


Holmes, et al., (2015) informs our understanding of how working memory relates to English Language Learning (ELL) and what role Cogmed can play.

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Agenda

- What is Working Memory (WM)?
- Why does WM matter?
- New Cogmed Research on Low Language Ability (LLA) Children.
- Cogmed Research on Low Income Minority Children Improves VSWM, VWM and behavioral self-regulation.
- Salience of WM for Learning Language.

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What is Working Memory (WM)?



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

To keep information in your mind for a **short period of time (seconds)** & use in your thinking

Processes all stimuli we encounter – updating

Delegates to different parts of our brain to take action - shifting


Allows us to **block out unnecessary information** – inhibition

Keeps us updated on what's happening – & **focused** on what matters

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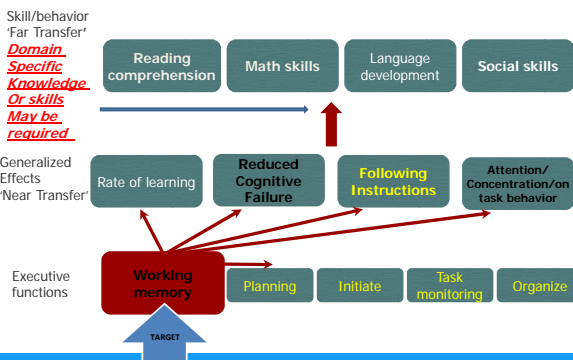
Is there ample room to do work on your desk?
Working Memory: The Mental Workspace

“...working memory as a mental workspace in which products of ongoing processes can be stored and integrated during complex and demanding activities (Just & Carpenter, 1992). Such an activity would be learning English.



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Poor WM can impede progress in learning language.



Skill/behavior 'Far Transfer'

Domain Specific Knowledge Or skills May be required

Reading comprehension Math skills Language development Social skills

Generalized Effects 'Near Transfer'

Rate of learning Reduced Cognitive Failure Following Instructions Attention/Concentration/on task behavior

Executive functions

Working memory Planning Initiate Task monitoring Organize


TARGET

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Why is working memory important for Learning Language?

Working memory is used for:

- Attentional Control
- Resisting distraction
- Organization
- Complex thinking
- Problem solving
- Remembering tasks



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NEW Cogmed Research: Improving Working Memory in Children with Low Language Abilities
(Holmes, et al., 2015)

- Can WM training improve the verbal memory of children with low language abilities (LLA)?
- Children ages 8 to 11 with LLA **matched on nonverbal abilities with peers who had age-typical language performance.**
- Short-term memory, WM, language & IQ were assessed before and after training.


Intriguing results

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Improving Working Memory in Children with Low Language Abilities
(Holmes, et al., 2015)


- **Participants:** All native English speakers (87 males, mean age 9 years, 3 months, SD=10.7 months).
- 179 kids, ages 8-10 at two primary schools in south-east England
- Screened
 - **Receptive language** test (Peabody Picture Vocabulary Test (PPVT), Dunn & Dunn, 2007).
 - **Expressive language** test (Recalling Sentences subtest of the Clinical Evaluation of Language Fundamentals (CELF), Semel, Wiig, & Secord, 2006)
 - **Nonverbal reasoning** (Matrix Reasoning subtest of the Wechsler Abbreviated Scales of Intelligence (WASI), Wechsler, 1999).
- **16 children with standard scores <86 on PPVT and scaled scores <7 on CELF Recalling Sentences formed = LLA (low language abilities) group.**
- **Control:** 16 children matched on age to within 90 days, gender, and on nonverbal reasoning.
- **The two groups differed on:**
 - CELF Recalling Sentences, $t(30) = -10.692, p < .001, d = 3.784$,
 - PPVT, $t(30) = -7.69, p < .001, d = 2.987$.
- No group differences on the nonverbal reasoning task, $t(30) = -.244, p = .809, d = .086$. Both groups scored in the low average range on this task.

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 **Measures:**
AWMA, CNRep, CELF, PPVT, WASI,
 (Holmes, et al., 2015)


- Working Memory: AWMA: Automated Working memory Assessment verbal & visual short term memory (STM) & verbal and visual working memory (WM).
- IQ: Wechsler Abbreviated Scales of Intelligence (WASI)
 - Similarities
 - Vocabulary
 - Block Design
 - Matrix Reasoning
- Language:
 - Children's Test of Nonword Repetition (CNRep)
 - Understanding Spoken Paragraphs subtest & recalling sentences test of the CELF, a measure of listening comprehension.
 - Peabody Picture Vocabulary Test (PPVT)

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 **Pre-training Group Differences**
 (Holmes, et al., 2015)


- **STM:** Significant group difference in which LLA group scored significantly lower.
- **Language:** Significant group differences on CELF language tasks, CN-Rep test. LLA group significantly lower on all language tests.
- **IQ:** Significant group difference LLA group significantly lower on Verbal IQ.
- **WM:** On both VWM & VSWM **no significant differences.**

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 **Unusual Approach:**
All completed Adaptive Cogmed
 (Holmes, et al., 2015)

- Cogmed was completed by all in both groups.
- Training was done in small groups at school.
- Community sample of children aged 8 to 11 years with LLA and a comparison group with matched nonverbal abilities and age-typical language performance. 4 Core areas assessed before and after training:
 - Short-term memory
 - working memory
 - language
 - IQ
- Cogmed Training Description Basics:
 - Cogmed 20 sessions. 45 minute sessions.
 - Approximately 45 min. and involved repeated practice
 - 33 span-like STM and working memory tasks.
 - Participants completed eight out of a possible 12
 - 34 tasks in each session, with 15 trials on each task.

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 **Distinct Detailed Description of Cogmed including STM as well as WM activities**
(Holmes, et al., 2015)

Cogmed Detailed Description:

- **7 of the tasks involved the serial recall of visuo-spatial information.**
 - Of these, 4 required mental manipulation (e.g. spatial rotation) prior to recall (visuo-spatial working memory) and
 - 3 required simple serial recall (visuo-spatial STM).
- **3 further tasks required the serial recall of verbal information**
 - in the same order (verbal STM) or
 - in reverse or ascending order (verbal working memory).
- **2 other tasks required the recall of verbal information associated with specific spatial locations,**
 - one in forward order (STM) and
 - one in reverse sequence (working memory).

NOTE: This description is both more detailed and more accurate than the typical description of Cogmed as a program for training working memory. Additionally, this clarifies that more than just WM are being trained with Cogmed.

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 **Improving Working Memory in Children with Low Language Abilities**
(Holmes, et al., 2015)

* (Can) Cogmed training overcome the working memory problems typically found in children with low language learning abilities?*


Specific Language Impairment (SLI) is characterized by "poor language learning in the *absence of general intellectual problems*".

Widely reported deficits on both:

1. Verbal STM &
2. Verbal complex memory span (Archibald & Gathercole, 2006; Bishop et al., 1999; Botting & Conti-Ramsden, 2001; Montgomery, 1995).

Yet, performance on "**visuo-spatial memory tasks is appropriate for their age** (Archibald & Gathercole, 2006; Bavin et al., 2005)." In other words there is no deficit in this area.

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 **Improving Working Memory in Children with Low Language Abilities**
(Holmes, et al., 2015)

- *Interestingly*, those with **reading difficulties** present with a "similar profile of predominantly verbal impairments in working memory... (Pickering, 2006; Catts et al., 2002)."
- Intriguingly, one might posit this as a "**domain-specific**" deficit as conceptualized previously herein.
- The question becomes, can Cogmed, which is predominantly focused upon visual spatial working memory, facilitate improvement on verbal short term memory in this LLA group?

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Surprising: Differences in many other areas did not meet Bonferroni threshold.
 (Holmes, et al., 2015)

- Significant main effects of training were observed for the whole sample from pre- to post-test on two visuo-spatial STM tasks, Dot Matrix, Block Recall, and for the derived composite visuo-spatial STM score (see Table 2).
- Scores were higher after training on Digit Recall ($p=.05$), Backward Digit Recall ($p=.02$), Spatial Recall ($p=.017$) and the verbal STM composite score ($p=.03$),
- but in all cases these effects did not meet significance at the Bonferroni threshold.

Significant gains from pre- to post-test were also observed for the **total nonword repetition** score and for performance on this test at syllable lengths 3 and 5.

VIQ and PIQ significantly Improved: There was a main effect of training on both verbal and performance IQ, with significantly higher scores after training (Table 3).

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Cogmed study of Preschoolers (Low income & Predominantly minority)
 (Foy & Mann, 2014)

- N=23, Cogmed, 27 control group. Average age: 5.2 years old
- Predominantly Hispanic & African American children from schools with high proportions of low-income children. All spoke English fluently, some were also fluent in Spanish.
- Trained with Cogmed JM – all VSWM.
- **Significantly improved upon VSWM, VWM and behavioral self-regulation.**
- There were no direct impact upon pre-reading skill, but **phoneme awareness was independently linked with self-regulation.**
- There was no follow up.

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Executive Control through the Head-Toes-Knees-Shoulders Task (HTKS)

- Executive Control includes a “collection of top-down processes” including Working memory (WM) Inhibitory Control (IC), and cognitive flexibility (Diamond, 2013).
- Executive Control Measure: Head-Toes-Knees-Shoulders (HTKS) test (Ponitz et al., 2008; Ponitz et al., 2009) “a reliable and valid measure of executive control (behavioral self-regulation) in children aged 4-6 years (McClelland et al., 2007a/b; Ponitz et al., 2008).
- What is the HTKS?



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Executive Control Measure: Head-Toes-Knees-Shoulders test (HTKS)

- The HTKS consists of a structured observation involving four behavioral rules involving touching four body parts (head, toes, should, knees), and requiring children to perform the opposite of a response to four different oral commands. (If I say "toes", they touch their head.)
 - If children pass the head/toes part of the task, they complete advanced trials where the knees and shoulders commands are added.
 - The HTKS task was conceptualized as a measure of IC (a child must inhibit the dominant response of imitating the examiner), WM (a child must remember the rules of the task) and attention focusing (the child must focus attention to the directions being presented by the examiner).
- The HTKS has been shown to be predictive of academic achievement in pre-kindergarteners and kindergarteners (McClelland et al., 2007a; McClelland et al., 2007b).
- Examiners were trained according to a video and written protocol developed by the authors of the HTKS. The scores on each of the 3 subtests at T2 were summed to create a composite measure of Executive Control. Parallel forms (A and B) of the HTKS were administered at the two testing times.

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Cogmed study of Preschoolers (Low income & Predominantly minority)
(Foy & Mann, 2014)

This finding now adds to the growing body of literature showing that phoneme awareness in young children is associated with Executive Control (EC) abilities (Matthews, Ponitz, & Morrison, 2009) and specifically with Inhibitory Control (IC) (Working memory) (Blair & Razza, 2007; Foy & Mann, 2013).

- WM and IC (Impulse control) skills may have distinct and separate roles in early reading acquisition, with WM having an independent effect on letter knowledge and IC having an independent effect on phoneme awareness.
- Our findings are consistent with the suggested role of WM in EC (Best & Miller, 2010; St. Clair-Thompson & Gathercole, 2006), as well as the interrelatedness of different types of WM measured in different domains


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Cogmed & Typically Developing Preschool Children
(Shinaver & Entwistle, 2015)

Study	Study design	Sample	Measures
Bergman Nutley, et al., 2010	RCT-double-blinded, Pseudo-randomized, (stratified for sex)	Typical Pre-schoolers	VSWM-complex memory span task (Odd one out)
Thorell et al., 2009	RCT- double-blinded	Typical Pre-schoolers	Attention - Auditory CPT
Grunewaldt, et al., 2013	Stepped Wedge Design (waitlist control)	Very Low Birth Weight (VLBW) Pre-schoolers	Auditory attention, phonological awareness, visual and verbal memory & sentence repetition.
Foy & Mann, 2014	Randomized, waitlist control	Economically disadvantaged Typical Preschoolers	VWM, Executive Control- Heads-Toes-Knees-Shoulders (HTKS)
Söderqvist, et al., 2011	Pseudo-randomized, (stratified for sex)	Typical Pre-schoolers	WM, fluid intelligence, variation in DAT1 influenced improvement.

Shinaver & Entwistle Chapter: "Computerized Cognitive Training based upon Neuroplasticity"
Book: Mental Health Care in a Digital World: A Clinician's Guide, Ed, Naakesh Dewan, MD

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 Consider that SLI_{Low WM} were worse on encoding and retrieving verbal information following a delay. (Lum, et al., 2015)

Verbal declarative memory functioning in Specific Learning Impairment (SLI) and its relationship to working memory. The areas of **encoding, recall, and recognition of verbal information** was examined in SLI_{Avg WM} & SLI_{Low WM}


The SLI_{Low WM} group was **significantly worse** than both the SLI_{Avg WM} & TD_{Avg WM} groups at **encoding verbal information and at retrieving verbal information following a delay.**

SLI_{Avg WM} group showed no verbal declarative memory deficits. So, not all those with SLI will have WM deficits, but those who do struggle with encoding, recall & recognition of verbal information.

Verbal declarative memory deficits in SLI only occurred when verbal working memory was impaired.


SLI declarative memory is largely intact and deficits are likely to be related to working memory impairments.

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 Findings from this study suggest that those with SLI may benefit like LLA did. (Holmes, et al., 2015)

- That is that Cogmed WM training may also result in improved Verbal Short Term memory gains for SLI as it did for the LLA (Low Language Ability) students in this study.

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 WM plays a role in encoding, recall and recognition of verbal information & in MA Ignoring this may affect results

ELL interventions that ignore the adverse role that WM deficits play in language acquisition run the risk of limiting the success of their intervention.

Those with WM deficits are likely to struggle to encode, recall and recognize verbal information.


Those with WM deficits are also likely to struggle with MA interventions which will affect their MA performance.

There are other ways deficits in WM create a bottleneck in learning for ELL students.

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**English Language Learners:
Poor Phonological WM relates to difficulties.**


- Poor phonological working memory is expected to be associated with poor second-language acquisition and in learning the "sound structure of new words" (Gathercole et al., 1992; Swanson, et al., 2006).
- Difficulty in holding in the phonological loop, new "sound structures" of unfamiliar phonological patterns makes **encoding** of this information into long term memory representations more difficult. One would expect 'automaticity' to be slower and more difficult to attain.



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**English Language Learners:
Phonological WM related to vocabulary knowledge**


- Phonological working memory linked to **vocabulary knowledge** (Gathercole, et al., 1992), better phonological memory = better vocabulary.
- **New word learning** in second language related to phonological working memory in first language (Cheung, 1996; Service, 1992; Thorn & Gathercole, 1999)
- Phonological working memory also important in **second-language reading acquisition** (e.g. Harrington & Sawyer, 1992; Stanovich & Siegel, 1994).



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**English Language Learners:
Hypothesis: Both STM & WM play a role.**
(Swanson, et al., 2004)

- Swanson, et al., 2004 suggest that with bi-lingual English Language Learners who were first graders (First Language - Spanish) that deficits in a language specific short term memory (**STM**) system might underlie reading problems in second-language development.
- Children at risk for RD showed a **deficit in general WM system, but also STM deficits within a specific language system** which differentiated them from non-RD children (Swanson, et al., 2004),



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Spanish Speakers Learning English challenged if they have memory deficits in Spanish STM and WM
(Swanson, et al., 2004)

- In a sample of Spanish speaking English Language Learners...
- **Spanish short term memory (STM)** in grade 1 predicted basic Spanish-reading skills and Spanish comprehension in Grade 2.
- In grade 1, English STM performance predicted English vocabulary and comprehension in grade 2.
- Most importantly children at risk for RD in Grade 1 differed from their counterparts in Grade 2 on both **English and Spanish measures of reading, but their deficits in memory were isolated to Spanish STM and working memory.**

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STM & WM in Spanish ELL
(Lanfranchi & Swanson, 2005)

- n=90
- Grade 1 English STM shared a common construct with Spanish STM.
- Grade 2 STM was language dependent.
- **In contrast, WM measures were language independent across grades 1 and 2.**
- Performance on Spanish and English STM tasks were a function of high and low Spanish and English vocabulary knowledge, where as **Working memory was not dependent upon vocabulary knowledge in each language.**



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Many studies find this critical role of WM capacity and Language acquisition for ELL students

- Difficulty with accessing comprehension skills was linked to lower WM in the 2nd language (Walter, 2007).
- Children with language impairment had lower counting span (complex WM task) whether only English-speaking or Spanish-English bilingual children. (Danahy, et al, 2007)
- Spanish speaking and English language learning children in 5th and 6th grade who were average or failing in reading were differentiated by grammar and working memory while listening comprehension and vocabulary were significant predictors of comprehension (Rosston, 2009).
- **National Assessment of Educational Progress in 2005 ranked only 7% of English Language Learners in the proficient level while 73% were ranked below basic.** (Rosston, 2009). So when referring to ELL students many of these students are below the basic level of proficiency level. This suggests that they hypothesis of possible WM deficits among this group is a reasonable consideration.

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Can growth in a specific memory system result in growth in English Language Learning?
 (Swanson, et al., 2006)

- Follow up study from Swanson, et al., (2004), Do children identified at risk for RD in grade 1 differ from children not at risk for RD on measures of growth in the area of memory, reading, and related skills (e.g. vocabulary)
- Does growth in a language-specific or non language-specific memory system predict growth in English literacy?**
- n=112 first grade students from Southern California. 64 boys, 48 girls, ages 6-7. Low SES.
- 95% Mexican descent. 5% Anglo American. 81% spoke Spanish at home. All children received school instruction in English beginning in Kindergarten. None participated in ESOL classes.
- 50% of students designated as not English proficient.
- Children of average intelligence.



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Can growth in a specific memory system result in growth in English Language Learning?
 (Swanson, et al., 2006)

- English Language Learners (First Language - Spanish) originally tested in grade 1, followed up in grades 2 & 3.
- In grade 1, bi-lingual measures of STM, WM, vocabulary and reading were administered in English and Spanish.
- Results** English word ID best predicted by **general WM latent measure combining Spanish and English task performance** and a **Spanish-specific latent measure related to STM**.
- INTERPRETATION: Second language word reading correlated to both general WM processes and first-language STM span.**
- However, when children were sub grouped by risk for RD, **children at risk for RD were found to perform more poorly on Spanish measures of STM than children not at risk.**

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Can growth in a specific memory system result in growth in English Language Learning?
 (Swanson, et al., 2006)

- Children at risk for RD experienced less growth in language-specific STM and language-general WM than children not at risk.**
- Arguably this concern mirrors that of children with ADHD.**
- Performance deficits for at risk RD children emerged on the STM tasks in Spanish which included measures of forward and backward digit recall.
- Performance **deficits for the at-risk RD group emerged on WM tasks administered in both English and Spanish** that included concurrent processing and storage of phonemically similar words.
- Conclusion:** Weaknesses in phonological memory within Spanish language system and monitoring of WM across both language systems are BOTH important indicators of RD in ELL samples.
- However,** even when Spanish STM deficits were removed Spanish WM still predicted English Literacy. **Some might argue this may be related to controlled attention of the Spanish central executive system.**

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Can growth in a specific memory system result in growth in English Language Learning?
(Swanson, et al., 2006)


- **The non-risk group performed better on Spanish comprehension.**
- Performance for at-risk group was seen in some WM tasks, but not in all. Performance deficits were specific to WM tasks that included phonemically similar words in English or Spanish.
- **WM in the Spanish language system was an important predictor of the level of performance and growth in English reading.** So, in this study WM ability in one's primary language system predicts the level and rate of growth in English reading skills.
- Spanish STM and WM are well suited to identify children at risk for reading problems in their second language



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English Language Learners at Risk for Reading Disabilities Related to a Working Memory Factor
(Swanson, et al, 2011)

- English Language Learners (English Language Learners (First Language - Spanish) at risk for Reading Disabilities were administered several measures in both English and Spanish.
- n=471
- ELL Children at risk for RD share similar cognitive difficulties: problems in English phonological processing and naming speed, as well as on **language general measures of working memory** and ratings of **classroom attention**.



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English Language Learners at Risk for Reading Disabilities Related to a Working Memory Factor (2)
(Swanson, et al, 2011)

- Differences among RD subgroups were isolated to measures of **Spanish phonological processing, classroom inattention**, English naming speed, both **WM & STM** contributed significance to L2 reading and language acquisition.
- *Both Spanish WM & STM contributed unique variance to L2 (English) reading and language acquisition beyond the contribution L1 phonological processing skills.*
- Also, English STM, English executive WM, & Visual Spatial WM contributed to significant variance to all criterion measures.
- *Performance as a function of language status and RD was also related to a language general working memory factor.*

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English Language Learners at Risk for Reading Disabilities Related to a Working Memory Factor (3)
(Swanson, et al, 2011)

- English phonological processing significantly predicted all criterion measures in English. Spanish phonological processing correlated to the English criterion measures were not significant. **Thus the influence of phonological processing was language specific in this study.**
- Spanish phonological processing predicted Spanish word identifications well as both of the Spanish vocabulary measures. **Spanish executive WM predicted all criterion measures.**
- In contrast, and most critically both English and Spanish STM and WM measures predicted English reading comprehension.**
- Also, teacher ratings of inattention were uniquely predictive of English & Spanish word identification and English comprehension.**
- The finding that STM and WM in both languages predicted reading comprehension is consistent with the notion that skill acquisition in the encoding phase of learning is substantially affected by WM capacity, but also that language acquisition also has content-specific elements.
- Additionally, Holmes et al., 2015 findings that verbal short term memory increased with Cogmed training suggests the possibility that this may be the case with ELL students too.

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WM & Growth in Reading Skills of Children from Diverse Linguistic Backgrounds: 5-year Longitudinal study.
(Lesaux, et al, 2007)


In kindergarten the ELLs performed approximately two thirds of a standard deviation lower than L1 speakers on working memory ($d = -.62$), approximately one fifth of a standard deviation lower on sound mimicry ($d = -.22$), approximately half a standard deviation lower on rhyme detection ($d = -.54$), and approximately one third of a standard deviation lower on oral cloze ($d = -.34$).

- Letter identification, **working memory**, rhyme detection, and oral cloze, administered in kindergarten were identified as **significant predictors of fourth-grade reading comprehension.**
- Very similarly, letter identification, **working memory**, rhyme detection, and phoneme deletion were the **kindergarten predictors of fourth-grade word reading.**


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Working Memory Span may be related to the Strategies learners adopt at very early stages of Language acquisition.
(Michael, 1999)

- A study of bilingual Dutch-English students found that WM span affects the strategies students use in very early stages of language acquisition.
- Additionally, in fluent bilingual students WM plays a larger role in forward translation from Language 1 (L1) to Language 2 (L2) than in backward translation from L2 to L1.
- This data further supports the conclusion that especially early in the phase of skill acquisition of a second language that WM capacity affects the process.





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 **Executive Functioning & Reading Achievement in school , Brazilian children assessed by teachers as "poor readers"** (Engel de Abreu, et al., 2014)

- Brazil. 106, 6 to 8 year old Brazilian children from a range of social backgrounds were examined for executive functioning (EF) and reading achievement.
- Focus was on understanding EF of children whose classroom reading performance was judged below standard by their teachers. These students were than matched to controls on age, sex, **school type (public or private)**, domicile (Salvador/BA or Sao Paulo/SP) and SES.
- Several tasks assessed each EF function. 12 EF tasks were given intending to tap cognitive flexibility, WM, inhibition and selective attention.
- Principal components analysis extracted 4 factors: WM/cognitive flexibility, interference suppression, selective attention and response inhibition.
- **Struggling readers showed limitations in WM/cognitive flexibility and was the best predictor of reading.** Group comparisons showed struggling readers showed limitations in WM/cognitive flexibility, but not in other EF functions compared to more skilled readers.
- **CONCLUSION:** *WM Capacity provides the "provides a crucial building block for the development of early literacy skills and extends it to a population of early readers of Portuguese from Brazil."*
- Deficits in WM/cognitive flexibility might be one contributing factor to reading difficulties in early readers. This has implications for how educators might intervene with children at risk of academic under achievement.

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 **Cogmed is presently offered in 12 Languages**



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