Working Memory, learning & Language

An 8-years-old child listening carefully as the teacher saying:

"After you are done with your math worksheet, get out your reading book and finish answering the questions on page fifteen, at the bottom of the page."

Other children quickly go to work but she timidly raise her hand and ask the teacher to repeat the directions.

Even though she is a bright child, routine oral directions such as this are hard for her to follow.

She is a bright child who has problems with working memory. This makes routine tasks, such as following lengthy oral directions, complicated and frustrating

origins of working memory

- early days of modern psychology:
  - John Locke(1690): bringing the ideas of mind and memory.
  - William James (1890): propose two types of memory: *primary* and *secondary memory*.
  - Thorndike(1910): The terms short- and long-term memory

- By 1950: recognized the need for some sort of special memory process that could account for recall of information in the short term.

Atkinson and Shiffrin's Modal Model

- **Environmental Input**
- **Sensory Registers**
  - Detect sensory input from the various modalities
  - Memories are held for only a few hundred milliseconds
- **Short-Term Store (STS)**

  Lasts a few seconds and is made up of:
    - Temporary working memory
    - Control processes:
      - Rehearsal
      - Coding
      - Decisions
      - Retrieval strategies
- **Long-Term Store**
  - Permanent memory store

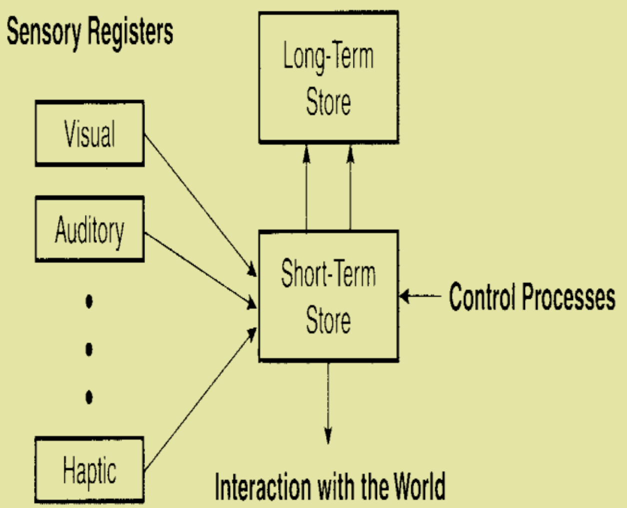


FIGURE 1.2 The Modal Model of Memory

Source: Atkinson & Shiffrin, 1968

The Atkinson-Shiffrin Modal Model

Atkinson and Shiffrin divide memory into three major types of storage:

- several peripheral sensory stores or buffers
- a short-term store
- and a long-term store

Atkinson and Shiffrin view short-term memory as the workspace for long-term learning.

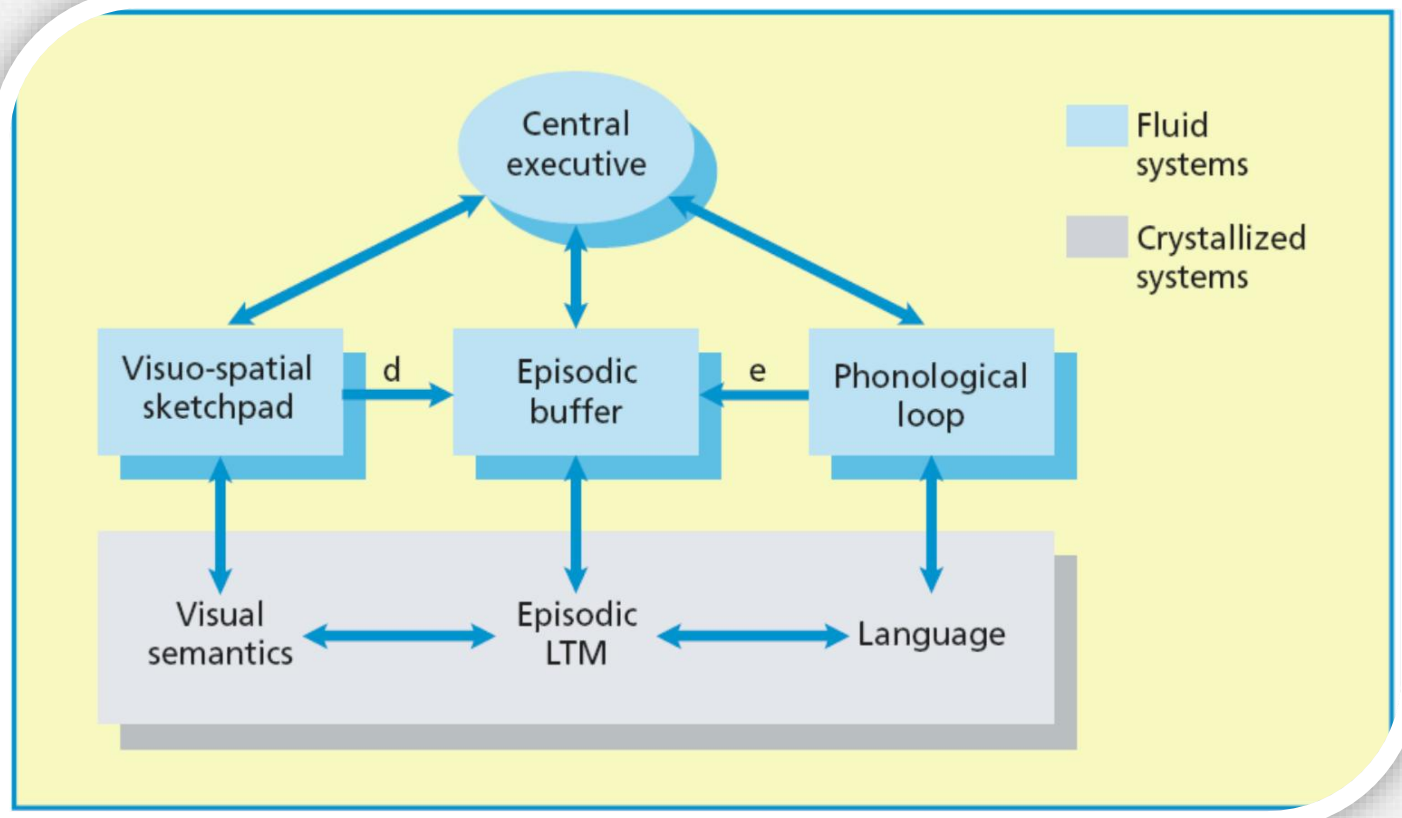
at mid-century, Introduction of information processing theory sparked numerous investigations into working memory and several models of working memory soon emerged.

Working Memory

a system that supports complex cognitive activities like reasoning along side storage (like STM).

This system has limited attentional capacity that can be allocated to information processing or storage or both

Multi-Component Model of WM



Multi-Component Model of WM: **Central Executive**

- responsible for the attentional control of working memory. it:
  - **Directs attention to relevant information**
  - **suppressing irrelevant information**
  - **coordinates cognitive processes involving more than one task**

- Executive processes are probably one of the principal factors determining individual differences in working memory span.

- Working memory span has proved to be a robust predictor of a wide range of complex cognitive skills.

Multi-Component Model of WM: **Phonological Loop**

- Stores phonological information (i.e., the sound of language) and prevents its decay

- The Phonological Loop:
  - Is the best studied component of WM.
  - Aids Language Learning

Neuropsychological Evidence suggests the loop is important to language learning because patients with impairments cannot learn a new language.

Phonological Loop

consists of two components:

a phonological store: involved in the temporary storage of verbal information. This storage is constrained by time and space.

If this stored information is not rehearsed in the articulatory control process, then it will be completely lost.

an articulatory control process: rehearsal of auditory verbal information

Controlled articulatory process

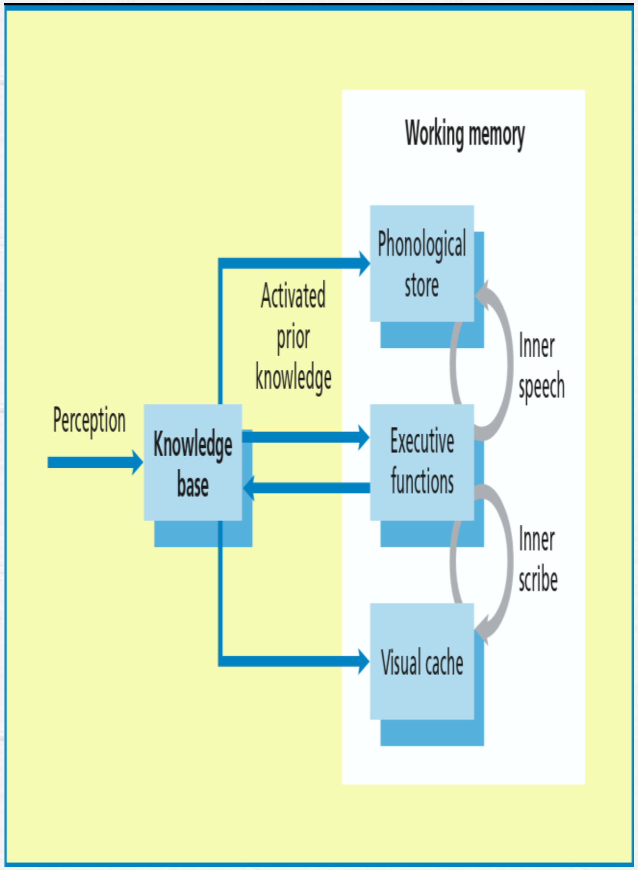
- Shorter word
- shorter articulation time required
- shorter rehearsal time
- less decay and better recall

the speed of articulation is the key to the capacity of short-term memory.

Multi-Component Model of WM:
Visio-Spatial sketch pad

Stores visually and/or spatially encoded items and arrays

- the structure of the visuo-spatial sketchpad is similar to phonological loop, in that it consists of:
  - The **visual cache**: A passive store.
  - The **inner scribe**: An active spatial rehearsal process



Multi-Component Model of WM: **Episodic buffer**

- A newly proposed fourth component of the WM system.

- Holds representation that integrate phonological, visual, spatial information

  Multiple dimensions: permit links between the subsystems, as well as with LTM & perception

- the roles performing by the episodic buffer
  - Allows long-term memory knowledge to be utilized in the working memory system
  - Offers an extra storage mechanism to back up other storage areas
  - Blends together or ‘binds’ information from different sources/ modalities into a coherent memory experience

WORKING MEMORY DEVELOPMENT

WM development

- Rudimentary forms of short-term and working memory emerge early in infancy:
  - object-permanence as early as 4 to 8 months
  - Imitation of speech sounds, a behavior that necessarily requires pSTM
- By age 6 years: diverse working memory components emerge
- The capacity of each component increases from early childhood into adolescence

WM development

- The executive is significantly linked to both storage devices beginning in early childhood. This finding indicates that:
  - the executive (attentional control) is associated with the coordination of the flow of information throughout WM
  - different WM mechanisms develop in an integrated fashion from an early age.

- Finally, pSTM and viso-spatial STM appear to develop relatively independently of each other, revealing their domain specificity

- 16 years of age: adult levels of working memory performance

pSTM Span

- In most children, pSTM appears to be firmly established by **3 years** of age
- **At 4 years** of age:
  - child can remember **two or three** words in sequence.
  - **subvocal rehearsal emerge**

- The **strategic rehearsal** develop around **7 years** of age.

Verbal Working Memory Span

- Verbal working memory span is shorter than pSTM span because the items must be retained while a secondary processing task is completed.

- doubles in size from **2 items in 5 to 7year-olds to 4 items in 11-to 12 year-olds**, at which point it approximates adult levels.

Given working memory capacity of only a few items of sequenced verbal information, how do some individuals comprehend sentences of considerable length and complexity?

Perhaps well-established long-term memory structures assist with retention and processing, compensating somewhat for the storage limitations of working memory.

Visuo-spatial Working Memory Span

- **4-year-old** children: can remember a sequence of **2 to 3 pictures**
- between the ages of **5 to 11 the** capacity doubles and span reaches an adult level of approximately **4 items**.
- Unlike phonological and verbal span, much of the improvement seems to result from actual growth in capacity, rather than improved system efficiency or use of strategies.

Visuo-spatial Working Memory Span

- The most unique characteristic of visuo-spatial memory functions: retention and rehearsal of information depends heavily on ***verbal working memory*.**
- **Visuo-spatial recoding** emerges between the ages of **6 to 8 years**, at about the same time children learn to read.
- The recoding process demonstrates the superiority of verbal storage in individuals.
- The ability to **use verbal working memory** to encode and retain visuo-spatial information **contributes to the expansion in visuo-spatial working memory span.**
- Interestingly, the development of **visuo-spatial recoding** may mirror the **development of central executive**.

Working Memory Strategies

- Increased use of strategies, such as subvocal verbal rehearsal, chunking, and organization, is also partially responsible for the apparent expansion in working memory capacity, especially for the increase in span after 6 years of age

- Although many children begin using a **simple rehearsal** strategy **around 5 years** of age, **spontaneous rehearsal** does not begin until **age 7**, and **consistent use of verbal rehearsal strategies** may not occur until the **age of 10**.

WORKING MEMORY AND LEARNING

WM and learning

- 20 years of researches has repeatedly affirmed the hypothesis that **WM processes underlie individual differences in learning ability.**

- Working memory is required whenever anything must be learned because learning requires:
  - manipulation of information,
  - interaction with long-term memory, and
  - simultaneous storage and processing of information.

WM and learning

WM capacity has documented significant relationships with:

- Reading decoding
- Reading comprehension
- Language comprehension
- Spelling
- Following directions
- Novel word learning and Vocabulary development
- Written expression
- Reasoning
- Complex learning
- Grade point average

WM & Learning disabilities

- one of the primary causes of learning disabilities may be deficits in one or more aspects of working memory

- working memory deficits discovered in many developmental, cognitive, behavioral, and mental disorders.

- The pervasive influence of working memory on so many diverse cognitive functions can mean only one thing:

  working memory is the linchpin of cognitive processing.

WM and Linguistic Processing

- There is sufficient evidence that linguistic processing is constrained by general WM capacity and effective utilization of that capacity

- language learning and comprehension depend on both pSTM and verbal WM

working Memory & Language

- Hayiou-Thomas, Bishop, and Plunkett (2004):

When the cognitive demands of the grammaticality judgment task increase (increase the length of information) TD children perform like children with SLI:

struggle to detect errors in verb morphology but not errors in noun morphology

memory deficits can indeed play a causal role in producing specific linguistic difficulties

- Leonard et al (2007) examined factors that predicted language abilities in a group of 14-year-old children. The two factors that best predicted language scores included:
  - Processing speed
  - working memory

word learning

- Word learning involves mapping sound to meaning
  - phonological memory for novel labels is encoded and retained for long periods (Fast Mapping).
  - This phonological memory of novel speech material presumably permits children to establish stable, long-term phonological representations of new words in long-term memory.
  - As the lexicon grows, word entries become more phonologically refined and better organized, with one organizational scheme involving words beginning with the same sound being stored together. Phonological STM and the ability to temporarily store new sound patterns may be an important factor in young children's lexical learning and organization.

WM and word learning

- Using a variety of methods, robust **associations between pSTM and new word learning have been reported for preschool-age** children through about age 8

- Although the relation of pSTM and word learning weakens after age 8 there continues to be a significant link through adolescence into adulthood

WM and word learning

Working Memory play an important role in *Word Learning* by

Storing and Processing

the *Phonological Information* for a novel lexical item

PWM and Vocabulary Development

- The proponents of the phonological loop model have claimed that storage of phonological information in the phonological loop is critical for learning words.
- Gathercole (2006) proposes: Although this is not the only route by which new phonological structures can be acquired (lexically mediated learning is one alternative), it is a primitive learning mechanism that is particularly important in the early stages of acquiring a language.
- Thus the theory currently emphasizes the role of the phonological loop as crucial to early lexical development

WM & Grammatical learning and functioning

- Domain Specific viewpoint: young children do not possess morphological rules, grammatical categories and syntactic structure

- Rather, children initially learn whole phrases and only later discover underlying rules, categories, and structures by using the distributional properties/regularities of the input. Phonological STM may serve as a mediating or moderating mechanism for this analytic process.

- Some support for this idea comes from:
  - pSTM predicts quantity and quality of spontaneous speech in 3-year-old children
  - STM is a better predictor of MLU in preschoolers than chronological or mental age.

Because morphological and syntactic learning entails building relational knowledge, it is likely that several executive functions are involved; however, little empirical work has directly addressed the issue.

WM and language comprehension

- In oral language comprehension, WM plays the critical role of *constructing and integrating ideas from a stream of successive words*
- Studies show that placing demands on WM impairs language comprehension and slows down retrieval from long-term storage.
- Children with greater WM capacity show more accurate comprehension than low-capacity children.
- Difficulties in comprehending spoken language may stem more from inefficiencies in verbal-WM than from failure to acquire critical language structures.
- much of spoken-language processing occurs without assistance from working memory, nevertheless, if the syntactic structure or meaning of the sentence is confusing, verbal and executive WM will be brought into play.

Disorders and Conditions with Working Memory Deficits

Disorders and Conditions with Working Memory Deficits

impairments in any higher level cognitive process or skill are either impacting WM functioning or can be partially attributed to WM dysfunctions.

WM deficit and Language Disabilities

- There are several related contributions and reciprocal influences connected with oral language impairments.
  - Overall, children with a language impairment have a limited capacity for processing and remembering verbal information.

Attention-Deficit/Hyperactivity Disorder (ADHD)

- Children with ADHD typically perform poorly on measures of short-term and working memory

- Prevailing models of ADHD suggest: WM impairments are central to ADHD because the both are associated with specific deficits in executive skills

- children with ADHD exhibit deficits in multiple components of working memory. Including:
  - large impairments in visuospatial working memory and
  - moderate impairments in verbal working memory.

Autism

- Autism is thought to be an executive disorder arising from frontal lobe dysfunction, So, WM hypothesized to be deficient in individuals with autism.

- However, investigations have yielded equivocal results. Some studies discovered intact verbal working memory in individuals with autism

- Williams et al (2005): high-functioning subjects with autism,. Have deficient in visuospatial but not verbal working memory.
- Steele et al (2007) also found that individuals with autism are deficient in visuospatial working memory.

- A current prevailing hypothesis: children with autism are impaired in WM because they fail to develop and utilize **working memory strategies**, probably because they have poor or **nonexistent inner speech**.
- If a strategy deficit exists, then their WM deficits will not become apparent until they are older or until complex tasks are demanded of them.

Cognitive Disabilities

- children with intellectual disabilities have weaknesses in working memory relative to their other cognitive abilities.

- Nevertheless, When children with cognitive disabilities are matched with subjects of the same mental age, they exhibit significantly lower digit and word spans and the gap seems to grow over time.

- children with intellectual disabilities have areas of relative strengths and weaknesses within working memory:

Their most consistent area of weakness is **verbal WM**, which is most likely related to their ***delayed use of verbal rehearsal strategies***.

Cognitive Disabilities

- children with Down’s syndrome typically have lower working memory than their overall cognitive ability, and, as their mental abilities grow, their memory span lags farther behind children

- with Down’s syndrome usually have weaker verbal working memory than visuospatial working memory.

Learning Disabilities

children with all types of learning disabilities and difficulties display poor WM performances, especially in verbal and executive working Memory

- students with general or multiple specific learning disabilities (literacy and mathematics) perform poorly in all aspects of working memory.
- In contrast, children with only one specific learning disability demonstrate fairly distinctive working memory profiles, with deficits limited to one or two components.
  - specific reading disability: pSTM and verbal WM
  - Specific mathematics disability: deficits in visuo-spatial and executive WM.
- Executive-loaded working memory tasks provide the best discrimination between children with and without learning disabilities

Acquired Brain Injury

- closed-head traumatic brain injury (TBI) usually involves the vulnerable frontal lobes, where executive processes and core working memory operations are headquartered.
- It is well established that children who suffer head injuries are at risk for ongoing memory problems, especially working memory impairments.
- The academic performance of children with TBI is often poorer than would be predicted from academic achievement measures, a finding consistent with intact long-term storage but damaged working memory.

Schizophrenia

- Impairments in working memory capacity, as well as in executive functions, are reported widely in Schizophrenia.

- These deficits appear to be related to overall reductions in cognitive processing capacity, caused by dysfunction in the prefrontal cortex.

- in children who are genetically at risk for Schizophrenia, the extent of their working memory deficit has been shown to be predictive of the likelihood of developing the disorder

Stress

- Stress is another factor that can be detrimental to working memory functioning
- Stress diminishes WM capacity because WM must dedicate attentional resources to inhibit irrelevant, unwanted, intrusive thoughts about stressful events.

- Evidence on the effects of stress on WM illustrates that working memory functioning depends on more than innate capacity, strategies, and the novelty of the task.

Assessment of Working Memory

Standardized assessment of working memory

- Working Memory Test Battery for Children (WMTB-C)
- Alloway Working Memory Assessment (AWMA)
- Children's Memory Scale® (CMS)
- Children's Test of Nonword Repetition

Working Memory Test Battery for Children (WMTB-C)

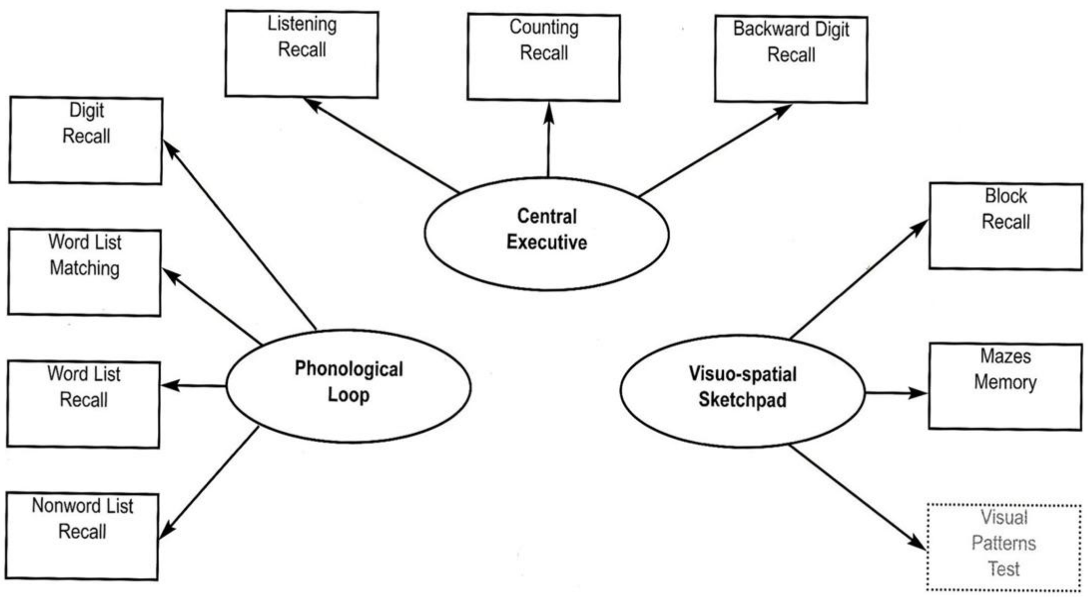
- Author(s) :

  Susan Pickering and Susan Gathercole,
- Publication Year : 2001

- Age Range: 5 to 15 years
- Administration: Individual - 60 minutes

Working Memory Test Battery for Children (WMTB-C)

Figure 1.2. WMTB-C Subtests and What They Measure



Testing Sequence

A brief description of each subtest is given in Table 3.1. It is recommended that the nine subtests are administered in the following order.

Table 3.1. Summary of WMTB-C Subtests

Order of Presentation	Subtest	Description
1	Digit Recall	Examiner speaks sequences of digits at the rate of one per second. Child recalls each sequence in the correct order
2	Word List Matching	Examiner speaks sequence of words twice. Child decides if the order of words in the second sequence is the same as the first. Each sequence is presented at the rate of one word per ¾ second. The gap between each pair of sequences is 1½ seconds.
3	Word List recall	Examiner speaks sequences of one-syllable words. Child recalls each sequence in the correct order. Each sequence is presented at the rate of one word per second.
4	Block Recall	Examiner taps sequences using the blocks on the block recall board, at the rate of one block per second. Child recalls each sequence in the correct order.
5	Nonword List Recall	Examiner speaks sequences of one-syllable nonsense words. Child recalls each sequence in the correct order. Each sequence is presented at the rate of one word per second.
6	Listening Recall	Examiner reads short sentences. Child judges if the sentences are true or false and then recalls the final word from each sentence. Spoken duration of each sentence should be as equal as possible (1-2 seconds in length).
7	Counting Recall	Examiner presents child with array of dots to count. Child counts the dot arrays and then recalls the tallies.
8	Mazes Memory	Examiner traces a route through each maze following a red line with their finger. Child draws an identical route in the response booklet.
9	Backward Digit Recall	Examiner speaks a sequence of digits at the rate of one per second. The child recalls the sequence in reverse order.

Alloway Working Memory Assessment (AWMA)

Alloway Working Memory Assessment (AWMA)

- **Author(s) :**
- Dr Tracy Packiam Alloway
- **Publication Year**
  - 2007
- **Age Range**
  - 4 to 22 years
- **Administration**
  - Individual - Screener: 5 to 7 mins;
  - Short form: 10 to 15 mins;
  - Long form: 45 mins

Alloway Working Memory Assessment (AWMA)

- **VERBAL SHORT-TERM MEMORY**
  - Digit recall
  - Word recall
- **VERBAL WORKING MEMORY**
  - Counting recall
  - Backward digit recall
- **VISUO-SPATIAL SHORT-TERM MEMORY**
  - Dot matrix
  - Block recall
- **VISUO-SPATIAL WORKING MEMORY**
  - Spatial recall

Children's Memory Scale® (CMS)

Children's Memory Scale® (CMS)

- **Author(s) :** Morris Cohen
- **Publication Date:** 1997
- **Overview:** Assess children's memory abilities
- **Age Range:** 5 to 16 years
- **Completion Time:** 30 minutes
- **Forms**: Two, one for ages 5-8, and one for ages 9-16

Children's Memory Scale® (CMS)

- The CMS is particularly beneficial in the study of memory functioning as it includes measures of focused attention
- STM/WM (Numbers Forward, Numbers Backward, Sequences, Picture Locations),
- visual STM and LTM (Dot Locations, Faces),
- verbal STM and LTM (Stories, Word Pairs, Word Lists).

Children's Test of Nonword Repetition (C-NRep)

- **Author(s)**
  - Susan Gathercole
  - Alan Baddeley
- **Publication Year**
  - 1996
- **Description**
  - Test short-term memory in children
- **Age Range**
  - 4 years to 8 years
- **Administration**
  - Individual - 15 minutes

Standardized assessments of aspects of STM and WM

Assessment	*Task*	*Aspect of memory*
Wechsler Intelligence Scale for Children (Wechsler, 2004)	Digit span	STM
	Backward digit span	WM
British Ability Scales (Elliott, Murray, & Pearson, 1983)	Digit span	STM
Working Memory Test Battery for Children (WMTB–C) (Pickering & Gathercole, 2001)	Digit span	Phonological loop
	Word span	Phonological loop
	Nonword span	Phonological loop
	Word-list matching [a]	Phonological loop
	Backwards digit span	Central executive
	Listening recall [b]	Central executive
	Counting recall [c]	Central executive
Children's Test of Non-Word Repetition (CNRep) (Gathercole & Baddeley, 1996)	Nonword repetition	STM
Test of Language Development (TOLD P–3) (Newcomer & Hammill, 1997)	Sentence recall	Episodic buffer
Clinical Evaluation of Language Fundamentals (CELF 4) (Semel, Wiig, & Secord, 2006)	Sentence recall	Episodic buffer

Note. STM = short-term memory; WM = working memory.

[a] The child hears a list of two or more words, which is then repeated either in the same order, e.g., "bed dot," "bed dot," or a different order, e.g., "rock dip," "dip rock." [b] Similar to Competing Language Processing task described earlier. [c] The child counts the number of dots in a series of arrays and then recalls the total number in each array.

Everyone is a genius. But if you judge a fish by it's ability to climb a tree, it will live it's whole life believing that it is stupid.

Albert Einstein

Thank You