What is working memory and how does it affect learning?

Do you observe these behaviours?

- Is easily distracted when doing something not highly interesting
- Has trouble waiting his/her turn
- Struggles with getting started and completing a task. Watches and depends on friends to remind them of the current task
- Difficulty organising something with multiple steps... frequently stops, frequently loses their place
- Often seems restless and on the go
- Fails to progress despite working hard

Quick mental arithmetic

\[
7 + 9 \times 3 - 4 = \\
35 \times 9 = \\
35 \times 76 =
\]
What is working memory?

A system for temporary storage and manipulation of information, necessary for wide range of cognitive tasks.

The ability to keep information active in your mind for a short period of time (seconds) keeping it available for further processing.

How does it differ from short term memory?

- Repeating multi-part instructions
- Carrying out instructions
- Remembering a street address
- Following driving directions
- Following driving directions as a new driver

Working memory is an essential function in everyday life

Processes all stimuli we encounter

Delegates it to the different parts of our brain that can take action

Allows us to block out unnecessary information

It keeps us updated on what’s happening — and keeps us focused on what matters

Alan Baddeley’s Working Memory Metaphor

Central Executive

Phonological Loop

Episodic Buffer

Visuo-Spatial Sketch Pad
Working Memory (WM) Capacity: Dependent on Many Variables

- **WM capacity** – affected by deficit: disease, genetics, age....but also fatigue, medication, mood.

- **WM load** – determined by the difficulty of a task as well as level of distraction from relevant and irrelevant stimuli. The more difficult the task, and the more stimuli attended to, the more demand on the WM.

\[
\text{WM capacity} + \text{WM load} = \text{WM performance}
\]
Working Memory impairments are associated with a wide range of developmental disorders of learning:

<table>
<thead>
<tr>
<th>Verbal STM</th>
<th>Visual-spatial STM</th>
<th>Verbal WM</th>
<th>Visual-spatial WM</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>60</td>
<td>✓</td>
<td></td>
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</tr>
</tbody>
</table>

SLI

Alloway et al., 2009

- First study in which participants selected on basis of WM rather than learning difficulties, developmental disorders or genetic syndromes
- 3,189 5-11 year olds, 308 identified with low WM using AWMA – 10%
  - High risk of making poor academic progress
  - Highly distinctive profile of inattentive behaviour and forgetting which disrupts classroom functioning
  - Older group performed significantly more poorly than younger group on learning measures

WM is related to IQ

- There is an overlap of 0.8 in reasoning and working memory tasks
- WM adds unique variance above and beyond measures of IQ (Gathercole, Alloway, Willis & Adams, 2006).
- Working memory is a useful prospective indicator of academic performance: Predict attainment on national assessments at 7, 11, 14 years of age (e.g. Gathercole, et al., 2004; St-Clair Thompson & Gathercole, 2006).
To what extent is it influenced by environmental factors?

Unlike IQ, free from SES and other crystallized knowledge that has been built from home, school and social experiences

(Engel, Santos & Gathercole, 2008)

Why does it matter?

Why is it important?

Working memory is used for:

- Controlling attention
- Resisting distraction
- Complex thinking
- Organisation
- Problem solving
- Remembering tasks

Working memory is key for academic performance

15% of all students have working memory deficits causing them to perform below average in many areas of learning

Working memory is crucial for areas such as math, reading comprehension, complex problem solving, and test taking
Evidence that even when general ability is accounted for, working memory skills predict reading and math scores

Mean working memory scores as a function of English and Math attainment groups, data from 11 year olds

Gathercole, et al., 2004; Si-Clair Thompson & Gathercole, 2006

Australian Curriculum

Learning Areas
- English
- Maths
- Science
- Languages
- Arts
- HPE

General capabilities
- literacy
- numeracy
- information and communication technology capability
- critical and creative thinking
- personal and social capability
- ethical understanding
- intercultural understanding

Cross-curriculum priorities
- Aboriginal culture
- sustainability
- engagement with Asia
ACARA – Personal and Social Capability

"Students with well-developed social and emotional skills find it easier to manage themselves, relate to others, develop resilience and a sense of self-worth, resolve conflict, engage in teamwork and feel positive about themselves and the world around them. The development of personal and social capability is a foundation for learning and for citizenship."

The capability involves students in a range of practices including:
- recognising and regulating emotions,
- developing empathy for and understanding of others,
- establishing positive relationships,
- making responsible decisions,
- working effectively in teams and
- handling challenging situations constructively.

ACARA – Creative and Critical Thinking

- Inquiring – identifying, exploring and organising information and ideas
- Generating ideas, possibilities and actions
- Reflecting on thinking and processes
- Analysing, synthesising and evaluating reasoning and procedures

Students develop capability in critical and creative thinking as they practice generating and evaluating knowledge, clarifying concepts and ideas, seeking possibilities, considering alternatives and solving problems. These same skills underpin our ability to manage our wellbeing and learning.

Psychological Processes associated with academic learning (Dehn 2012)

Visual-Spatial WM
- Following signs (e.g. +, -, x, ÷) during arithmetic calculation
- Keep place on page when reading
- Mental manipulation of images
- Reverse sequence of objects
- Transform information

Verbal WM
- Remembering instruction/content of instruction
- Remembering what to say when called upon
- Paraphrasing spoken information
- Comprehending syntactically complex sentences

Example Working Memory Characteristics

Verbal WM
- Remembering instruction/content of instruction
- Remembering what to say when called upon
- Paraphrasing spoken information
- Comprehending syntactically complex sentences

Visual-Spatial WM
- Following signs (e.g. +, -, x) during arithmetic calculation
- Keep place on page when reading
- Mental manipulation of images
- Reverse sequence of objects
- Transform information

Verbal STM
- Remembering/repeating multistep oral instructions
- Counting
- Blending phonemes into words when reading
- Phonetic decoding of text/phonetic recoding (spelling)
- Learning new vocabulary

Visual-Spatial STM
- Remembering objects
- Remembering colours
- Remembering location
- Remembering direction
Gathercole & Alloway 2008

Children with poor working memory make characteristic errors in their classroom work:
• failing to keep track of their place in demanding and complex activities
• Mistakes in writing and counting
• Failing to self-correct

“...Over time these frequent missed learning opportunities amount to slow educational progress and poor academic attainment”

How do you identify children with poor working memory?

Considerations for assessment in a school environment

• Looking for cognitive, behavioural and academic evidence of low working memory capacity
• Time taken to administer the assessments in school environment
• Ability to re-test within a specific timeframe (important for student and teacher/coach to monitor progress)

Identifying WM strengths & weaknesses

- WISC V
- AWMA
- TEA-CH, NEPSY
- BRIEF or D-REF
- WMRS
- Connors 3
- BASC 3
- Spelling, Reading Comprehension
- Mental arithmetic
Look beyond the behaviour
Can’t vs. Won’t

What can we do to manage working memory and improve performance?

Acquisition of literacy and numeracy is gradual process

Poor working memory disturbs rate of skill acquisition

Aims:
• assist children to work within their working memory capacity to build skills and knowledge over time
• minimise the chance the child will miss a learning opportunity because of working memory failure
• structure the learning activity to reduce the working memory demand but maintain the desired learning outcome

POOR WORKING MEMORY: IMPACT AND INTERVENTIONS Holmes et al: 3 strategies

1. Change the environment
2. Teach strategies for coping
3. Intensive training on WM tasks to strengthen working memory capacity

1. Example of environmental impact

Listening is made more difficult by:
- Extraneous noise
- Unfamiliar speech accents
- Speaking too rapidly
- Speaking too softly
- Simultaneous presence of visual stimuli that conflict or distract
- Irritating or distracting mannerisms of the speaker

http://www.psychologytoday.com/blog/memory-medic/201306/working-memory-executive-control-0

Example of environmental impact

Reading is made more difficult by:
- Font and page design selection
- Convoluted syntax, awkward sentence structure
- Unfamiliar vocabulary
- Distracting visuals
- Wordiness, poor grammar
- Poor reading technique (tracking with finger movements, random eye fixations, small fixation span (a few letters or one word at a time)

http://www.psychologytoday.com/blog/memory-medic/201306/working-memory-executive-control-0

2. Working memory strategies for the classroom

For Teacher:
- Evaluate working memory demands of learning activities
- Reduce the working memory load
- Reduce processing demands
- Increase repetition
- Encourage memory aids
- Build routines and familiarity

...Put information in the world, not in their heads

Strategy instruction for children with working memory deficits and reading disabilities

PACE
REHEARSAL
CHUNKING

Tocci – Working Memory Conference 2015
Thinking Routines, Rote Learning, Scaffolding and Mnemonics

The characteristics that make these strategies work include:

- meaningfulness,
- organisation,
- association,
- visualisation and
- interest

Why do they work? The more you already are familiar with something, the less you have to hold in memory

⇒ familiar routines, careful structuring of content

...Put information in the world, not in their heads

Strategies to cope

For Students:

- It’s ok to ask for help, e.g. repetition, simpler instructions
- Pair up with a friend and share the load
- Write things down, take a photo
- Limit distractions – e.g. social media, screen times
- Visualise – draw a picture in your head
- Stop Think Do - Ask for extra time to practice
- Take a deep breath when you feel overwhelmed

Limitations

- Strategies are difficult to teach and to remember

- What happens when you leave the structured environment of the classroom?

3. What can we do to strengthen working memory capacity?
Interventions Shown to Aid Executive Function Development in Children 4 to 12 years old

Adele Diamond and Kathleen Lee, Science 333, 959 (2011);

- Diverse activities have been shown to improve children's executive functions: computerized training, games, aerobics, martial arts, yoga, mindfulness, and school curricula.
- All successful programs involve repeated practice and progressive increase of the challenge to executive functions.
- Children with worse executive functions benefit most from these activities – importance of early intervention.
- To improve executive functions, focusing narrowly on them may not be as effective as also addressing emotional, social and physical development (shown by positive effects of aerobics, martial arts and yoga).

Neuroplasticity makes working memory training possible

The brain can physically change in response to focused, repeated, intensive activity - training.

Practice, at progressively challenging levels

Where am I?
What am I doing?
What should I be doing?

Principles of Neuroplasticity

- **Use it – Train!** - Knowing is not enough
- **Improve it** - Challenge is necessary for change
- **Specificity** - Neurons that fire together wire together
- **Repetition** - Need to practice
- **Intensity** - Need to work hard, get the right dose
- **Salience** - Needs to be meaningful, personalised
- **Transference** - change in function that results from one therapy, can augment the attainment of similar behaviors
- **Interference** - plasticity in response to one experience can interfere with the acquisition of other

What is Cogmed?

Cogmed Working Memory Training
An evidence-based intervention for working memory

- **Research-based** - Cogmed emerged out of research on the plasticity of working memory and backed up by peer reviewed, published, and fully independent studies
- **Specific** - working memory exercises, 3000 tasks, lots of practice
- **Adaptively Challenging** - the program automatically keeps the task within the zone of proximal development

Highly structured, highly supported program

- **Intensive** - choose from flexible protocols 15, 25 or 35 minutes, 3, 4, 5 times a week for 5-10 weeks
- **Meaningful and supported** - always provided through a coach, personalised goals and rewards.
- **Feedback** - supervised by training aide, progress monitored by Coach. Weekly one-to-one review. Strategies are noticed and practiced

Three products for Cogmed training

- **Cogmed JM**
  - Preschoolers
- **Cogmed RM**
  - School-age
- **Cogmed QM**
  - Adults

All the products share the same underlying design – the only difference is in the user interface >> engagement and rewards
School implementation

**Cogmed Coach** - Key person for the user tracking, following up and offering feedback on training with weekly feedback and reward meetings.

**Training Supervisor** - Person who will sit next to the user during training offering support and motivation. (Can be the coach but usually learning support staff or training aide).

Variable Protocols

<table>
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<tr>
<th>#</th>
<th>Session Length</th>
<th>Days per Week</th>
<th>Number of Sessions</th>
<th>Number of Exercises per Session</th>
<th>TOTAL TIME</th>
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<td>8 weeks</td>
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<td>25 mins</td>
<td>4</td>
<td>40</td>
<td>3</td>
<td>10 weeks</td>
</tr>
</tbody>
</table>

Rationale: Repeated recital of WM trials when difficulty level is not adapted typically leads to faster reaction times but not an increase in WM capacity - no generalization.

Adaptively Challenging
Rewarding e.g. RoboRacing: Cogmed RM

- Involves racing against other robots on different tracks
- The more you win, the more options you have
- The right and left arrows control the direction of the robot; the space bar to jump
- With the extra "energy" that the child has earned from Cogmed RM, they can get extra speed by pressing the CTRL button.

Cogmed Coaching Centre

Supporting Resources

Training Details
Cogmed Progress Indicator (CPI)

- **Protocol**
  - Shape up, Listen up, Add up tasks
  - Embedded in program
  - Math challenge (auto/manual removal)
  - CPI has cognitive load
  - Best performance out of Days 1 and 2 used as Baseline Measure
  - Occurs on 6 sessions (occurrence depends on training protocol selected)

- **Purpose**
  - Provides quantitative measure of training effect
  - Assess with non-trained working memory tasks
  - Track cognitive change as it occurs

Monitoring progress: Questionnaire

**GOALS**

- Captures users perspective of their Attention in everyday life
- Expectations for CWMT, Areas they would like to improve

Sources:
- 4-17yo: DSM-IV ADHD (attention) scale
- Intrinsic Motivation Inventory (IMI)

Pre: Prior to Day 1 CPI and Training, during Start-Up Session with Coach
Post: Available to complete after 80% of training has been completed

What evidence do we have for the effectiveness of working memory training?
Key questions

1. What does it mean to be “evidence-based”?
2. Does training improve working memory?
3. Does the training generalise beyond trained tasks to non-trained tasks?
4. Are the gains sustained?
5. Can working memory training improve literacy and numeracy outcomes?

Adaptive training leads to sustained enhancement of poor WM in children
Holmes et al., 2009

- 42 children, aged 8-11 years, with low working memory
  - Identified via routine screening of 345 children on two verbal WM tasks (Listening Recall and Backward Digit Recall) as per Gathercole et al., 2006
  - Scores <86 on both tasks (bottom 15th centile)
- Controlled
  - Adaptive, standard version of training program
    - training at maximum span level
  - Non-adaptive, control condition
    - training at fixed span level of two
- Assessments: Pre- and post-training
  - Working Memory (AWMA; Alloway, 2007),
  - IQ (WASI; Wechsler, 1999),
  - basic reading (WORD; Wechsler, 1993),
  - mathematical reasoning (WOND; Wechsler, 1996),
  - following instructions task (Gathercole et al., in press)

Enhancing poor WM in children with low WM
Developmental Science Holmes et al., 2009

Instruction task (Gathercole et al.): practical, real world assessment of WM capacity in classroom setting

Child placed in front of an array of props (rulers, pencils, etc.) in a range of colors and asked to follow set of instructions

Instructions designed to mimic span method with increasing number of instructions until child cannot perform task accurately

Take home: Cogmed improves WM capacity, attention, instruction following and math ability in school children with low WM.
Pre-training to post-training WM scores for non-adaptive (placebo) group

Holmes et al., 2009

Pre-training WM scores for adaptive (treatment) group

Holmes et al., 2009

Pre-training to post-training WM scores for adaptive (treatment) group

Holmes et al., 2009

Pre-training to follow up WM scores for adaptive (treatment) group

Holmes et al., 2009
Children with low WM improve attention and math up to six months after training

Holmes et al., 2009

“...This study provides the first demonstration that these commonplace deficits and associated learning difficulties can be ameliorated, and possibly even overcome, by intensive adaptive training over a relatively short period: just 6 weeks, typically...”

Summary
Holmes et al., 2009

- Fully independent - First published, peer-reviewed paper with no Karolinska or Klingberg
- Does not use ADHD paradigm, but strictly based on WM
- Tests for and finds academic improvements
- Shows the academic effect is not immediate, but emerges gradually
- Shows impact of training is specific
- Training took place in school
- Study executed by team at The Working Memory Research Centre
  - Leading WM institution, set up by Baddeley
  - Launched study fully convinced WM could NOT be trained

Cogmed improves WM capacity, attention, instruction following and math ability in school children with low WM.

What’s the bigger picture?

Language/MathsSkills | Cognitive Skills

<table>
<thead>
<tr>
<th>Far transfer</th>
<th>Near transfer</th>
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</thead>
<tbody>
<tr>
<td>Skill/behaviour</td>
<td>Affects</td>
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<tr>
<td>Reading comprehension</td>
<td>Rate of learning</td>
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<td>Maths skills</td>
<td>Manipulating information</td>
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<td>Remembering directions</td>
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<td>On-task behaviour</td>
<td>Attention/Concentration</td>
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<tr>
<td>Working memory</td>
<td>Planning</td>
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<td>Initiate</td>
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<td></td>
<td>Task monitoring</td>
</tr>
<tr>
<td></td>
<td>Organise</td>
</tr>
</tbody>
</table>
Interconnected Systems Supporting Learning

Performance-based factors

Knowledge base (LTM)

*working memory

*largely mediated by language

Lisa Archibald CogCon 2014

Working Memory and Learning

Learn more about Cogmed

Try the demonstration: http://mycogmed.com

“Try Out Cogmed”


Download the Resource Kit for Schools

Learn more about becoming a Clinical Coach

Contact: Mimma Mason at Pearson info@cogmed.com.au or your closest Cogmed Coach www.cogmed.com.au/find-a-coach