Working memory, language, and classroom learning

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Overview

• Key features of working memory

• Links between working memory and learning

• Characteristics of children with working memory deficits

• How can working memory deficits be overcome?
Key features of working memory

- Interacting cognitive and neural subsystems
Alloway et al 2006: Measurement model of the Automated Working Memory Assessment

Visuo-spatial tasks

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

Central executive

Visuo-spatial STM

Verbal STM

Verbal tasks

- Listen. recall
- Back. dig. recall
- Count. recall
- Word recall
- Nonword recall
- Digit recall
Routes through working memory to learning

Central executive

Visuo-spatial STM

Verbal STM

\[\text{reading, maths}\]

\[\text{word learning}\]
Routes through working memory to learning

- Central executive
  - Visuo-spatial STM
  - Verbal STM

→ reading, maths

word learning
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
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
- Relatively impervious to environmental factors
## Working memory deficits as features of other disorders

<table>
<thead>
<tr>
<th>Group</th>
<th>STM</th>
<th>WM</th>
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<tbody>
<tr>
<td>SLI</td>
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<td>Verbal</td>
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<td>Dyslexia</td>
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<td>Verbal</td>
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<tr>
<td>ADHD</td>
<td>Visuo-spatial</td>
<td>Verbal &amp; visuo-spatial</td>
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<td>DCD</td>
<td>Visuo-spatial</td>
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</table>
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
Multiple regression: dependent variable reading score

<table>
<thead>
<tr>
<th>Predictor</th>
<th>stand. β</th>
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<tbody>
<tr>
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<td>Verbal IQ</td>
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<td>Performance IQ</td>
<td>.026</td>
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<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

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<tr>
<th>Predictor</th>
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<tr>
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<td>Performance IQ</td>
<td>.024</td>
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<td>Phon. awareness</td>
<td>.181</td>
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<tr>
<td>Language</td>
<td>.072</td>
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</table>

* $p<.05$
Key Stage 2: Mean working memory scores as a function of English and maths attainment groups
But, why?
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”
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 blue)

- 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
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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)
Automated Working Memory Assessment: Standard scores

Holmes, Gathercole, Alloway, & Hilton, subm.
Academic attainment and IQ: Standard scores

![Graph showing mean standard scores for Maths, Reading, Verbal IQ, and Performance IQ for ADHD, Low WM, and Average WM.]
Teacher behaviour ratings: $T$-scores

![Bar chart showing mean $T$-scores for different behaviors and conditions.](Image)

- Oppositional
- Inattentive
- Hyperactive
- ADHD

Legend:
- ADHD
- Low WM
- Average WM

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Summary

- 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? Medication?
Training working memory

CogMed working memory training, developed by Klingberg

- Game-style environment designed to train working memory using high-quality graphics game-style environment
- Training on working memory tasks for 25 days over a 6-week period
- Adaptive: individual works at span level
Training environment
Training children with ADHD

Holmes, Gathercole, Place, & Elliott (2010)

• 25 children with ADHD aged 8-11 years, on psychostimulant medication

• Tested on working memory (AWMA) and IQ (WASI) before and after training.
Children with ADHD

**Before training**

**After training**

- **Verbal STM**
- **Visuo-spatial STM**
- **Verbal WM**
- **Visuo-spatial WM**
Training children with poor working memory

Holmes, Gathercole, Dunning, & Elliott (2009)

46 children aged 8-10 years with poor verbal WM scores (<15th centile on each of 2 tests) completed either:

• Adaptive training (experimental)
• Non-adaptive training (placebo)

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
Pre- and post-training WM scores for adaptive training

![Bar chart showing mean standard scores for Verbal STM, Visuo-spatial STM, Verbal WM, and Visuo-spatial WM before and after training.]
Gains with adaptive and non-adaptive training

![Graph showing gains in standard scores with different training methods.](image)
## Adaptive training: IQ, reading and maths scores

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

$p < .05$
How does it work?

- **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?**
  Intensity of training may allow child to develop strategies that capitalise on cognitive strengths.
Conclusions

• Verbal STM plays a significant role in the phonological aspect of word learning
• Poor working memory (CE) 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/ SCT
• Problems may be ameliorated with intensive cognitive training, although extent of functional transfer has yet to be established.
• Implications for other populations with working memory deficits
To find out more ....

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