Working memory, learning, and classroom behaviour

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Key features of working memory

- Interacting cognitive and neural subsystems

Visuo-spatial tasks
- Mr X
- Odd-one-out
- Spatial span
- Dot matrix
- Mazes
- Block recall

Verbal tasks
- Listen. recall
- Back. dig. recall
- Count. recall
- Word recall
- Nonword recall
- Digit recall

Visuo-spatial tasks

Verbal tasks

F1
- .80
- .50

F2
- .58

F3

Storage & processing

Storage only
AWMA measurement model

Visuo-spatial tasks
- Mr X
- Odd-one-out
- Spatial span
- Dot matrix
- Mazes
- Block recall

Central executive
- Visuo-spatial sketchpad
  - Spatial span
  - Dot matrix
  - Mazes
- Block recall

Phonological loop
- Nonword recall
- Word recall
- Digit recall

Verbal tasks
- Listen. recall
- Back. dig. recall
- Count. recall

Correlation coefficients:
- 0.80
- 0.58
- 0.50
Key features of working memory

- Interacting cognitive and neural subsystems
- Mental workspace
Key features of working memory

- Interacting cognitive and neural subsystems
- Mental workspace
- Catastrophic loss
Key features of working memory

- Interacting cognitive and neural subsystems
- Mental workspace
- Catastrophic loss
- Capacity limitation that varies between individuals
Mean scores on listening recall test from WMTB-C* as a function of age, with 10th & 90th centiles

*Working Memory Test Battery for Children, Pickering & Gathercole (2001)
Mean scores on listening recall test from WMTB-C as a function of age, with 10th & 90th centile bars.
Key features of working memory

- Interacting cognitive and neural subsystems
- Mental workspace
- Catastrophic loss
- Capacity limitation that varies between individuals
- Impervious to environmental factors: ethnicity, SES (Engel, Dos Santos, & Gathercole, 2008)
Working memory deficits as features of other disorders

Deficits in working memory are present of many developmental and acquired disorders:

- Specific learning difficulties, e.g., dyslexia, Specific Language Impairment
- ADHD
- Genetic disorders, e.g., Down syndrome
- Traumatic brain injury
- Patients receiving chemotherapy
- Hypertension
Working memory as a primary cause of slow learning

Poor working memory is a high risk factor for slow rates of learning that:

i) warrants detection in its own right, and
ii) requires, and benefits from, intervention
Working memory as a specific predictor of learning difficulties


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

Proportion

Cutoff score

81 86 91 96

WM Phon STM VIQ PIQ Language Phon. Proc.
### Multiple regression: dependent variable reading score

<table>
<thead>
<tr>
<th>Predictor</th>
<th>( \text{stand. } \beta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working memory</td>
<td>( .347^* )</td>
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<tr>
<td>Verbal IQ</td>
<td>( -.159 )</td>
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<tr>
<td>Performance IQ</td>
<td>( .026 )</td>
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<tr>
<td>Phon. awareness</td>
<td>( .206 )</td>
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<tr>
<td>Language</td>
<td>( .427^* )</td>
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* \( p < .05 \)
## Multiple regression: dependent variable maths score

<table>
<thead>
<tr>
<th>Predictor</th>
<th>stand. $\beta$</th>
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<tr>
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<td>.280</td>
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<td>Performance IQ</td>
<td>.024</td>
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<td>Phon. awareness</td>
<td>.181</td>
</tr>
<tr>
<td>Language</td>
<td>.072</td>
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</tbody>
</table>

* $p<.05$
SATs, Key Stage 2:

Gathercole et al. (2004):

Mean working memory scores as a function of English and maths attainment groups, data from 11-year olds
Characteristics of children with poor working memory
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.
  
  Instruction span: “Touch the blue pencil then pick up the yellow ruler and put it in the red box”, Gathercole, Durling et al. (2008)
Characteristics of children with poor working memory

- Poor academic progress
- Difficulties in following instructions
- Difficulties in combining processing and storage
Characteristics of children with poor working memory

- Poor academic progress
- Difficulties in following instructions
- 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
- Place-keeping difficulties
- Teachers say short attention span and high distractibility

“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”
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.
Working memory deficits and inattention: Different sides of the same coin?
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
Symptoms displayed by children with poor working memory (in yellow)

- 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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Conner’s Teacher Rating Scale scores

Holmes, Gathercole, Alloway, Hilton & Elliott
DSM-V: Inattentive subtype to be replaced with Sluggish Cognitive Tempo

- Passive, daydreamy, shy, hypoactive both mentally and physically
- As if “in a fog”
- Slow at information processing
Main findings

- Children with poor working memory and those with ADHD share deficits in working memory and other executive functions, and are highly inattentive.

- Children with ADHD are distinguished by elevated levels of hyperactivity and rule-breaking behaviour.

- Low working memory = inattentive form of ADHD/Sluggish Cognitive Tempo?
Can working memory deficits be overcome?

2 approaches:

- **Classroom-based support**

- **Training**
Training environment
Training children with ADHD

Holmes, Gathercole, Place, Dunning, Hilton & Elliott (Applied Cognitive Psychology, in press)

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

- Verbal STM
- Visuo-spatial STM
- Verbal WM
- Visuo-spatial WM

Off meds

On meds, pre-training

Post-training

Follow-up
Training children with ADHD

- Verbal STM
- Visuo-spatial STM
- Verbal WM
- Visuo-spatial WM

- Off meds
- On meds, pre-training
Training children with ADHD
Training children with ADHD
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
Adaptive training
Adaptive training
Adaptive training

![Bar chart showing performance in Verbal STM, Visuo-spatial STM, Verbal WM, and Visuo-spatial WM before (Pre), after (Post), and follow-up (Follow-up). The chart indicates significant improvement in Visuo-spatial STM and WM in the Post and Follow-up conditions.]
Gains with adaptive vs non-adaptive training in low memory children

![Bar chart showing gains in standard scores for different memory types and training methods. Gains are compared for non-adaptive training and adaptive training, with and without a 6-month delay.]
### Adaptive training: IQ, reading and maths scores

<table>
<thead>
<tr>
<th>Time of testing:</th>
<th>Measure</th>
<th>Pre-training</th>
<th>Post-training</th>
<th>6mth follow-up</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
<td>$SD$</td>
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<tr>
<td>Verbal IQ</td>
<td>88.73</td>
<td>11.14</td>
<td>90.86</td>
<td>11.52</td>
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<tr>
<td>Performance IQ</td>
<td>88.05</td>
<td>13.09</td>
<td>90.68</td>
<td>12.96</td>
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<tr>
<td>Reading</td>
<td>83.68</td>
<td>12.35</td>
<td>83.00</td>
<td>15.06</td>
</tr>
<tr>
<td>Mathematics</td>
<td>84.27</td>
<td>12.28</td>
<td>85.68</td>
<td>12.70</td>
</tr>
</tbody>
</table>

$p < .05$
Dunning, Gathercole & Holmes: RCT of working memory training with low memory children
Whole class training

Holmes, Dunning & Gathercole
45 children aged 9-10 years, mixed ability

- 26 children active group: Cogmed training
- 19 children control group: no intervention
Working memory gains by working memory ability

Bottom 25%: less than 89
Middle 50%: 90-101
Highest 25%: 102+
Hypertensive vs normotensive adults: group effect sizes

![Bar chart showing group effect sizes for systolic and diastolic blood pressure, IQ, and working memory.](image)

Gathercole, Fuat, Murphy, Littlewood, & Conway (in prep)
Hypertensive vs normotensive adults: group effect sizes

Can training help?

Gathercole, Fuat, Murphy, Littlewood, & Conway (in prep)
How does it work?

- Training-induced neural plasticity?
- Strategy development?
Conclusions

- Poor working memory skills place a child at extremely high risk of i) poor academic progress, and ii) inattentive behaviour

- May be a primary cause of slow learning, and correspond to inattentive form of ADHD

- Problems may be ameliorated through effective classroom management and cognitive training.

-Extent of functional transfer yet to be established.
To find out more


*Understanding working memory: A classroom guide*

[www.york.ac.uk/res/wml](http://www.york.ac.uk/res/wml)

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