Improving Working Memory

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Outline

- Define the term working memory
  - Brain structures involved in working memory
- How to assess working memory
- Define the effects of working memory deficits on learning
- What types of improvement to expect from working memory programs
- What can be done to improve working memory

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The Memory Systems

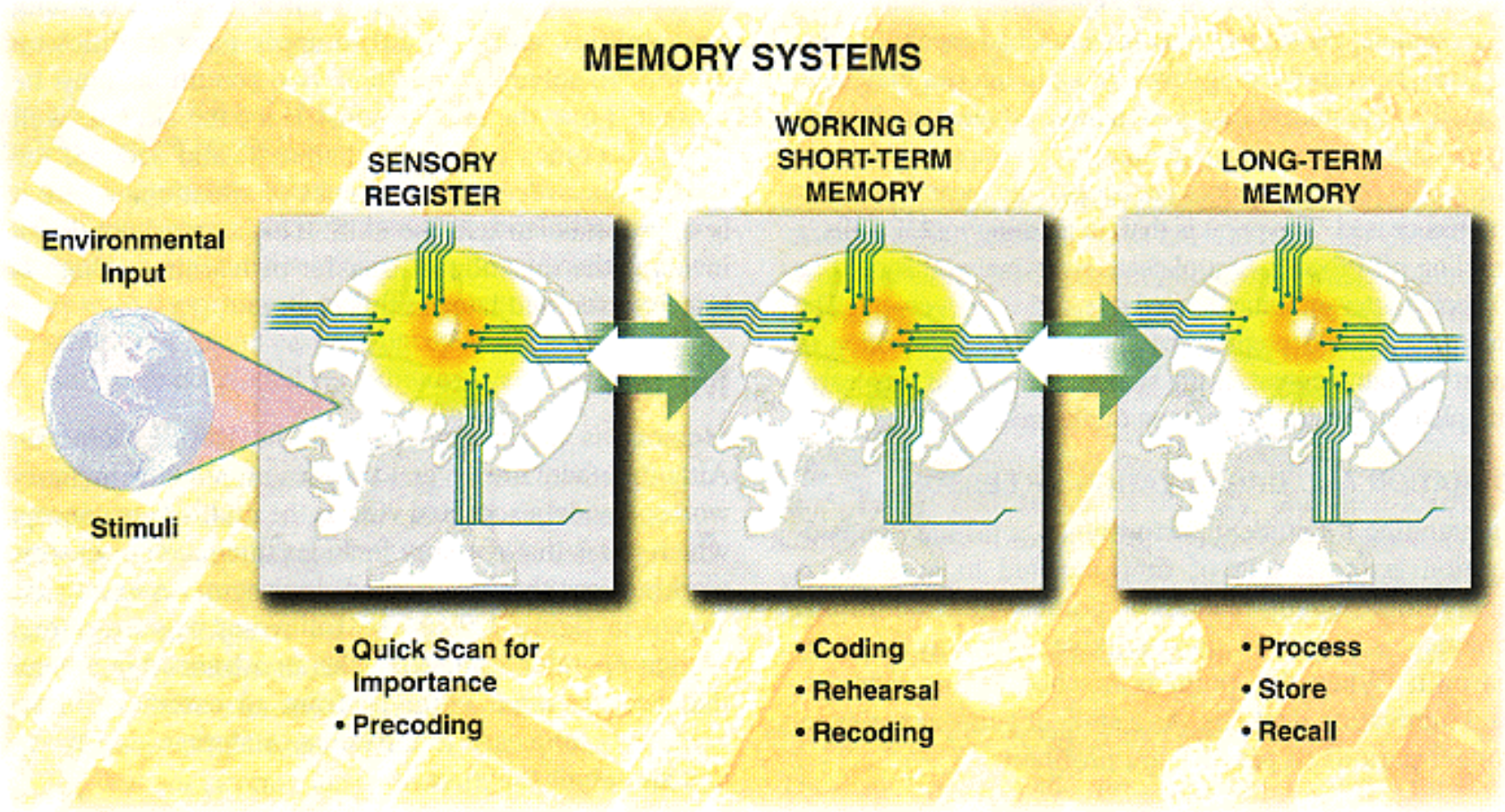
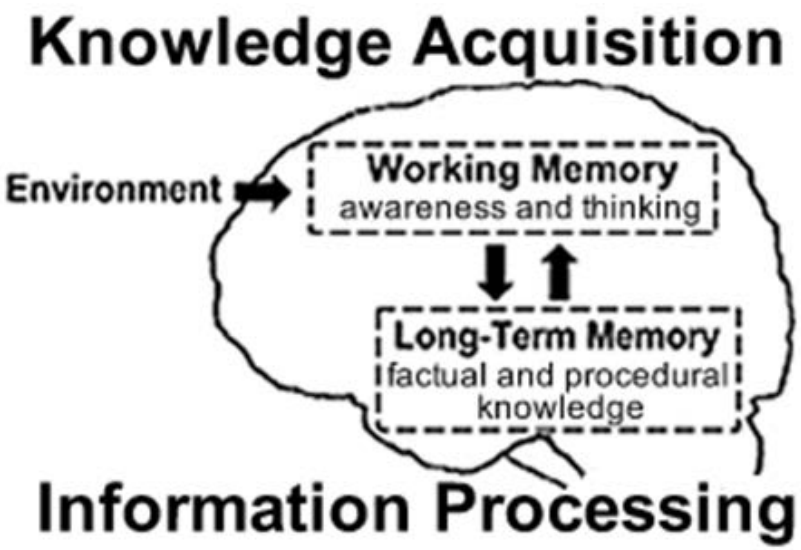


Figure 1-9. Information processing within the sensory register, working or short-term memory, and long-term memory includes complex coding, sorting, storing, and recall functions.

Atkinson & Shiffrin, 1971

Environment/working memory/ long term memory



The **environment** is continually providing *information*.

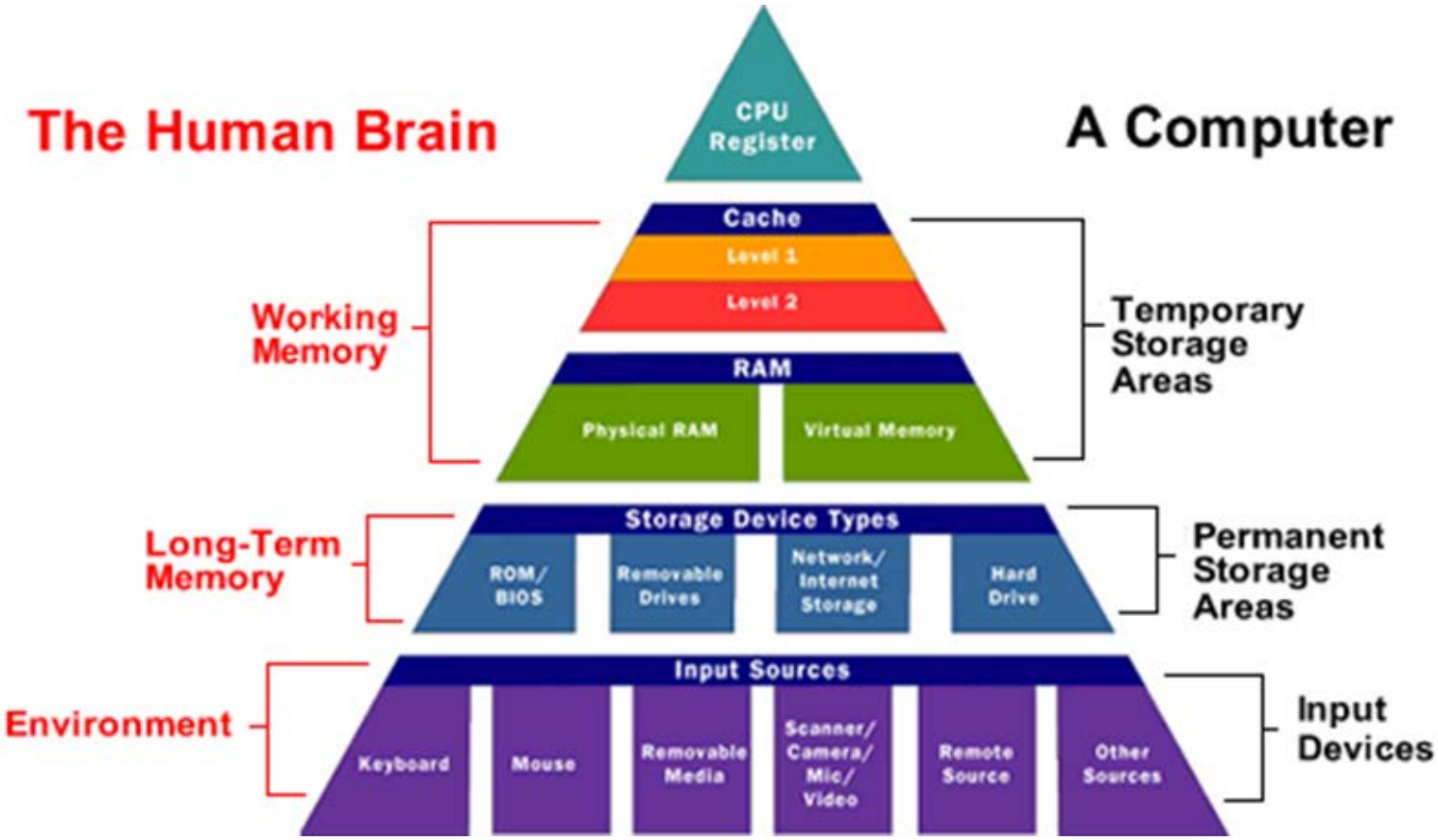
Working memory holds information we are *actively* thinking about and is *aware* of our environment.

Long-term memory stores what has been learned. This *knowledge* resides outside of our awareness and is recalled into working memory *only* when needed.

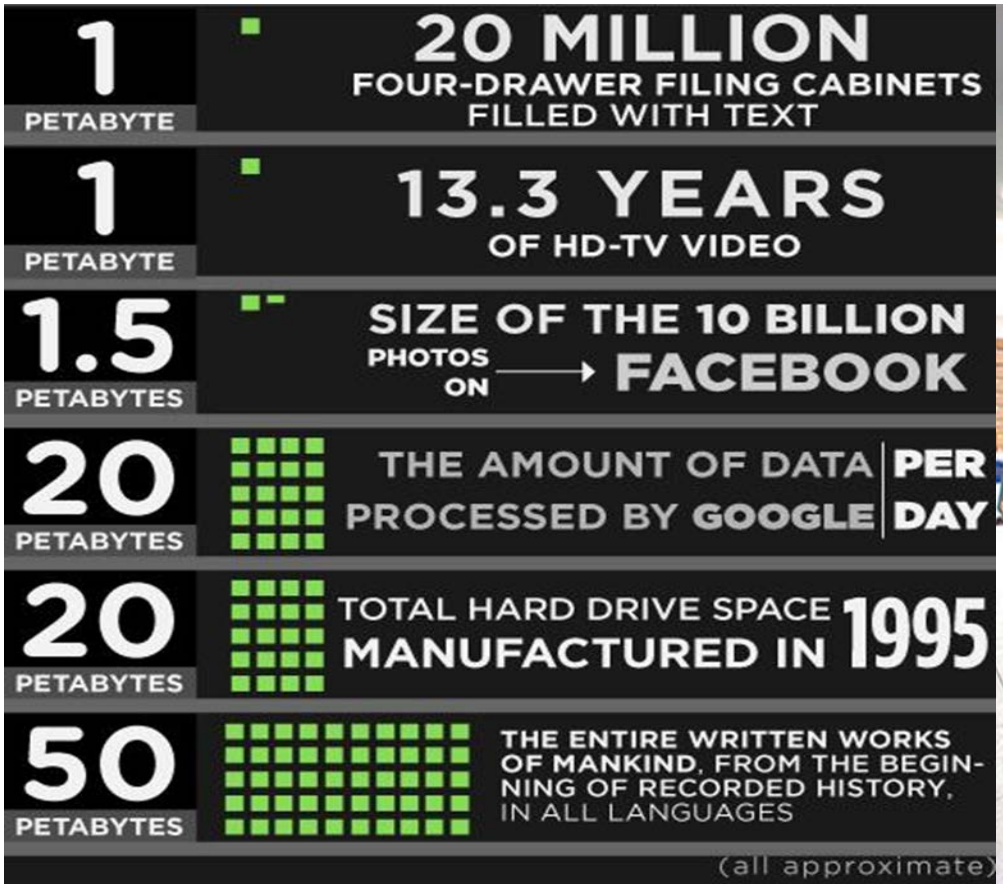
- Working Memory is finite

- Long Term Memory is close to infinite

Memory Capacity



If the brain were a computer



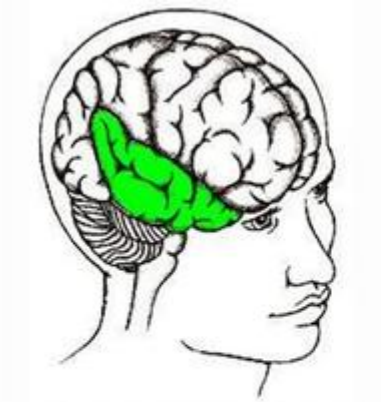
Current Estimates are that the brain could hold 2.5 Petabytes of information

Paul Reiber, Scientific America, April, 2010

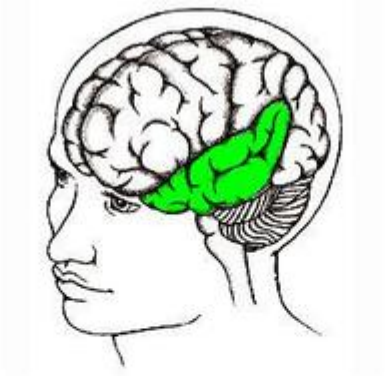
Working Memory Models

- Alan Baderly (1974)
  - keep information “in mind”
  - a system for both temporary storage and manipulation of information, which is necessary for a wide range of cognitive tasks
  - might be the single most important factor in determining general intelligence

Parts of the brain involved in working memory



Phonological loop - temporal lobes of the left hemisphere



Visuospatial memory – right hemisphere

Central executive – dorsolateral prefrontal cortex

The Phonological Loop

This system was proposed to give an account of the substantial evidence that had already accumulated concerning short-term verbal memory, typically involving the classic digit span procedure. The articulatory loop was assumed to comprise two components, a phonological store and an articulatory rehearsal system. Traces within the store were assumed to decay over a period of about two seconds unless refreshed by rehearsal, a process akin to subvocalization and one that is dependent on the second component, the articulatory system (Baddeley & Hitch, 1974).

The question of whether short-term forgetting represents trace decay or interference, a classic issue of the 1960s, remains unresolved. The trace decay assumption was adopted on the basis of rather slender evidence, together with its greater simplicity. An interference theory interpretation invites a much tighter specification than my colleagues and I have felt able to achieve. For example, should it follow the classic stimulus–response associationist principles, as Melton (1962) proposed, or should it be closer to the Waugh and Norman (1965) concept of interference resulting from subsequent items displacing earlier traces within a limited capacity system? Indeed, even trace decay could be seen as a form of interference; given that the nervous system appears to be continuously active, a greater delay will involve more subsequent neural activity leading to a greater potential disruption of the memory trace. Testing any of these is likely to demand a more precise specification of the phonological loop than Baddeley and Hitch (1974) were able to offer.

The Visuospatial Sketchpad

This system is assumed to be capable of temporarily maintaining and manipulating visuospatial information, playing an important role in spatial orientation and in the solution of visuospatial problems

The sketchpad is assumed to form an interface between visual and spatial information, accessed either through the senses or from LTM. As such, it allows a range of channels of visual information to be bound together with similar information of a motor, tactile, or haptic nature

The Central Executive

The third component of the working memory framework, the central executive, was initially conceived in the vaguest possible terms as a limited capacity pool of general processing resources. For the first decade, it served principally as a convenient ragbag into which could be thrust such awkward questions as what determined when the sketchpad or phonological loop was used and how they were combined. Implicitly, the central executive functioned as a homunculus, a little man who took the important decisions as to how the two slave systems should be used.

, the *episodic buffer* (Baddeley, 2000a, 2001, in press). The episodic buffer is assumed to represent a storage system using a multimodal code. It is assumed to be episodic in the sense that it holds integrated episodes or scenes and to be a buffer in providing a limited capacity interface between systems using different codes. It fulfills some of the functions implicitly assigned by Baddeley and Hitch (1974) to the executive.

Working Memory Models

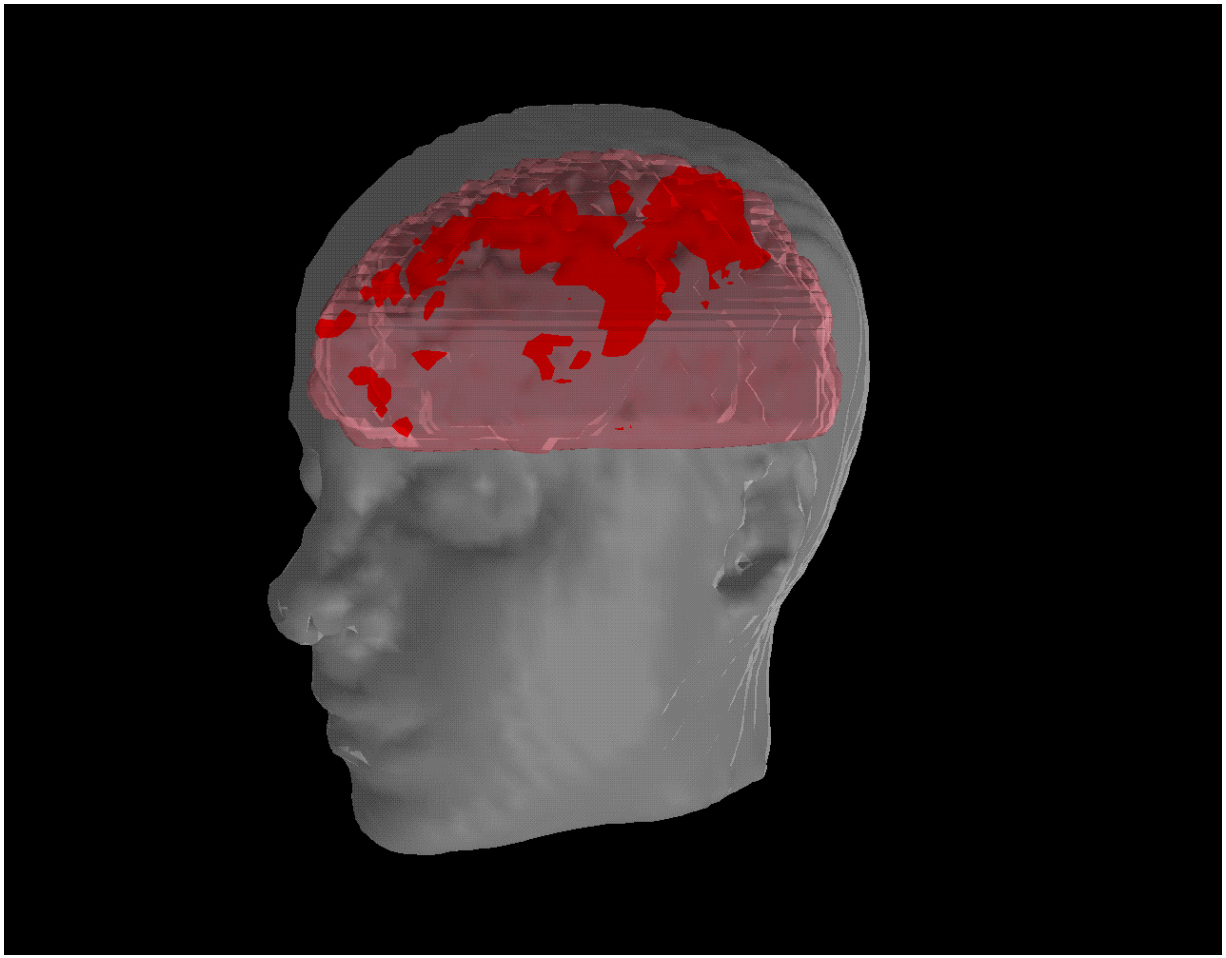
- Alan Kaufman
  - WISC-R to WISC-III
    - 3rd factor
    - Named it Freedom from Distractibility
    - Renamed Working Memory

    - WISC-IV – we look at the effects of working memory on verbal comprehension
      - If you're only attending to 30% of the information, only 30% gets comprehended

Working Memory Models

- Nelson Cowan (2001)
  - a passive store component, plus attentional control
  - Differentiates between working memory and short term memory
  - Refutes Dan Miller's *Magic Number Seven –w/o active rehearsal*

Parts of the brain involved in working memory

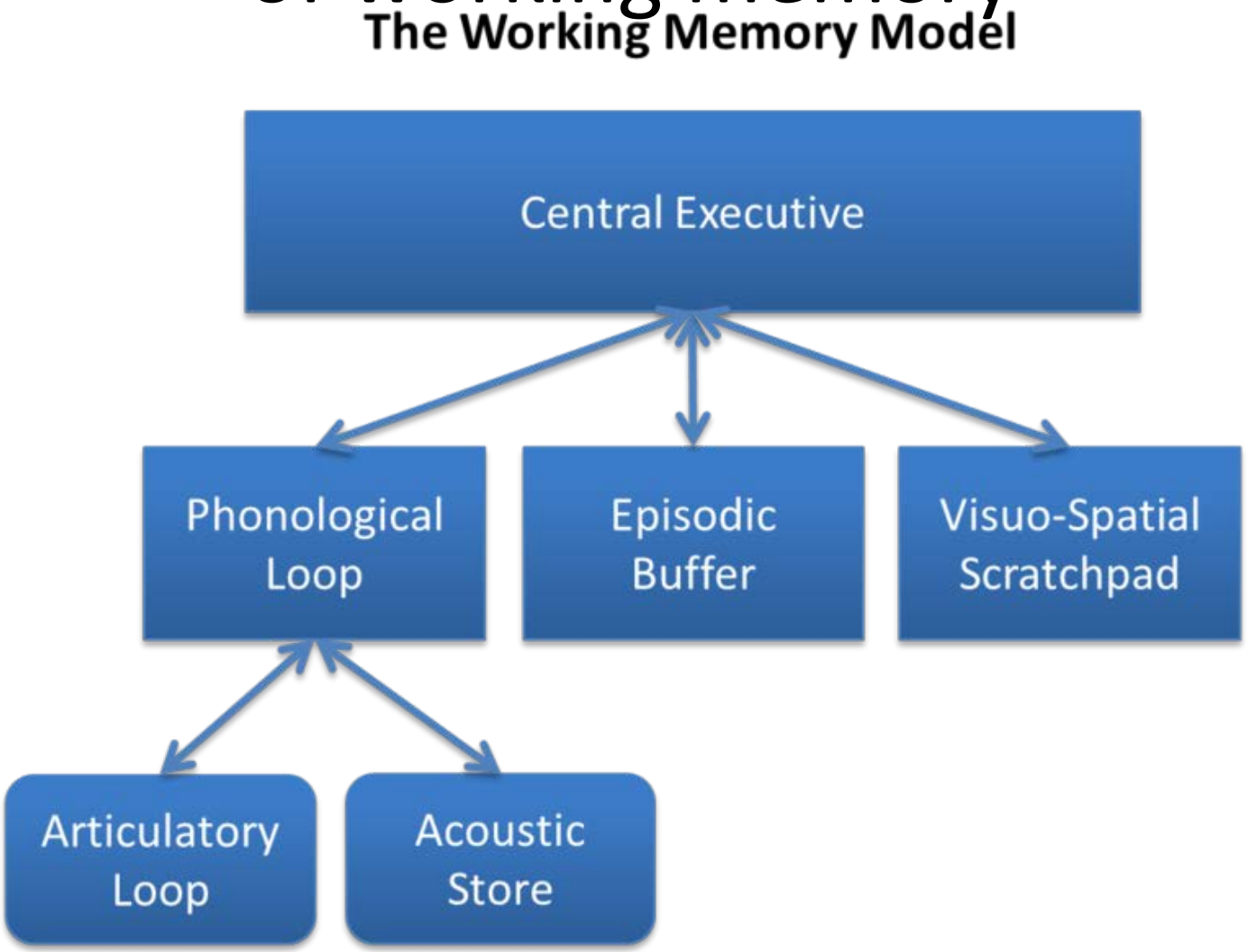


Working Memory Models

- Awh & Jonides, (2001)
  - working memory is necessary for the control of attention
  - it is not possible to separate working memory and control of attention

  - Thus, we assess no prior learned rote tasks (Digit Span) and prior learned (Arithmetic)

Alan Baderly's revised model of working memory



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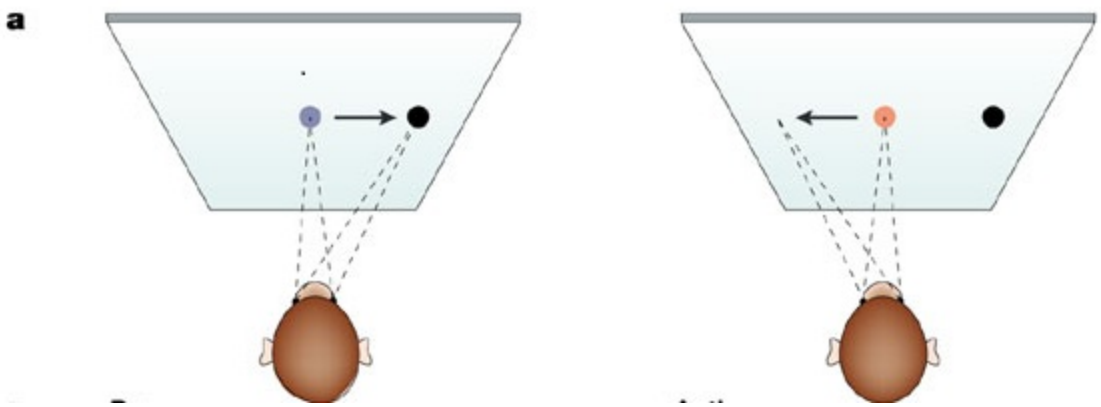
Assessing Working Memory

- Traditional measures
  - Digit Span – nonsense sequence
  - Spatial Span– novel images

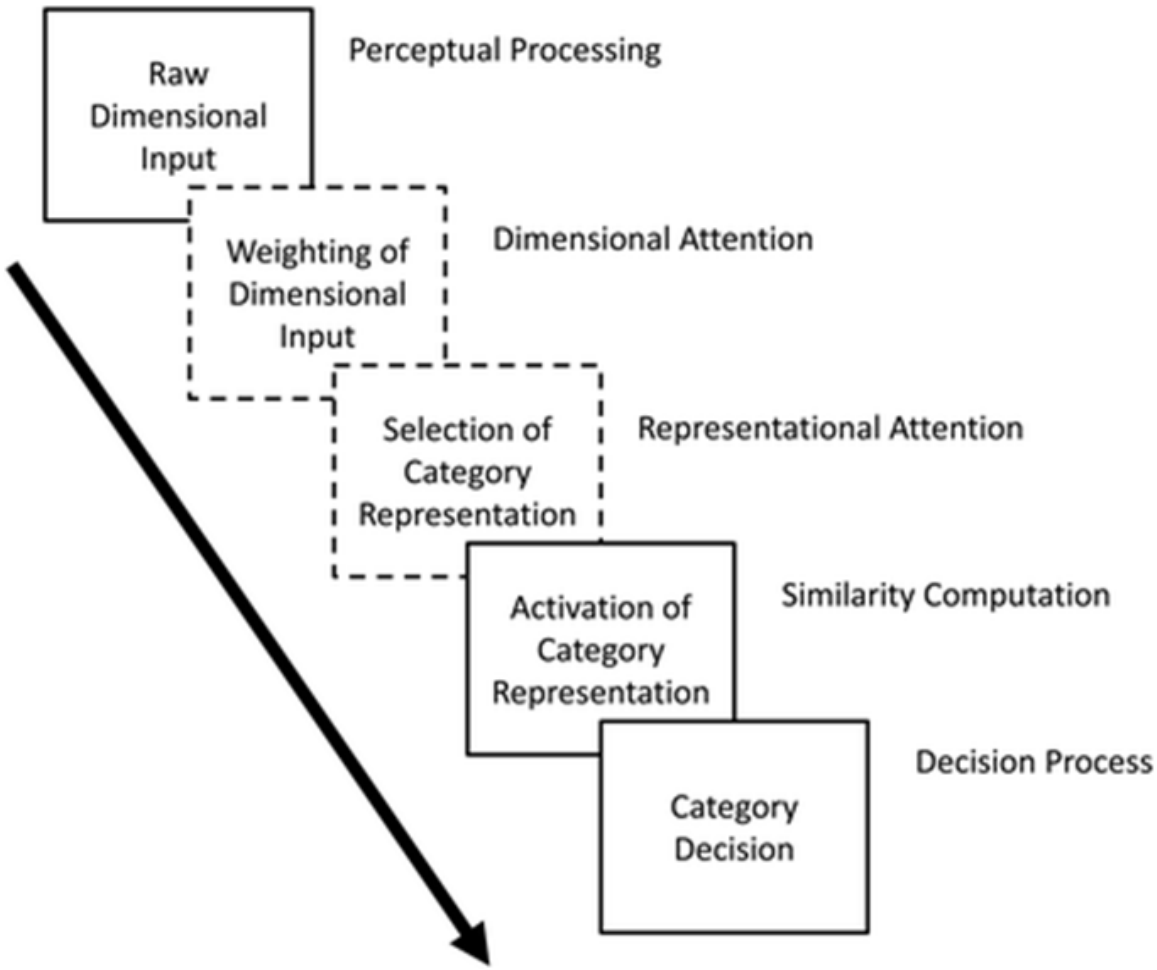
Assessing Working Memory

- Anti-saccade Task and the voluntary control of eye movement
- Measures the central executive



Bad Good

Level of Processing



Assessing Working Memory

- Reading Span Test

- True or False
  - The brother of one of your parents is an UNCLE
  - A word made up of five letters is UNCLE

- After receiving two to five sentences, participants were prompted to recall the final word of each sentence
- A Distracter Task for 2 min
- Surprise Recall

Assessing Working Memory

- Visual Reading Span test – looks at how depth of processing helps working memory
  - Remember - **Pink**, **Car**, **Robot**
  - Which one was written in green ink? (visual)
  - Which rhymes with stink? (phonological)
  - Which is a method of transport? (semantic)

Assessing Working Memory

Table 1

Mean (SEM) Proportion of Items Correctly Recalled on the LOP Span Task and Correctly Recognized as Old on the Delayed Recognition Test for Items Initially From Three- or Eight-Item Lists

	Level of processing		
Task	Visual	Phonological	Semantic
Immediate Recall			
3 items	.99 (.01)	.92 (.02)	.98 (.01)
8 items	.56 (.02)	.44 (.03)	.51 (.02)
Delayed Recognition			
3 items	.61 (.05)	.66 (.04)	.73 (.04)
8 items	.69 (.04)	.69 (.03)	.82 (.03)

Note. The false alarm rate was .19 (.02).

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Assessing WM

- In order for WM to demonstrate construct validity it must have differential affects on different diagnoses

- Conversely by assessing WM we can discriminate between diagnoses

Poor WM and Reading

- **Reading Disorders**
- Traditional Approach – do better on stories than word lists
  - Reduced verbal working memory (VWM)
  - Intact Visual WM, central executive, and long-term memory functioning.
  - Their deficit in STM appeared specific to tasks requiring phonetic coding of material. (*Child Neuropsychology, Vol 14(6), Dec, 2008. pp. 525-546*)
- Newer Research
  - Deficits in visuospatial working memory
  - Or
  - Deficits in phonological short-term memory and phonological awareness
  - Thus
  - Working Memory accounts for individual differences in reading ability

Poor WM and Math

- **Arithmetic** Learning Disability
  - Deficits in Phonological loop processes – create difficulties recalling the sequence of problem solving
  - Trouble with the central executive, allows for impulsive errors if the whole problem is not considered

Poor WM and AD/HD

- Attention Deficit Hyperactivity Disorder
  - Deficits in the central executive effect planning and sequencing
  - Deficits more in Spatial WM (dots) than Verbal WM (word lists)
  - Dot performance improves with stimulents
  - Poor Planning or Poor Processing

Poor WM and Autism

- Autism & Spatial Working Memory
  - **memory** abilities in the children with **autism** was characterized by relatively poor **memory** for complex visual and verbal information and spatial **working memory** with relatively intact associative learning ability, verbal **working memory**, and recognition **memory** (Neuropsychology, Vol 20(1), Jan, 2006. pp. 21-29

Poor WM and Mood Disorders

- Stress and Working Memory
  - acute stress impairs WM performance for tasks requiring executive functions that operate on the stored material but not for WM tasks that only require maintenance (Behavioral Neuroscience, Vol 123(5), Oct, 2009. pp. 1066-1075)

WM affects across domains

- Acquisition of Knowledge
- Affects automaticity of skills with complex sequences
- Affects recall of information

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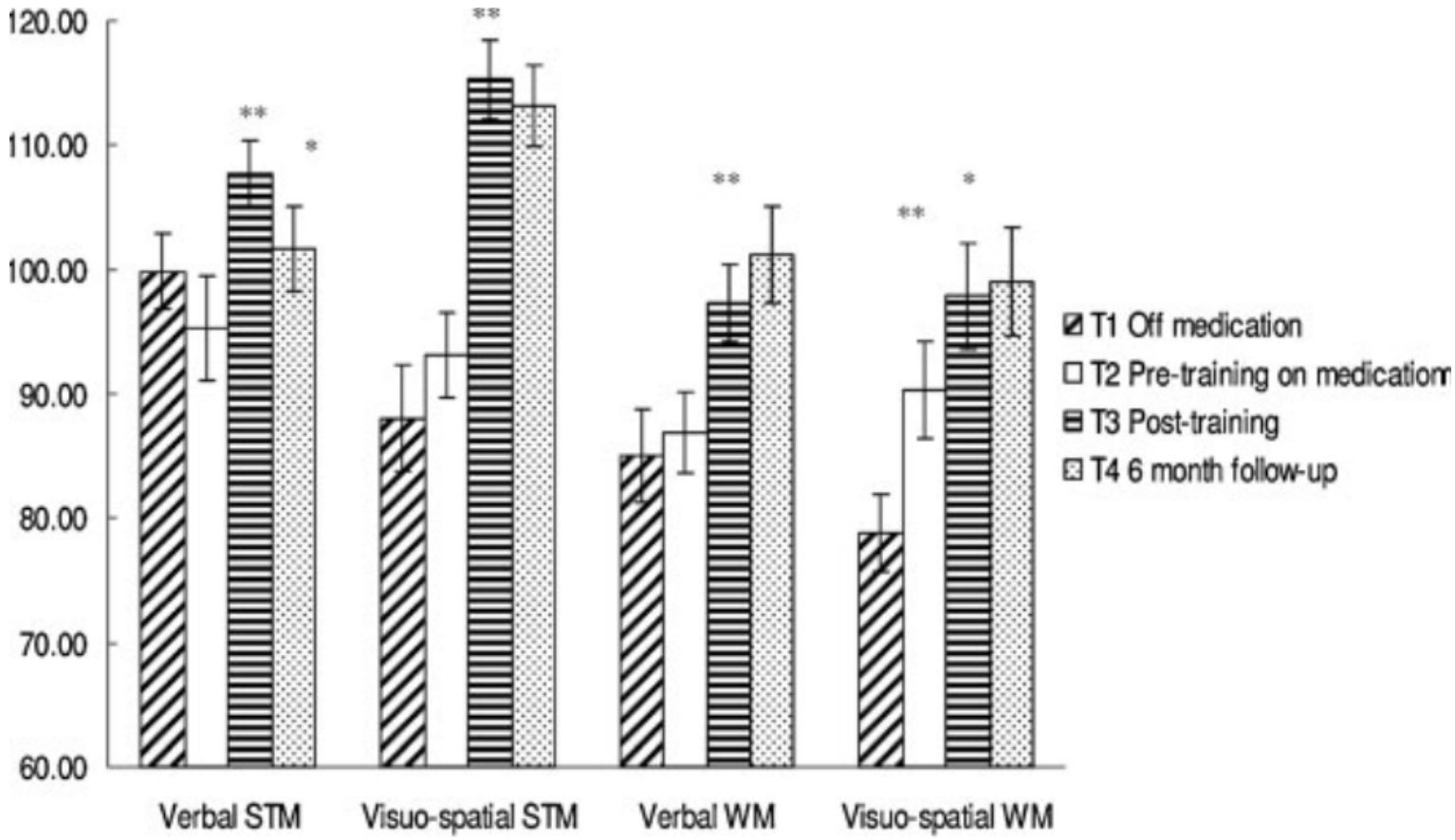
Working Memory Training Effects

- The observed training effects suggest that [working memory] training could be used as a remediating intervention for individuals for whom low [working memory] capacity is a limiting factor for academic performance or in everyday life. (Klingberg, 2010, p. 317)
- Fluid intelligence is trainable to a significant and meaningful degree… and the effect can be obtained by training on problems that, at least superficially, do not resemble those on the fluid-ability tests. (Sternberg, 2008, p. 6792)
- Future research should not investigate *whether* brain training works, but rather, it should continue to determine factors that moderate transfer. (Jaeggi et al., 2011, p. 10085)
- Does [working memory] training yield generalized cognitive enhancement? In the case of core training, our answer is a tentative yes. (Morrison & Chein, 2011, p. 57)

- Increased WM capacity effects
  - Learning computer languages (Shute, 1991),
  - Sight-reading music (Meinz & Hambrick, 2010),
  - Multitasking (Bühner, König, Prick, & Krumm, 2006; Hambrick, Oswald, Darowski, Rench, & Brou, 2010)
  - Regulating emotion (Kleider, Parrott, & King, 2010; Schmeichel, Volokhov, & Demaree, 2008).

- Working Memory Training requires effort
- What types of improvements can be expected

The impact of training and medications on Working Memory



*p<.05, **p<.01

Applied Cog Psych. 24: 827-836 (2010)

Effects of Training

- WM training increases WM capacity
- BUT

- Very little effect on fluid reasoning
- the evidence of transfer to attention is sparse

WM Training Effects

- Improving WM does not improve attention
- Improving WM does not improve IQ

- BUT

- Improving attention does help WM
  - Dots and Stimulant Medications

Working Memory Training Effects

- Improved Remembering of Instructions
  - Better work completion
- Faster acquisition of knowledge
  - Less repetition required
- More Efficient Long Term Memory Storage

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The Adaptive Working Memory Training Paradigm – Klingberg 2010

- 3 parts to an effective intervention

- Training should not teach specific strategies for simply remembering more information (e.g., rehearsal techniques or mnemonic devices)
  - not the same as changing the underlying ability.
  - A rehearsal technique that helps a person remember a series of digits will be useless when applied to nonverbal materials (e.g., snowflakes
  - people with cognitive deficits tend to have difficulty recognizing situations in which a strategy might apply

The Adaptive Working Memory Training Paradigm – Klingberg 2010

- Part 2
- the training program should be specifically focused on WM tasks. The inclusion of other types of training will be time consuming and thus dilute the efficacy of the intervention. This further implies that WM tasks do not simply measure WM capacity but also stimulate neural plasticity

The Adaptive Working Memory Training Paradigm – Klingberg 2010

- Part 3
- Training schedules should be rigorous (roughly 20 sessions, each lasting 30–60 min) and training programs should adapt to user performance. If a person is meeting specific performance criteria, task difficulty should increase. When these criteria are not met, task difficulty should decrease

Transfer of training

- Improved performance on the training task does not signal an increase in WM capacity. For instance, Chase and Ericsson (1982) reported a participant (S.F.) who, after several months of training on an adaptive span task, was able to recall sequences of more than 80 digits. However, when the digits were presented at a faster rate, his scores returned to normal levels. The reason for this decline was that S.F. had developed a strategy of mapping short sequences of numbers onto preexisting knowledge (i.e., cross-country running times, historical dates). When the testing conditions were changed, his strategy could not be employed.

Primary Methods of Intervention

- Repetitive WM training
- Cogmed (computer-based)
- Mindsparkle (computer-based)

Alternative Interventions

- Mindfulness or meditation training (e.g., Fabbro, Muzur, Bellen, Calacione, & Bava, 1999; van Vugt & Jha, 2011; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010; see also Tang & Posner, 2009),
- Neurofeedback (Cannon et al., 2006; Vernon et al., 2003)
- Physical exercise (Lachman, Neupert, Bertrand, & Jette, 2006)
- Long-term training on musical instruments (George & Coch, 2011; Jones, 2007)
- Learning other skills (Lee, Lu, & Ko, 2007).

Non Computerized WM training

- Stroop Practice
- Backward Digit Span
- Flash Cards (visual scan)

Cogmed Working Memory Training (2006)

- Cogmed training involves several verbal and visuo-spatial simple span tasks that have been embedded within simple video games. Some games involve static displays, while other games require participants to track movement.
- Cogmed is an adaptive task, in that trial-by-trial performance determines how much information a trainee is required to remember. Both forward and backward recall are practiced

Cogmed Results

Table 2
Transfer Results for Studies With Children

Training program (by group characteristic)	Authors	Control group	Near			Far						Age in years *M* (*SD*)
				WMC								
			STM	BS	CS	Gf	Ach.	Attn.	ADHD Obj.	ADHD Subj.	*n*	
Children with ADHD and/or low WMC												
Cogmed (ADHD)	Beck et al. (2010)	No contact								?	51	11.75 (32.59)
Cogmed (ADHD)	Gibson et al. (2011)	None							—	✓	37	12.59 (1.21)
Cogmed (ADHD)	Holmes et al. (2010)	None	✓	✓	✓	—	—				25	9.75 (.92)
Cogmed (ADHD)	Klingberg et al. (2002)	Nonadaptive task	✓			✓		✓	?		14	11.20 (2.55)
Cogmed (ADHD)	Klingberg et al. (2005)	Nonadaptive task	✓			✓		✓		?	44	9.80 (1.30)
Cogmed (ADHD)	Mezzacappa & Buchner (2010)	None	✓	✓						✓	8	8.75 (.89)
Cogmed (cochlear implants)	Kronenberger et al. (2011)	None	✓	?							9	10.20 (2.2)
Cogmed (low WMC)	Holmes et al. (2009)	Nonadaptive task	?		✓	—	—				42	8–11[c]
Cogmed (special education)	K. I. E. Dahlin (2011)	Klingberg et al. (2005)	✓	✓		—	?	—			57	10.71 (1.09)
JungleMemory (learning disability)	Alloway (in press)	Learning support			✓		✓				15	13.00 (.78)
OddYellow (borderline IQ)	Van der Molen et al. (2010)	Response time task	?	—	—	—	—	—			93	15.21 (.69)
Typically developing children												
Cogmed	Bergman Nutley et al. (2011)	Nonadaptive task	?		✓	—					101	4.30 (.25)
Cogmed	Shavelson et al. (2008)[b]	Nonadaptive task	✓		—	—					37	13.50 (.70)
Cogmed	Thorell et al. (2009)	Computer games	✓			—		?			62	4.70 (.43)
n-back	Jaeggi et al. (2011)	Knowledge training				?		DNR			62	9.03 (1.49)
Running span[a]	Zhao et al. (2011)	Computer games				✓					33	9.76 (.61)

Note. ✓ = significant transfer; ? = mixed transfer; dash = no transfer; DNR = did not report; STM = short-term memory; WMC = working memory capacity; BS = backward span; CS = complex span; Gf = general fluid intelligence; Ach. = achievement; Attn. = attention; ADHD = attention-deficit/hyperactivity disorder; Obj. = objective measurement; Subj. = subjective measurement; *n* = number of participants included in posttest session.
[a] Training task did not adapt to performance. [b] Study not published in a peer reviewed journal. [c] Data unavailable; age range substituted.

8 out of 11 studies show transfer effects