working memory	.347*
Verbal IQ	-.159
Performance IQ	.026
Phon. awareness	.206
Language	.427*

* $p < .05$

Multiple regression: dependent variable maths score

Predictor	stand. β
Working memory	.339*
Verbal IQ	.280
Performance IQ	.024
Phon. awareness	.181
Language	.072

* $p < .05$

Characteristics of children with poor working memory

- Poor academic progress

More than 80% of children with poor working memory fail to achieve expected levels of attainment in either reading or maths, typically both (Gathercole & Alloway, 2008)

Characteristics of children with poor working memory

- Poor academic progress
- Difficulties in following instructions

“Put your sheets on the green table, arrow cards in the packet, put your pencil away and come and sit on the carpet.”

John (6 years) moved his sheets as requested, but failed to do anything else. When he realized that the rest of the class was seated on the carpet, he went and joined them, leaving his arrow cards and pencil on the table.

Characteristics of children with poor working memory

- Poor academic progress
- Difficulties in following instructions
- Difficulties in combining processing and storage

e.g., identifying the pair of rhyming words in a 4-line poem or the missing digits in the spoken sequence 1, 2, 4, 5, 6, 8

Characteristics of children with poor working memory

- Poor academic progress
- Difficulties in following instructions
- Difficulties in combining processing with storage
- Place-keeping difficulties

When the teacher wrote on the board Monday 11th November and, underneath, The Market, which was the title of the piece of work, Nathan lost his place in the laborious attempt to copy the words down letter by letter, writing moNemarket.

Characteristics of children with poor working memory

- Poor academic progress
- Difficulties in following instructions
- Problems combining processing with storage
- Place-keeping difficulties
- Teachers say: short attention span and highly distractible

“he’s in a world of his own”

“he doesn’t listen to a word I say”

“she’s always day-dreaming”

“with him, it’s in one ear and out of the other”

Observation

Adam (5 years) struggles to maintain attention, particularly during whole-class teaching when the pupils join together on the carpet. Hence, he sits directly in front of the teacher and is frequently prompted to sit correctly and to pay attention as he regularly fidgets, looks around the classroom and distracts other children near him.

Why do these children struggle to learn?

- Learning is a step-by-step process, based on successes in individual learning activities.
- Children with working memory impairments often fail in the classroom because the working memory loads are excessive for them.
- Working memory failure leads to inattentive behaviour, simply because the child forgets what s/he is doing.

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ADHD: DSM-IV symptoms of *inattention*

At least 6 of the following:

- Often does not give close attention to details or makes careless mistakes in schoolwork, work, or other activities
- Often has trouble keeping attention on tasks or play activities
- Often does not seem to listen when spoken to directly
- Often does not follow instructions and fails to finish schoolwork, chores, or duties in the workplace
- Often has trouble organizing activities
- Often avoids, dislikes, or doesn't want to do things that take a lot of mental effort for a long period of time
- Often loses things needed for tasks and activities
- Is often easily distracted
- Is often forgetful in daily activities

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Symptoms displayed by children with poor working memory (in red)

- Often does not give close attention to details or makes careless mistakes in schoolwork, work, or other activities
- Often has trouble keeping attention on tasks or play activities
- Often does not seem to listen when spoken to directly
- Often does not follow instructions and fails to finish schoolwork, chores, or duties in the workplace
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Gathercole & Alloway (2008), Gathercole, Alloway, Elliott, & Kirkwood (2008)

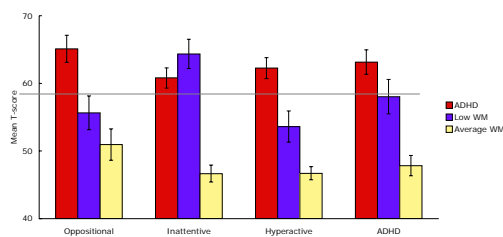
ADHD: DSM-IV symptoms of *hyperactivity/ impulsivity*

At least 6 of the following:

- Often fidgets with hands or feet or squirms in seat
- Often gets up from seat when remaining in seat is expected
- Often runs about or climbs when and where it is not appropriate (adolescents or adults may feel very restless)
- Often has trouble playing or enjoying leisure activities quietly
- Is often "on the go" or often acts as if "driven by a motor"
- Often talks excessively
- Often blurts out answers before questions have been finished
- Often has trouble waiting one's turn
- Often interrupts or intrudes on others (e.g., butts into conversations or games)

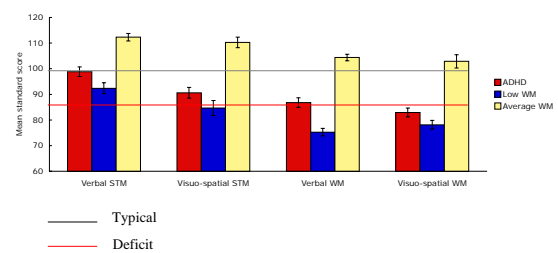
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Teacher behaviour ratings

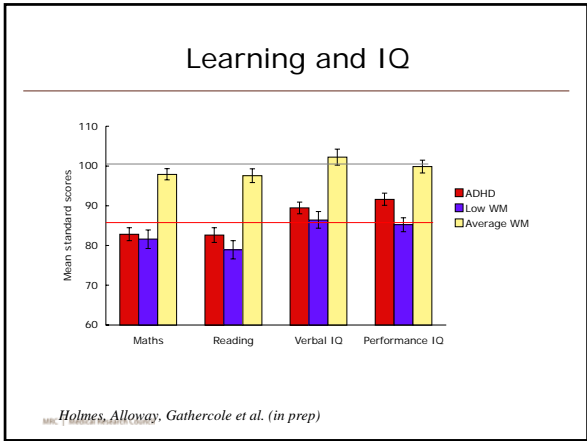
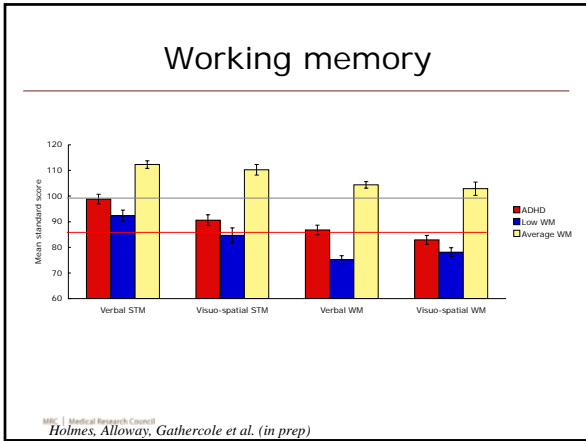


Holmes, Alloway, Gathercole et al. (in prep)

Working memory



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Holmes, Alloway, Gathercole et al. (in prep)



Executive function measures: effect sizes

Measure	<i>(d)</i>	
	ADHD	Low WM
Verbal STM	-0.81	-1.15
Verbal WM	-1.05	-1.66
Visuo-spatial STM	-0.97	-1.08
Visuo-spatial WM	-1.02	-1.19
Trails accuracy	-0.63	-0.79
Stroop errors	-0.74	-0.75
Walk - don't walk	-1.24	-1.15
Stroop time	-0.47	-0.74
Card sort no.sorts	-0.80	-0.95
Tower rule violations	-0.92	-0.50
CPT commissions	0.79	0.22

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Supporting children with working memory problems

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1: Classroom support

Learning difficulties arise because memory loads of learning activities are often too high, leading to task failures and lost learning opportunities.

Developed a classroom-based intervention designed to minimise learning difficulties by preventing working memory overload.

Understanding Working Memory: A Classroom Guide

The book cover features a grid of yellow squares and the title 'Working Memory Learning: A Practical Guide for Teachers' by Sarah E. Gathercole and Tracy Packiam Alloway.

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- ### The principles of the intervention
- Be aware of the warning signs of working memory failure
 - Monitor the child
 - Reduce amount of information to be stored
 - Reduce difficulty of processing
 - Be prepared to re-present important information
 - Encourage the use of memory aids
 - Help the child to use strategies
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Evaluation

Teachers say ...

- relatively easy to implement as they can work with existing curriculum activities
- enabled them to understand that many task failures are due to forgetting
- the child benefits from working within own capacity, with greater rates of task success

Gathercole SE & Alloway TP (2008). *Working memory and learning: A practical guide for teachers*. Sage Publishing.

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2: Training working memory

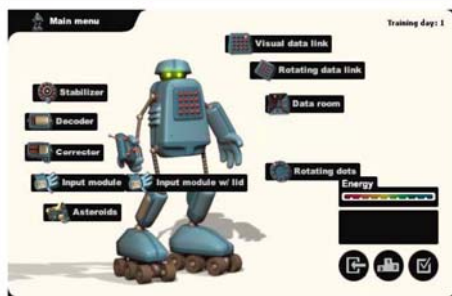
Cogmed WM training, developed by Klingberg

Key features:

- Game-style environment designed to train working memory using high-quality graphics game-style environment
- Training on working memory tasks for 20-25 days over a 6-week period
- Reward features
- Adaptive: individual works at maximum capacity continuously

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Training environment



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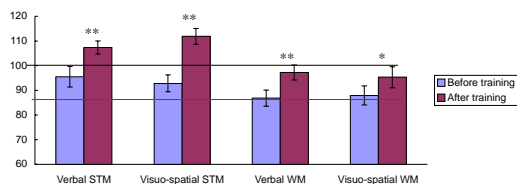
Training children with ADHD

Holmes, Gathercole, Place, & Elliott (2010)

- 25 children with ADHD aged 8-11 years, psychostimulant medication
- Tested on working memory (AWMA) and IQ (WASI) before and after training

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Children with ADHD



Holmes, Gathercole, Place, & Dunning (2010)

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Training children with poor working memory

Holmes, Gathercole, & Dunning (Dev Sci, 2009)

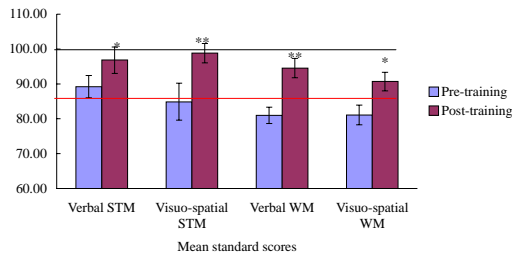
- Adaptive training: 22 children mean age 10y 1mo (12 m, 10 f) with poor verbal WM scores (<15th centile on each of 2 tests)
- Non-adaptive training: 20 children mean age 9y 9mo (15 m, 5 f) with poor verbal WM scores

Pre- and post-training assessments

- Working memory (AWMA), IQ (WASI), maths, reading
- Instruction span: *Touch the blue pencil then pick up the yellow ruler and put it in the red box*

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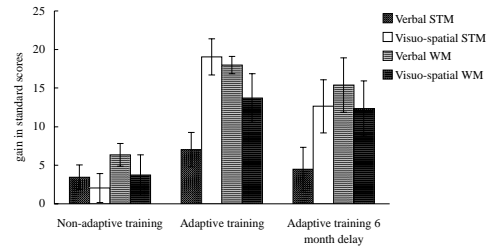
Children with low working memory



Holmes, Gathercole, & Dunning, 2009

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Gains with adaptive vs non-adaptive training in low memory children



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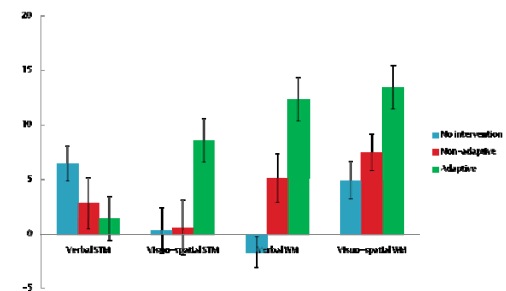
Adaptive training: IQ, reading and maths scores

Time of testing:	Pre-training		Post-training		6mth follow-up	
	M	SD	M	SD	M	SD
Verbal IQ	88.73	11.14	90.86	11.52	92.78	9.10
Performance IQ	88.05	13.09	90.68	12.96	87.11	9.07
Reading	83.68	12.35	83.00	15.06	82.83	14.14
Mathematics	84.27	12.28	85.68	12.70	89.94*	9.88

p < .05

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Dunning, Gathercole & Holmes: RCT



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WM training with other groups

- Boosts WM in children and adults with typical WM skills, and in stroke patients
- Holmes et al.: WM gains either nonsignificant or restricted to visuo-spatial tasks in children with dyslexia, language impairments, and Down syndrome

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How does it work?

Training-induced neural plasticity?

Increased prefrontal and parietal activity on untrained visuo-spatial working memory tasks (Olesen et al., 2004): training-induced plasticity (Westerberg & Klingberg, 2007)

Strategy development?

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Conclusions

- Poor working memory skills place a child at extremely high risk of:
 - poor academic progress
 - inattentive behaviour
- May be a primary cause of slow learning, and correspond to inattentive form of ADHD
- Problems may be ameliorated with cognitive training, although extent of functional transfer yet to be established.

To find out more

Gathercole SE & Alloway TP (2008). *Working memory and learning: A practical guide for teachers*. Sage.

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Working Memory  Learning

A Practical Guide for Teachers

Susan B. Gathercole & Tracy Packiam Alloway