Working memory: A cognitive system that supports learning?

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Ross Truss seminar Melbourne, 29th August 2011

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

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

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

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


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>
<td>Working memory</td>
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<td>Performance IQ</td>
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<td>Phon. awareness</td>
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<td>Language</td>
<td>.427*</td>
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Multiple regression: dependent variable maths score

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<th>Predictor</th>
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<td>Verbal IQ</td>
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<td>Performance IQ</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
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)

- 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.

- 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

- 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.

- 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.

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 forgetful in daily activities

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 interrupts or intrudes on others (e.g., butts into conversations or games)

Teacher behaviour ratings

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
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- Often does not follow instructions and fails to finish schoolwork, chores, or duties in the workplace
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- 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

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

Working memory

Holmes, Alloway, Gathercole et al. (in prep)
### Executive function measures: effect sizes

<table>
<thead>
<tr>
<th>Measure</th>
<th>ADHD</th>
<th>Low WM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal STM</td>
<td>-0.81</td>
<td>-1.15</td>
</tr>
<tr>
<td>Verbal WM</td>
<td>-1.05</td>
<td>-1.66</td>
</tr>
<tr>
<td>Visuo-spatial STM</td>
<td>-0.97</td>
<td>-1.08</td>
</tr>
<tr>
<td>Visuo-spatial WM</td>
<td>-1.02</td>
<td>-1.19</td>
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<tr>
<td>Trails accuracy</td>
<td>-0.63</td>
<td>-0.79</td>
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<tr>
<td>Stroop errors</td>
<td>-0.74</td>
<td>-0.75</td>
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<tr>
<td>Walk - don’t walk</td>
<td>-1.24</td>
<td>-1.15</td>
</tr>
<tr>
<td>Stroop time</td>
<td>-0.47</td>
<td>-0.74</td>
</tr>
<tr>
<td>Card sort no.sorts</td>
<td>-0.80</td>
<td>-0.95</td>
</tr>
<tr>
<td>Tower rule violations</td>
<td>-0.92</td>
<td>-0.50</td>
</tr>
<tr>
<td>CPT commissions</td>
<td>0.79</td>
<td>0.22</td>
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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*
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


2: Training working memory

Cogmed WM training, developed by Klingberg
Key features:
- Game-style environment designed to train working memory using high-quality graphics
- Training on working memory tasks for 20-25 days over a 6-week period
- Reward features
- Adaptive: individual works at maximum capacity continuously

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

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 by 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

Holmes, Gathercole, Place, & Dunning (2010)
Children with low working memory

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

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pre-training M</th>
<th>Pre-training SD</th>
<th>Post-training M</th>
<th>Post-training SD</th>
<th>6m follow-up M</th>
<th>6m follow-up SD</th>
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<tbody>
<tr>
<td>Verbal IQ</td>
<td>88.73</td>
<td>11.44</td>
<td>90.86</td>
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<td>Performance IQ</td>
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<td>Reading</td>
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<td>83.00</td>
<td>15.06</td>
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<td>85.68</td>
<td>12.70</td>
<td>92.94*</td>
<td>9.88</td>
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Dunning, Gathercole & Holmes: RCT

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

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?
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 ....


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