Multiple Components of Memory

- Short-term Memory
- Working Memory
- Long-term Memory

3 Types of Memory

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Short-term</td>
<td>Passively holds a small amount of information in the mind for about 7 seconds</td>
</tr>
<tr>
<td>Working</td>
<td>Active, conscious processing and storage of information</td>
</tr>
<tr>
<td>Long-term</td>
<td>Passive storehouse of information</td>
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</tbody>
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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 in your mind for a short period of time (seconds) and be able to use the information in your thinking.

Responsibilities of Working Memory

- Controlling attention
- Resisting distraction
- Complex thinking
- Organization
- Problem solving
- Remembering tasks
Working memory is an essential function in every day 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

Working memory impacts your daily life

Working memory is used for…

- Organization
- Concentration
- Problem solving
- Remembering tasks

Working Memory Subtypes

- Auditory/Verbal
  - Analysis, manipulation, & transformation of verbal material
    - Repeating digits backwards
    - Repeating sentences
- Visuospatial
  - Analysis, manipulation, & transformation of images
- Executive
  - Management of memory systems
  - Coordinates storage & processing

Visual WM task

- Spatial Span

Repeat body parts back from highest to lowest.

Which comes first?
What is Executive Functioning?

Collection of inter-related functions that are responsible for purposeful, goal-directed, problem-solving behavior

“What CEO of the brain.”

Executive Skills

• Part I: Achieve Goals/Solve Problems
  - Planning
    • Roadmap to complete a task
  - Organization
    • Keep track of materials/information
  - Time management
    • Estimate time & deadlines
  - Working Memory
    • Hold information in mind
  - Metacognition
    • Self-evaluation; “birds-eye view”

Executive Skills

• Part II: Guide our Behavior
  - Response Inhibition
  - Emotional Control
  - Sustained Attention
    • Pay attention despite fatigue, boredom, or distraction
  - Task Initiation
    • Begin a task in timely manner
  - Flexibility
    • Revise plans
  - Goal directed persistence
    • Follow thorough to complete task

Behavior Associated with Deficits in Executive Functions

• Disinhibition
  - lack of behavioral control, impulsive

• Perseveration
  - repeats non-functional behavior, inability to change behavior despite corrective feedback, difficulties learning from experience

• Forgetfulness
  - off-task behaviors, mental errors, loses track of what they were doing

Behavior Associated with Deficits in Executive Functions

• Inefficiency
  - takes more steps to complete task than necessary

• Difficulty understanding
  - consequences and cause-effect relationships

• Frequently violate rules
  - despite apparent knowledge of the rules

• Apathetic
  - lacks motivation, does not set goals, engages in behavior only when prodded
EF Impairment & ADD/ADHD

- Listening attentively
- Organizing work
- Sustaining effort
- Screening out distractions
- Keeping track of assignments & belongings
- Remembering what has been read/learned
- Ability to monitor & correctly interpret emotions in self & others

Working memory and ADHD

- Numerous studies have found children & adolescents with ADHD to have deficits in working memory
- Most children with ADHD have moderate to serious weaknesses in working memory
- Working memory weaknesses more strongly related to symptoms of inattention than symptoms of hyperactivity/impulsivity

Why is Working Memory Important?

- Working Memory (WM) predicts academic learning
- WM deficits found in many disability profiles
- Better understanding of student behaviors (e.g., lack of motivation vs. deficit in WM)
- Early identification through efficient assessment is imperative to identify those students “at-risk”

Why is working memory important?

- School success predicted better by WM than by IQ
- Poverty begets stress, begets poor WM, begets poverty
- Daydreaming is more prevalent in people with poor WM
- Standardized tests results driven by your WM
- Poor reading and math grades often explained by weak WM
- Aging causes natural WM decline
**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.

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**Age** | **WM is crucial for...** | **Indicators that WM needs improvement**
---|---|---
Pre-school | Learning the alphabet Completing a puzzle independently | Unwillingness to learn
Elementary school | Understanding textual content (reading comprehension) Mental arithmetic | Inability to understand what is read Problems memorizing the multiplication table
Middle school | Completing homework independently Complex math problems, especially word problems | Can’t complete homework without parental supervision and direction Inability to grasp/break down word problems
High school | Writing essays | Difficulty writing neat, coherent essays
College | Studying for an exam Participation in group projects Keeping focus/interest during a lecture | Constantly procrastinates; panics the night before an exam Doesn’t listen or participate during a group project Difficulty remaining attentive during lectures

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**Working memory capacity in school-age children**

- Working memory is important both clinically and educationally
  - Poor working memory function is associated with neurodevelopmental disorders
  - Risk factor for learning difficulties
- WM supports learning
- WM is associated with reading (Gathercole & Pickering, 2000) and math ability (Geary et al., 2004)

**Working memory capacity in school-age children**

- Children with poor working memory make poor academic progress (Gathercole & Alloway, 2008)
  - Research finding
    - 300 children with poor working memory
    - 83% scored poorly on either reading or math tests and the vast majority of these scored poorly in both areas

**Classroom Learning Demands on WM**

- Common classroom activities that impose simultaneous demands on storage and processing:
  - Listening to a speaker while trying to take notes
  - Following complex instructions
  - Decoding unfamiliar words
  - Writing sentences from memory
  - Mental arithmetic
  - Reading comprehension
  - Math Word problems
WM Components and Academic Learning

<table>
<thead>
<tr>
<th>Reading Decoding</th>
<th>Reading Comprehension</th>
<th>Written Language</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonological STM</td>
<td>Executive WM Verbal WM</td>
<td>Executive WM Phonomological STM</td>
<td>Vissuospatial WM Executive WM</td>
</tr>
</tbody>
</table>

Dehn, 2008

The brain can physically change in response to focused repeated intensive activity - training. Improved working memory generalizes to other cognitive abilities and behavior.

Research discovers working memory can be improved

Led by neuroscientist T. Klingberg, MD, PhD

The findings challenged the first time the long-held assumption that working memory is a fixed characteristic, unable to be changed.

Training WM in Children with ADHD

Klingberg et al., 2002

Population: Children with ADHD, ages 7 -15 years, some medicated

N = 14 children (n = 7 in each treatment and active control groups)

Design: Randomized, Active placebo controlled, Double blinded, Test-repeat

Treatment group improved significantly over active control on outcomes measures:

1) Trained visuo-spatial WM task
2) Non practiced visuo-spatial WM task (Span Board; Corsi Block Test)
3) Non verbal reasoning task (Raven’s Colored Progressive Matrices)
4) Response inhibition task (Stroop)
5) Hyperactivity (# of head movements during continuous performance test)

Training WM in Children with ADHD

Klingberg et al., 2002

SUMMARY

- Intensive and adaptive, computerized cognitive training (Cogmed) gradually increased the amount of information the children could keep in their working memory
- Children with ADHD improved on neuropsychological tests after WM training
- The first published research on working memory training

Take home: Effects of Cogmed generalize to non-practiced tasks. Children with ADHD improve on neuropsychological evaluations after WM training.
What is Cogmed?

Three products for Cogmed training

All the products share the same underlying design - the only difference is in the user interface

The student experience

Five weeks of training – five times per week (25 sessions)

Every session is 30-40 minutes

Training catered to fit the student’s schedule

Weekly rewards recommended

Supported by a Coach, supervised by training aide/Coach

Trains in a quiet space – separated from students and distractions

How do you train your working memory with Cogmed?

The difficulty level will automatically adjust based on the performance of the users, so that they will always train on the limits of their working memory capacity

Confirmation in a multi-center trial (I)

Klingberg et al., 2005

Population: Children with ADHD (combined & inattentive), ages 7-12 years, no stimulant medication

N = 53 children (n = 24 in treatment group and n = 26 in active control groups), 3 withdrew

Design: Multi-site, Randomized, Placebo controlled, Double blinded, Test-retest

T1 = Baseline, T2 = Post intervention, T3 = 3 month follow up

Larger study confirms working memory training helps kids with ADHD

Computerized Training of Working Memory in Children With ADHD—A Randomized, Controlled Trial

Torkel Klingberg, M.D., Ph.D., Elisabeth Forneell, M.D., Ph.D., Perzille J. Olesen, M.Sc., Marcus Johnson, M.D., Per Carlsdotter, M.D., Ph.D., Kristin Ingvarsson, M.D., Christopher G. Gillberg, M.D., Ph.D., Hans Forsberg, M.D., Ph.D., and Helena Westberg, L.P., M.D.

Confirmation in a multi-center trial (I)

Klingberg et al., 2005

Treatment group improved significantly over active control on outcomes measures:

1) Main outcome measure = Non practiced visuo-spatial WM task (Span Board; WAIS-RNI)

2) Non practiced verbal WM task (Digit Span; WISC III)
Confirmation in a multi-center trial (III)
Klingberg et al., 2005

3) Non verbal reasoning task (Raven’s Colored Progressive Matrices)

4) Response inhibition task (Stroop)

5) Parent ADHD symptom ratings (DSM-IV & Conner’s Parent Rating Scale)

Summary
Validation and expansion of the 2002 study, with multi-site format 3-month follow up and rating scale data.

“This study shows that WM can be improved by training. In addition, we saw effects on reasoning, response inhibition, and a decrease in parent-rated symptoms of ADHD.”

Study shows:
- Results remain after 3 months
- Effects on parent ratings (blinded)
- Effects on neuropsych tests (attention and impulse control)
- Improvement on complex problem solving

Children improve math and listening skills with working memory training
Developmental Science

FAST-TRACK REPORT
Adaptive training leads to sustained enhancement of poor working memory in children
Joni Holmes, Susan E. Gathercole and Darren L. Dunning

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 (verbal STM, verbal WM, visuo-spatial STM and visuo-spatial WM (AWMA; Alloway, 2007)
- IQ (WASI; Wechsler, 1999)
- Basic reading (WORD; Wechsler, 1993)
- Mathematical reasoning (WOND; Wechsler, 1996)
- Following instructions (Gathercole et al., in press)

Enhancing poor WM in children with low WM (II)
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

Adaptive training leads to sustained enhancement of poor WM in children
Holmes et al., 2009
Enhancing poor WM in children with low WM (IV)

Treatment group improved significantly at T2 and T3 on outcome measures:
1) Visuo-spatial WM, verbal WM and visuo-spatial and verbal STM tasks (AWMA; Alloway, 2007)
2) Instruction task (Gathercole et al.)
3) Math reasoning (WOND; sig at T3 only, realistic expectations)

Treatment group improved over control in visuo-spatial WM, verbal WM and visuo-spatial STM

Treatment group showed no significant gains on measures:
1) Performance and verbal IQ (WASI) – distinguishes impact of WM and IQ on learning
2) Basic word reading (WORD)

Summary

"...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..."

1. Fully independent study
2. Found academic improvements
3. Shows impact of training is specific
4. Training took place in school
5. Study executed by team at The Working Memory Research Centre

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

This study reported on the results of 2 different types of WM training – auditory training or visual-spatial training – conducted with 46 children aged 7-12 who were participating in an intensive summer treatment program for ADHD.

“...Computerized training of visuospatial working memory tasks can increase WM performance on tasks that were not specifically trained upon. Visuospatial, but not verbal WM training is associated with improvements in observed behaviors during training...”

1. Results support the benefits of WM training for children with ADHD and indicate that training of visual-spatial working memory is especially important.
2. The fact that this training was associated with an increase in positive behavior above and beyond medication and behavior treatments already in place is a very encouraging result.

Parents report decreased inattentive symptoms in children with ADHD
Beck et al., 2010

A controlled trial of working memory training for children and adolescents with ADHD
Steven J. Beck, Christine A. Hanson, and Sylvia K. Puflickberger
Department of Psychology, Ohio State University

Moderate to strong effect of Cogmed intervention on parent ratings of ADHD symptoms, inattention and reduction in attentive symptoms similar to that found in Klingberg et al., 2005.


WM training: Children with ADHD
Journal of Clinical Child and Adolescent Psychology
Beck et al., 2010

Will training lead to improvements on parent and teacher rating of ADHD symptoms?

Population: ADHD children and adolescents, ages 7 -17, 61% on stimulant medication
N = 52 (n = 27 in treatment group and n =24 in waitlist control)

Design: Randomized, Waitlist control, Screened for WM constraint with BRIEF (WM scale) or at least 6 inattentive symptoms (DSM-IV-TR) and P-ChIPS for ADHD
T1 = Baseline, T2 = 1 month post intervention, T3 = 4 month follow up

Treatment groups improves significantly over waitlist control on rating scales:
1) Conner’s Parent Scale (T2 & T3)
2) BRIEF Parent Form (T2 & T3)

Take home: WM training associated with reduced parent report of inattentive behavior and ADHD symptoms at 1 month and 4 months after training. No significant difference in teacher ratings (Conner’s Teaching Scale & BRIEF Teacher Form)

Training children with attention or hyperactivity problems
School Mental Health
Mezzacappa & Buckner, 2010

Population: N = 9, urban, Low SES, Children ages 8 - 10.5 years

Design: Test-retest, Teachers not blinded

Pilot group had statistically significant improvements on outcome measures:
1) Teacher ADHD-RS-IV
2) Visuo-spatial WM (Finger Window (ES =.73); WRAML)
3) Verbal WM (Digit Span, forward & backward; WISC IV)

Take home: Evidence for improved WM and decreased teacher rated ADHD symptoms for urban, low SES hyperactive/inattentive group after Cogmed.

Training children with attention or hyperactivity problems
School Mental Health
Mezzacappa & Buckner, 2010
Cogmed Working Memory Training
An evidence-based intervention for working memory

- Research-based - Cogmed is backed by peer reviewed, published, and fully independent studies
- Highly supported structure - Schools receive training and support Schools support the students through the program
- Fits with RTI framework - Cogmed can be used in RTI programs as a tier two or tier three intervention
- Proven track record - Cogmed training has an over 90% completion rate to go along with its proven results

Who is a Cogmed candidate?

Is easily distracted
Has trouble waiting his/her turn
Struggles with reading comprehension
Struggles with problem solving that require holding information in mind - such as math calculations
Struggles with completing tasks, especially multiple step tasks
Has difficulty integrating new information with prior knowledge
Has difficulty taking notes and listening at the same time

Cogmed helps children with ADHD

Given the link between attention and working memory, children with ADHD are generally good candidates for Cogmed.
From a research perspective, changes in daily behavior were noted in children with ADHD and observed by their parents and teachers.

In addition to ADHD...

- Cogmed is for those with working memory constraints or wish to improve their ability
- Possible candidates also include:
  - Learning Disabilities
  - Traumatic Brain Injury
  - Underperforming students
  - Gifted/enrichment program students

What makes Cogmed work?

1. Scientific - Designed by leading neuropsychologists
2. Adaptive - On task time
3. Intensive - Hard work
4. Sustained - 25 sessions
5. Targeted - Working memory only
6. Supported - We support you, you support the student
Executive Functioning Intervention Principles

- Move from External to Internal
  - Intervene at the level of the environment
  - Intervene at the level of the child
    - Teach the child the weak skill
    - Motivate the child to use the skill

Modifying the Environment

- Change the physical or social environment
  - Seating arrangements, distractions, organizing structures
- Modify the tasks the child is expected to perform
  - Shorter explicit steps, schedules, task choice
- Change the way adults interact with the child
  - Verbal prompts, praise, rehearsal

7 Steps to Teaching Executive Skills

1. Identify the problem behavior
2. Set a goal
3. Outline the steps needed to reach the goal
4. Turns the steps into a list, checklist, or short list of rules
5. Supervise the child following the steps
6. Evaluate the program’s success
7. Fade the supervision

Classroom Structures to support Working Memory

- Simple verbalizations
  - Simple, brief, concise
- Simple, isolated procedures
  - Template for note-taking
- Lots of repetition
- Time for rehearsal & processing
- Promote higher level processing (active reasoning)

Classroom Structures to support Working Memory

- External memory aids
  - Visual cues, checklists
- Quiet learning environment
- Organized presentations
- Advance organizers
  - Metaphors, analogies, diagrams, models

Recommended Reading

Working memory and academic learning: Assessment and intervention
Milton Dehn
Wiley, 2008

The Overflowing Brain: Information Overload and the limits of Working Memory
Torkel Klingberg
Oxford University Press, 2009