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Effects of Cogmed on Receptive and Expressive Language: A Case Study

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EFFECTS OF COGMED™ ON RECEPTIVE & EXPRESSIVE LANGUAGE: A CASE STUDY

by

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The final copy of this thesis has been examined by the signatories. We find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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Title: Effects of Cogmed™ on Receptive and Expressive Language: A Case Study

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Abstract:

Objective: Working memory capacity has been correlated with receptive and expressive language skills. Research suggests that Cogmed™, an adaptive working memory training program, improves working memory capacity. This study analyzed the effects of Cogmed™ on trained working memory tasks and whether the presumed gains in working memory capacity generalized to improved language skills for a 10-year-old child with language deficits. ***Method***: The six-week Cogmed™ training was completed. CELF-4 was used to measure language skills at baseline and 7-months post-training. A sentence repetition task was used during the intervention. ***Results**:* The participant improved minimally on trained working memory tasks, more than one standard deviation below the average improvement reported by Cogmed™. There was no improvement on language measures. ***Conclusion***: Working memory capacity may be improved through training, but far transfer effects are unlikely. The amount of resources and motivation needed to complete Cogmed™ make it challenging to implement in a school setting.

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I. Introduction

In the past decade, "brain training" programs promising to improve some aspect of cognition have seen a significant increase. Of particular interest are the numerous programs that claim to improve working memory. Working memory, which supports our capacity for complex cognitive tasks, has been conceptualized as a mental workspace, a place to hold information while engaging in other activities. It has been correlated with executive functions, such as attention and inhibition, as well as mathematic abilities and language skills; thus, it is critical to academic achievement.

Although working memory capacity is limited, it may be improved through training. One particular computerized working memory training program, Cogmed™, has substantial research to back up claims of statistically significant gains in working memory capacity after individuals participate in the intensive intervention (see *http://www.cogmed.com/research* for a list of the published research); however, controversy exists as to whether improvements in working memory capacity are maintained long-term, or more importantly, whether improvements generalize to real-world skills, such as reading comprehension and vocabulary development.

This case study analyzed the effects of Cogmed™ in children with specific learning disabilities who have deficits in receptive and expressive language. It investigated whether gains on trained working memory tasks occurred after completing the Cogmed™ intervention and whether the presumed gains were maintained at 7-months post-training. Further, it explored whether training effects generalized to improvements in receptive and expressive language skills during the intervention and at 7-months post-training. If an intervention such as Cogmed™ proves to not only increase performance on trained working memory tasks, but improvements to working memory are maintained and far transfer effects to language skills can be determined, it could become an integral intervention for children who struggle to meet the language demands of the classroom.

II. REVIEW OF LITERATURE

a. Working memory

Baddeley and Hitch's 1974 model of working memory, which is the one most widely used by researchers, includes three separate but interactive systems. The first two subsystems, the phonological loop and visuospatial sketchpad, passively store information for a short period of time; the phonological loop processes verbal and acoustic information while the visuospatial sketchpad processes visual, spatial, and possibly kinesthetic information (Baddeley, 2003). The third subsystem, the central executive, is considered the "attentional control system" (Baddeley, 2007, p. 7); it actively coordinates the passive storage components and is linked with directing and focusing attention. The storage or processing capacity of each system component is limited (Baddeley, 2007).

More recently, Baddeley (2000) proposed a fourth multi-dimensional storage subsystem, the episodic buffer. Like the central executive, it depends on higher order executive processing, but it is not an active attentional control system. Rather, the episodic buffer is a temporary storage system that integrates information from the phonological and visuospatial subsystems with information held in long-term memory; it "binds information from diverse sources into unified chunks" (Baddeley, 2007, p 148). For example, researchers propose that during sentence recall tasks, the episodic buffer system integrates phonological information from temporary stores with syntactical and semantic information from long-term memory (Alloway & Gathercole, 2005; Baddeley, 2000). This example also highlights the concept that the first three subsystems are temporarily activated while the episodic buffer represents "permanent crystalized skills and knowledge" (Baddeley, 2012, p 12). Figure 1 is a representation of Baddeley's current model of working memory.

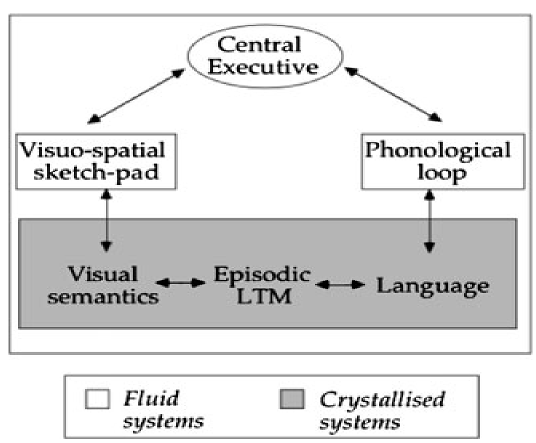


Figure 1: Baddeley's Working Memory Model

Although there is still much to be learned about working memory systems, researchers agree that working memory capacity is highly correlated with language. It plays a critical role in language comprehension and production (Carretti, Borella, Cornoldi, & De Beni, 2009; Daneman & Merikle, 1996; Gathercole, Alloway, Willis, & Adams, 2006). It supports language acquisition, phonological awareness, vocabulary growth, and syntactic knowledge (Gathercole & Baddeley, 1993). In the classroom, working memory has been associated with reading (Baddeley, Gathercole, & Papagno, 1998; Swanson, 2003; Swanson & Jerman, 2007), and writing skills (Berninger et al, 2010; McCutchen, 1996).

While evidence supports the role of working memory in language tasks, researchers disagree as to whether it is a domain specific-verbal process or a domain general-attentional control process. Some researchers argue that the phonological loop is most associated with language tasks (Acheson & MacDonald, 2009; Gathercole & Baddeley, 1993). For example, Baddeley, Gathercole, and Papagno (1998) propose that the phonological loop is critical during language acquisition and learning of new words. This is logical, as it has been associated with the left hemisphere, specifically Broca's area (Smith & Jonides, 1997). Baddeley (2003) argues that deficits in the phonological loop can have a serious negative effect on language processing. But, how do the other components of working memory interact with the phonological loop and effect language skills?

Other researchers argue that a domain-general system is responsible for language performance. Swanson (2003), a key researcher of the relationship between reading deficits and working memory, compared skilled readers' performance and individuals with learning disabilities' (LD) performance on phonological, visuospatial, and semantic complex span tasks without cues, with cues, and with a delay. The correlation between LD readers' and skilled readers' performance was nearly perfect (r=.97), regardless of whether it was a phonological or visual-spatial task, suggesting that demands on capacity were taxed at the system level, not within a subcomponent system. Daneman & Merikle (1996) believe this is related to resource allocation. If an individual has deficits in attending to, processing, and integrating incoming language (i.e. deficits in the central executive component), they have fewer resources to allocate to short term storage (i.e. in the phonological loop subsystem). However, even Swanson, a firm proponent of the domain general model, acknowledges that questions remain as to how the systems interact – how do deficits in phonological systems relate to deficits in the central executive, and vice versa?

This debate is significant when considering the Cogmed™ intervention, which relies heavily on visuospatial tasks. In fact, Holmes, Gathercole, and Dunning (2009) found that Cogmed™ did not have a "significant impact on verbal STM, a distinct subcomponent of WM . . . that has been suggested to support language learning" (p F13). If language is significantly associated with the phonological subsystem of working memory, then gains in the visuospatial subsystem should not be expected to have an effect on language skills. However, if it is a domain general-system at the helm during language tasks, then interventions that target visuospatial working memory or attentional processes may have an impact on receptive and expressive language skills.

b. Cogmed™ working memory training

Cogmed™ is an intensive intervention developed to increase working memory function. It is the most researched working memory training program, with 35 peer-reviewed published studies and a multitude of unpublished studies currently underway (Shinaver, 2013). Cogmed™ was originally designed as an intervention for children with ADHD, and the majority of the peer-reviewed research relates to this population (e.g. Beck et al, 2010; Holmes et al, 2010; Klingberg et al, 2005); however, research supports the use of Cogmed™ in a range of populations, such as adults with traumatic brain injury (Johansson & Tornmalm, M), adults post-stroke (Westerberg et al, 2007),children with hearing loss (Kronenberger et al, 2011), and children with learning disabilities (Dahlin, 2011; Swanson, 2003). At this time, Cogmed™ markets its product to anyone who is held back by working memory deficits (Shinaver, 2013).

From the current research, evidence is strong that significant gains immediately following training are made on simple and complex span tasks, similar to those used in the Cogmed™ training program, but maintenance of these gains are debatable. A recent study by Holmes, Gathercole, and Dunning (2009) analyzed the effects of Cogmed™ training on 42 children with poor verbal working memory who were not diagnosed with ADHD (treatment group, n=22; control group, n=20; average age 10 years). They found significant improvement on measures of verbal and visuospatial working memory in the Cogmed™ treatment group immediately after training and at 6-months post, as well as significant gains on a *Following Instructions* task, which they used to measure a practical classroom skill. However, this "untrained" *Following Instructions* task mirrored a Cogmed™ Progress Indicator task. In contrast, Kronenberger et al (2011) conducted a study on children ages 7-15 years who had cochlear implants (n=9) and found that gains on working memory measures were not maintained at 6-month follow-up.

Although Cogmed™ has research to support their claims of improved working memory capacity, criticism as to whether working memory training is effective still exists. Some researchers suggest that gains in trained tasks may not actually be due to increases in working memory capacity, but rather to the development of compensatory strategies, such as verbally rehearsing information or using imagery (Holmes et al, 2009; Holmes et al, 2010; Morrison & Chein, 2011). More vocal opponents, Shipstead, Hicks, and Engle (2012) call Cogmed™ an "expensive and ineffective product" (p. 191). They argue that the "limited variety of simple span tasks" (p. 190) that Cogmed™ research uses to measures gains in working memory capacity are not valid or reliable measures. Further, the tasks used in the supporting research are grossly similar to the tasks that participants train on during Cogmed™ intervention. Shipstead, et al (2012) proclaim that the "only unequivocal statement that can be made is that Cogmed™ will improve performance on tasks that resemble Cogmed™ training" (p 190).

In a meta-analysis of working memory training, Melby-Lervag and Hulme (2013) contend that programs such as Cogmed™ are based on a "fairly naive 'physical-energetic' model such that repeatedly ‘loading’ a limited cognitive resource will lead to it increasing in capacity, perhaps somewhat analogous to strengthening a muscle by repeated use” (p 272). They conclude that working memory training programs may have moderate to large effects immediately following training for both verbal and visuospatial working memory, but these effects are not maintained long-term. Clearly, more robust research is needed to unequivocally answer the question about the ability to increase working memory capacity. Even Charles Shinaver, the cognitive consultant for Pearson who presented at the 2013 ASHA conference, admitted that the critics had some valid points and that Cogmed™ is continually being developed as more research comes out.

c. Transfer effects of working memory training

Although questions remain about effectiveness of working memory training, let us assume that an intervention such as Cogmed™ improves performance on trained working memory tasks. The more contentious question relates to near and far transfer effects of working memory training. Further, if generalization to untrained skills is found after training, are they maintained? If so, for how long? Relevant to this case study, researchers strongly disagree as to whether gains in working memory capacity following training have transfer to language skills. Some researchers suggest that this may occur, but study designs have been questioned and claims of generalization are inconclusive at this time.

In a study of 50 low-achieving British students from two grade levels, Holmes and Gathercole (2013) conclude that “. . . memory training can benefit educationally relevant measures of school performance” (p 8). They support this claim by leaning on the data from one grade that showed a level gain for English of 2.00 for the trained group compared to 1.12 for the untrained group (average expected level gains for British students is 2.0). However, they conveniently gloss over the data from the other grade level, which showed a level gain for English of 1.48 for the trained group compared to 2.36 for the untrained group. In contrast to these positive results, an earlier study by these researchers

(Holmes et al, 2009) found no evidence of generalization of training effects immediately after or at 6-month follow-up on verbal IQ (p=.08, d=.39) or a basic word reading measure (d=.07).

Dahlin (2011) investigated the far transfer effects of Cogmed™ on 57 children ages 9-12 years old with ADHD and other undefined special education needs and found a significant effect of training on reading comprehension for the treatment group (n=42) compared to the control group (n=15) immediately following Cogmed™ intervention (d=.88) and at 6-months post-treatment (d=.91); however, she found weak effect sizes for word decoding(d= .37, .17) and negative effect sizes for spelling (d=-.39,-.13). The control group was not post-tested, so Dahlin compared data from Klingberg's 2005 study to conclude that Cogmed™ training resulted in improvements in reading comprehension. Due to the questionable design of this study, skepticism remains about these far transfer effects; however, Cogmed™ relies exclusively on Dahlin's work to support their claims of improved reading comprehension post-training (Shinaver, 2013).

Kronenberger et al (2011) also found positive transfer effects. They examined the relationship between Cogmed™ training and sentence repetition performance, a "core speech-language skill that is ... strongly related to working memory" (p 3), on children with cochlear implants (n=9) and found that raw scores on this task improved almost 1 SD at the 6-month follow up from the baseline scores. Interestingly, the magnitude of improvement was greater for the sentence repetition task than for working memory measures, which raises questions about what was affected by training. Due to the small sample size and lack of control group, claims regarding transfer of training are weak. In fact, parent reports following training bring the conclusions into question; on a questionnaire, not one parent agreed with the statement that Cogmed™ improved the child's language, and a third of the parents actually disagreed this statement.

In their meta-analysis, Melby-Lervag and Hulme (2013) found no evidence that working memory training results in immediate or delayed far-transfer effects in academic measures, including verbal ability and reading. They conclude that without the evidence of far-transfer effects, it would be "difficult to justify the use of working memory training programs . . . to the treatment of reading and language disorders" (p. 282). However, researchers are hopeful that far transfer effects are possible. Morrison and Chein (2011), who are critics of Cogmed™, have an "optimistic view of the potential for WM training to produce meaningful and generalizable gains. . . . but the stamp of scientific approval cannot yet be placed" (p 208) on any working memory intervention on the market, including Cogmed™. The purpose of this case study is to join this fascinating conversation by adding to the research on the effectiveness of working memory training and the far transfer effects of training to language skills.

III. METHODS

a. Participants

Two 10-year old males, OM and AS, were identified by the special education district coordinator to participate in this study. Informed, written assent from the children and consent from a parent were obtained before initiating the project. Participants were English-Spanish bilinguals, but they were in English-only classrooms for more than two years. There were no withdrawals from the study; however, only OM completed the study. Due to absences from school and scheduling conflicts, the intervention for AS was not implemented with fidelity. Cogmed™ recommends training five days a week for five consecutive weeks; AS completed 24 sessions over a fifteen-week period. During the initial five-week period, he completed only 16 sessions without a single week of five consecutive training days. Due to the inconsistent and incorrect implementation of the Cogmed™ intervention, the decision was made to exclude AS from the study.

OM has been diagnosed with specific learning disabilities (SLD) in the areas of basic reading skills, reading comprehension, written expression, oral expression, and listening comprehension. He has had an individualized education program (IEP) for the past three years. Hearing and vision screenings were passed by the participant within the past two years, and no other health concerns were reported.

Throughout the academic year that this research project took place, OM received one hour of reading intervention daily and 30 minutes of speech and language services weekly. The special education district coordinator reported that multiple language and reading intervention programs and strategies have been tried with limited success. OM has participated in the Lindamood-Bell Seeing Stars® decoding program, the Visualizing and Verbalizing® comprehension program, and Systems 44®, a foundational reading and phonics intervention technology program ("System 44", 2013). Due to the limited success with intervention programs focused on reading and phonics, the special education district coordinator wanted to try an intervention that specifically addressed deficits in working memory, an underlying skill required for growth in language skills (Gathercole & Baddeley, 1993).

b. Procedure

After securing assent from OM and consent from his mother, baseline measures were taken. The Clinical Evaluation of Language Fundamentals, 4th Edition (CELF-4), which is a norm-referenced tool for children ages 5-21 with good to excellent reliability and validity measures, was used for baseline and follow-up measures. Core Language, Receptive Language, Expressive Language, Language Memory, and Working Memory subtests were administered, audio recorded, and scored by the primary researcher. In addition, a speech language pathology graduate clinician who was an unfamiliar listener scored the *Recalling Sentences* and *Formulated Sentences* subtests to check for scorer reliability on the more subjective subtests (Semel, Wiig, & Secord, 2003). For the *Recalling Sentences* subtest, the primary researcher and graduate clinician had 100% agreement. For the *Formulated Sentences*, they had 86% agreement; the CELF-4 inter-scorer reliability for *Formulated Sentences* is 90% (p. 233). In addition to the CELF-4 scores, interviews with the teacher and participant were conducted at baseline and at the 7-month follow-up.

The Cogmed™ training began immediately after baseline measures were taken. Training consists of 25 sessions that should ideally be completed five days a week for five weeks. Only one training session should be completed per day, and each session should take between 30-45 minutes. The participant completed all 25 sessions over the course of six weeks. Three sessions were completed over the course of two days. Total training times were between 24 and 96 minutes; 44% (11/25) of the sessions exceeded the recommended maximum of 45 minutes. After the first week of excessive training times, the special education district coordinator contacted Cogmed™ to decrease the number of trials, and the total training times significantly reduced. The Cogmed™ training was implemented by the participant's special education instructor, a para-educator, or the primary researcher during school hours.

The Cogmed™ program is composed of twelve tasks, with the majority of tasks implicating visuospatial memory. For example, the Visual Data Link task presents a 4x4 grid of dots; a series of dots light up, and the participant must click on the dots in the same order. Other visuospatial working memory tasks include a rotating grid, a three dimensional box with dots, a rotating wheel with the dots, and a rotating cube with panels that light up. Cogmed™ training also includes two numbers reversed tasks, Input Module and Input Module with Lid; the first shows a keypad while the numbers are presented auditorily, and the second hides the numbers while they are presented auditorily (Figure 1).

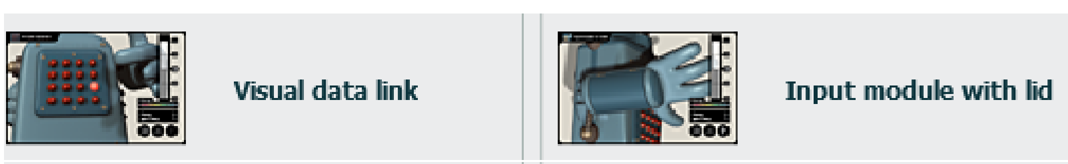


Figure 2: Visual data link and Input module with lid tasks from Cogmed.

The participant completed 15 trials of 8 working memory tasks each day. In addition, every five sessions, the participant completed an additional visuospatial working memory exercise and following directions exercise to compute the Cogmed™ Progress Indicator (discussed in detail below) to gauge the effects of training (Figure 2). In Cogmed™, the difficulty level of each trial adjusts based on performance to ensure a participant is always working at his maximum working memory capacity. At the end of training each day, the participant may play a racing game as a reward. In addition, external motivators are strongly encouraged by the Cogmed™ developers. OM received a reward for each five days of training that he completed and a larger reward when he completed the entire training.

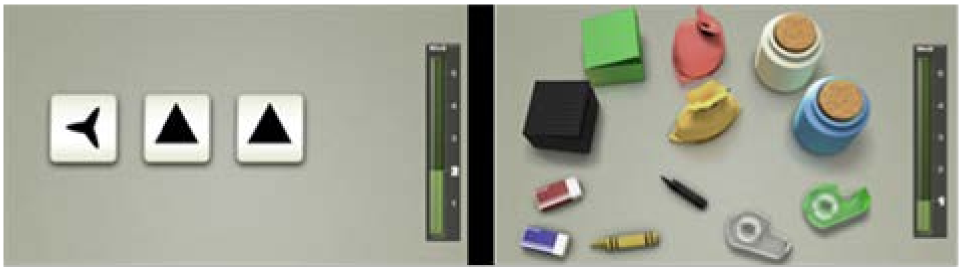


Figure 3: Cogmed™Progress Indicator tasks. *Working Memory* and *Following Instructions* tasks.

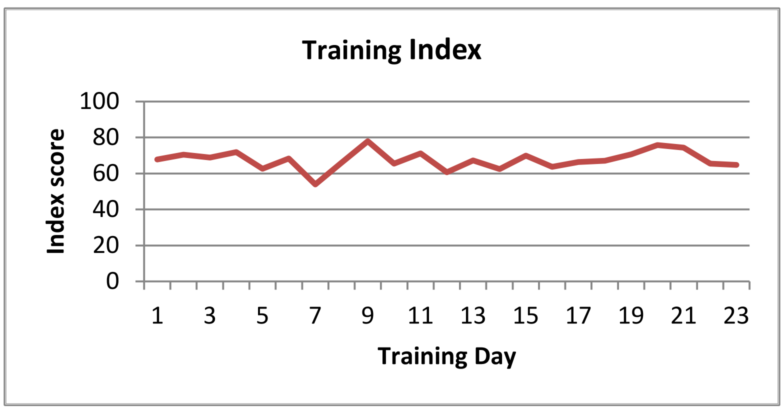
Performance on a sentence recall task was also measured during the intervention phase to gauge immediate effects of working memory training to an untrained language task. Research shows that sentence recall is a reliable clinical marker for individuals with language impairment and is associated with language skills (Alloway & Gathercole, 2005; Conti-Ramsden, Botting, & Faragher, 2001; Polišenská, 2011). In addition, there is a significant correlation between performance on sentence repetition and non-word repetition, a classic working memory task (Conti-Ramsden, Botting, & Faragher, 2001). Due to ease of implementation and the norm-referenced *Recalling Sentences* subtest on the CELF-4, which was used for baseline and follow-up measures, the sentence recall task was chosen as a the language measure during the intervention. The primary investigator developed four lists of ten sentences which matched the structure of the sentences used in the CELF-4 subtest; stimuli included simple sentences, compound sentences, and sentences with embedded clauses. The primary investigator or the participant's special education instructor orally administered the sentence repetition task five times during the intervention phase; all administrations of the task were audio-recorded and the CELF-4 procedures were used to score the tasks.

IV. RESULTS

a. Performance on Cogmed™ Working Memory tasks

Cogmed™ computes a Training Index and a Progress Indicator (CPI) scores. The Training Index is a measure of improvements on three trained tasks – the Visual Data link, Input Module with open lid, and Input Module with closed lid (see Figure 1 and Appendix 1). The Start Index is the average of the three best trials on days 2 and 3, and the Max Index is the mean of the three best trials on the two best training days during the entire intervention. For children age 7-17 (n=6080), the average Start Index is 73, and the average Max Index is 100 (O'Neal, 2012). OM had a Start Index of 68 and a Max Index of 79. Improvement is measured by the difference between the Start Index and the Max Index. For children age 7-17, the average index improvement is 27 (SD=13). OM had an index improvement of 11, which is based off his best performance that occurred on day 11 of training (Table 1).

Table 1: OM's daily performance on training tasks. Computed by the online Cogmed™ training tool.



The Cogmed™ Progress Indicator (CPI), which is used to gauge the effects of training on two untrained tasks, appears on training days 1, 2, 10, 15, 20, and 25. There are three tasks – a visuospatial working memory task, a following instructions task, and a simple arithmetic timed-challenge (see Figure 2). The first two tasks are considered measures of near transfer, and the math task is considered one of far transfer (Nutley, n.d). Cogmed™ eliminates the arithmetic task if the user performs below chance level during the first two sessions, which was the case for OM. CPI scores are calculated by taking the top success level (e.g. the number of directions the participant follows correctly) – (the number of misses at the top level x .03) – (the number of misses at other levels x .015). The CPI is reported as a percentage, and the baseline, which is calculated from the initial administration of the tasks, is considered 0%; all future CPI measures are compared to the baseline as percent improvement. OM's baseline measure for the CPI *Working Memory* task was 2.25, and on day 20, his CPI score was 3.55; thus, his improvement on the CPI *Working Memory* task was 58%. OM's baseline measure for the CPI *Following Instructions* task was 1.4, and on day 25, his CPI score was 2.4; thus, his improvement on the CPI *Following Instructions* task was 71% (Table 2). For comparison, in a pilot study conducted by Cogmed™, users age 10-13 (n=73), the average improvement was 19% on the CPI *Working Memory* task and 25% on the *Following Instructions* task (Nutley, n.d.).

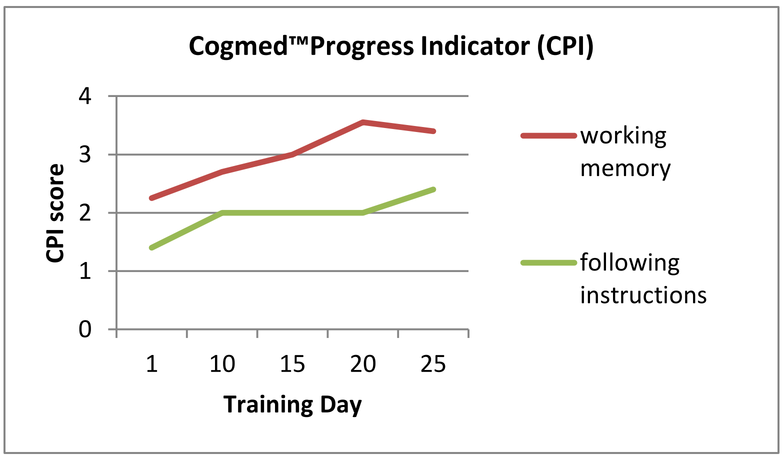


Table 2: OM's performance on the two Cogmed™ Progress Indicator tasks. The CPI score is computed by the Cogmed™ online training tool.

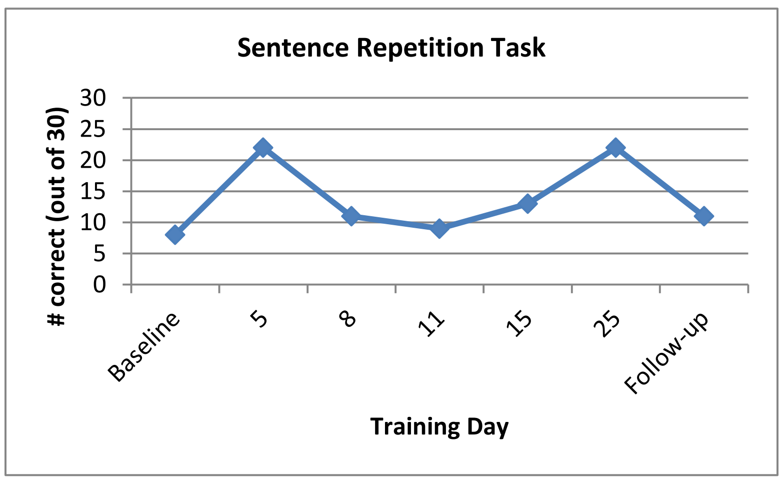
b. Performance on expressive and receptive language assessments

At the 7-month follow-up, CELF-4 standard scores were relatively unchanged from baseline to follow-up; OM remained at or below the first percentile for all index scores. Interestingly, on the *Concepts & Following Directions* subtest, which is similar to the Cogmed™ Progress Indicator *Following Instructions* task, OM had a scaled score of 3 at baseline and at 7-month follow-up. In contrast to the Cogmed™ task, the CELF-4 scores reflect no improvement in his ability to following directions after participating in training. Baseline and 7-month follow-up results from the CELF-4 are found in Table 3.

Table 3: CELF-4 results	Baseline measures		7-month follow-up measures	
	Standard Score	Percentile rank	Standard Score	Percentile rank
Core Language	54	0.1	54	0.1
Receptive language	64	1	64	1
• Concepts & Following Directions	Scaled score: 3	NA	Scaled score: 3	NA
Expressive language	55	0.1	57	0.2
• Recalling sentences	Scaled score: 2	NA	Scaled score: 2	NA
Language memory	54	0.1	52	0.1
Working Memory	60	0.4	54	0.1

Performance on the sentence repetition task was inconsistent. For baseline and follow-up, items 6-15 from the CELF-4 subtest were used. The sentences created by the primary researcher were administered during intervention; sentence list #1 was used on day 5; list #4 on day 8; list #3 on days 11 and 15; and list #2 on day 25 (see appendix). Each sentence was worth 3 point, with a total of 30 possible points. Results from this task are found in Table 4.

Table 4: Results from the sentence repetition task.



c. Teacher and participant interviews

Interviews with OM's teacher and OM were conducted throughout the course of this study. When this project was initiated, OM's teacher reported that his attention span was minimal, and he required significant prompting to stay on task. During the intervention, his teacher reported that he felt special for being able to use the computer each day and that his confidence noticeably increased. At the 7-month follow-up, she reported that she observed an increase in self-confidence during Cogmed™

implementation and immediately following it, but “it did not last for long”. Further, she reported that she worked with him during the summer, which was five months post-intervention, and “he really struggled with expressive language skills and getting started on tasks without direct assistance” (K. McCall, personal communication, Sept 22, 2013).

OM was cooperative throughout the project. At the start of intervention, OM was excited to take part in computer training. Although he felt special for taking part in the intervention, as was reported by his teacher, he did become frustrated with it on occasion. In one session, he stated “I wish I could go back to specials right now” and when we finished, he stated “At least we are done.” However, he generally enjoyed looking at his data for completed activities on the Cogmed™ website and took pride in those he did well on (OM, personal communication, Jan-March, 2013).

V. DISCUSSION

This case study considered two questions. First, does Cogmed™ Working Memory training increase working memory capacity for an individual with SLD? Second, do the presumed gains in working memory capacity generalize to gains in expressive and receptive language skills? If indeed no gains on trained working memory task are found for OM, the second question becomes a theoretical discussion.

Based on the results from the Cogmed™ training, the CELF-4 Working Memory subtests, and teacher reports, it is inconclusive as to whether gains in OM’s working memory capacity were made following Cogmed™ training. Although OM’s Training Index improvement score increased by 11 points, this is more than one standard deviation below the average increase reported by Cogmed™.Further, this increase is based off of his best performance, which occurred on day 11 of training. When looking at his daily performance (see Figure 3), there is no upward trend of improvement noted. However, OM increased his maximum span on every individual task, and an upward trend of performance is noted (Appendix 1). In addition, his performance on Cogmed™ Progress Indicator tasks improved over the course of training. This may be explained by the fact that these tasks, which are administered every five days, are actually trained tasks. However, this then begs the question as to why he didn't show a greater increase in the Training Index measure. Another possibility is that OM's interest was piqued during these tasks as the visual displays for these drastically differ from the other trained tasks presented. Based purely on the data computed by Cogmed™, it can be concluded that OM improved on trained simple and complex span measures, which is in line with the research. However, when including the CELF-4 measures, it becomes less clear. On the CELF-4 Working Memory Index, OM's core was stagnant, remaining below the 1st percentile at baseline and follow-up. Based on these mixed results, it is not possible to conclude that OM's working memory capacity improved after participating in Cogmed™. Rather, it lends weight to the critics' statements regarding the benefits of Cogmed™ to trained tasks only.

Given the equivocal evidence for improvement of OM's working memory capacity, the question of far transfer to language skills is moot. However, for discussion sake, let us assume that improvement to working memory was made based solely on the Cogmed™ outcomes. First, based on his inconsistent performance on the sentence repetition task, no conclusions can be drawn on the effects of training on phonological short term memory or language skills during or after intervention. Second, OM's CELF-4 Language Index scores were nearly identical to baseline at 7-month follow-up; similar to the Working Memory Index, he remained at or below the 1st percentile on all measures. Also, his teacher reported difficulty with initiation and expressive language five months after intervention. Based on these results, no indication of changes to his language functioning exist.

Before discussing the larger implications that may be drawn from this case study, weaknesses in the design and implementation must be acknowledged. First, as a case study, it has a low level of evidence. Results cannot be generalized; it is simply a descriptive record of a single case. More specific to the design of this project, there were problems with data collection. Only one baseline measure was taken and no measures on untrained tasks were taken immediately after the intervention was completed.

Also, the sentence repetition task was implemented sporadically throughout the intervention; it was intended to be implemented daily, but the teachers did not have the time to do this.

Most important, the Cogmed™ intervention was not implemented with fidelity. The Cogmed™ Coaching Manual states that the prerequisites for training are a highly motivated user, ideal training conditions, and an involved Cogmed™ Coach. The coach is expected to train the teachers or para-professionals who implement the intervention, to oversee the data for appropriate effort by the user, and to conduct weekly calls with the child to discuss progress, praise, and motivate him. None of these requirements were adequately met. Limitations of time and staff support were the biggest obstacles. Teachers and para-educators did not receive adequate training on how to implement the intervention. Further, although the concept of working memory training and details of Cogmed™ were explained to OM and his mother before beginning the project, more time should have been spent discussing the theory behind the intervention, setting up goals and expectations, and getting buy-in from OM. His motivation quickly fizzled as the training became more laborious.

The intensive nature of Cogmed™ makes it extremely challenging, if not inappropriate, to implement during a school day. For five weeks, OM was pulled from class for up to an hour. On one visit to the school, his math teacher inquired about the duration of the intervention, reporting that OM was missing large portions of math class and it was hurting his progress. In addition, limited time also resulted in a lack of training of the individuals who implemented Cogmed™ and a lack of involvement by the Cogmed™ Coach. To implement Cogmed™ with absolute fidelity to the specifications outlined by the developers is not possible at the individual level in a typical school setting.

This important lesson was taken into account when planning future Cogmed™ administrations. After this research project was concluded, the special education district coordinator reported that Cogmed™ was implemented on two more students. This time, the intervention was after school and overseen by the parents. More support was provided by the district coordinator, including providing proper training to the parents regarding implementation and ensuring buy-in from the students. The training time was on par with the publisher's guidelines from the start and the external motivators were increased. The results on trained tasks reflected the improved administration; both students that completed Cogmed™ after this research project concluded had a Training Index improvement above the average reported by Cogmed™ for children ages 7-17. However, even though working memory capacity may be improved through training, the benefits may not be worth it when considering the time and financial investments required. Kronenberger et al (2011) included a parent survey that highlights the concern of time and effort; 78% of participants parents reported that the program took a significant amount of effort from the children, especially during the final week. In addition, only about half of the parents reported that they were happy with the results.

Another inherent weakness of this study was our hypothesis of generalization to language skills. The district coordinator concluded that "we shot too far" with expectations of transfer effects to language skills, and this sentiment is supported by the current research. If there are no transfer effects of training, what is the practical benefit to participating in such an intensive program? For the two students who completed the training after this research project ended, even with the more reliable implementation and higher gains on trained tasks, the students failed to improve on the Cogmed™ Progress Indicator tasks. One student improved 0% on the working memory task, while the other improved a mere 12%; comparably, OM showed a 58% improvement on this task. Further, both of these students decreased performance on the math task by more than 60%! These results clearly raise questions about Cogmed's claims of near and far transfer effects. Until there is clear evidence of significant far-transfer effects to real-world skills, I would argue that intensive working memory training may not be worth the time and effort.

Some researchers suggest that instead of training working memory, a more practical approach to assist children with low working memory capacity may be to teach them strategies to reduce attentional demands or access information stored in long-term memory (Carretti et al, 2009; Holmes et al, 2010; Alloway & Gathercole, 2005). For example, teach a child to focus on one thing at a time and remove distractions in his environment, reducing the cognitive load; teach him to sketch out a narrative before writing if he has strong visuospatial skills; or provide technological aids, such as a scheduler or word prediction program (Alloway, 2006). In fact, many children will develop their own strategies. AS, the child who did not complete the training, began to successfully use rehearsal strategies during the second week of Cogmed™ training. Although Cogmed™ does not support the use of strategies during training, they are effective compensatory measures that can be applied to real-life situations; parents and educators should help children become aware of the strategies they might already be using and encourage them to use them in more situations.

Based on the results of this case study and the current research, it appears that Cogmed™ may benefit working memory capacity immediately following training; however, I would argue that the implementation requirements cannot be met within a typical elementary school setting. Further, even if the ideal training conditions are feasible and gains in trained tasks are made, due to the lack of evidence of far transfer effects and a clear understanding of how working memory subsystems interact, I would argue that Cogmed™ is not worth the time and effort at this time.

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APPENDIX: Cogmed™daily exercises

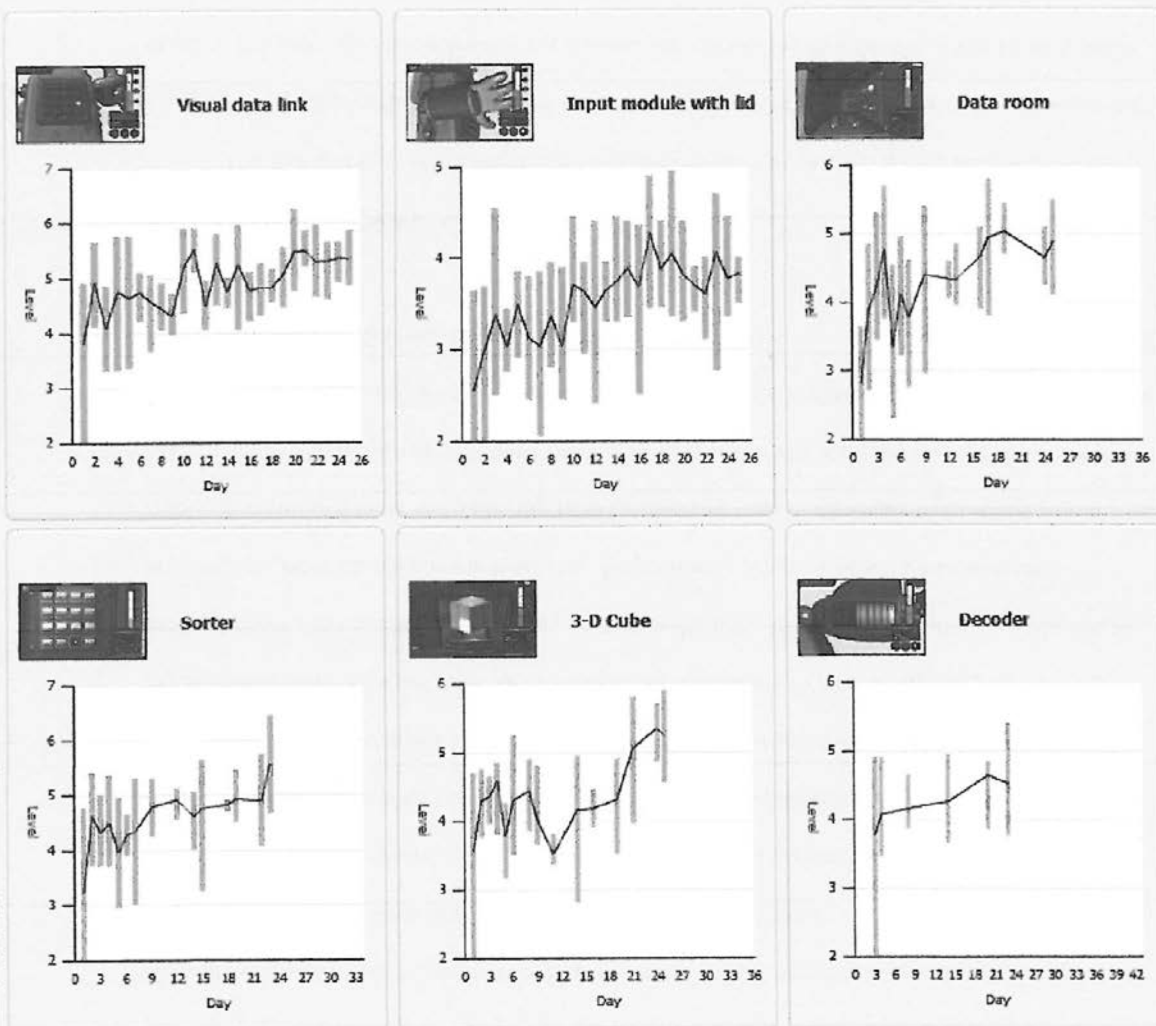
Exercise Graphs

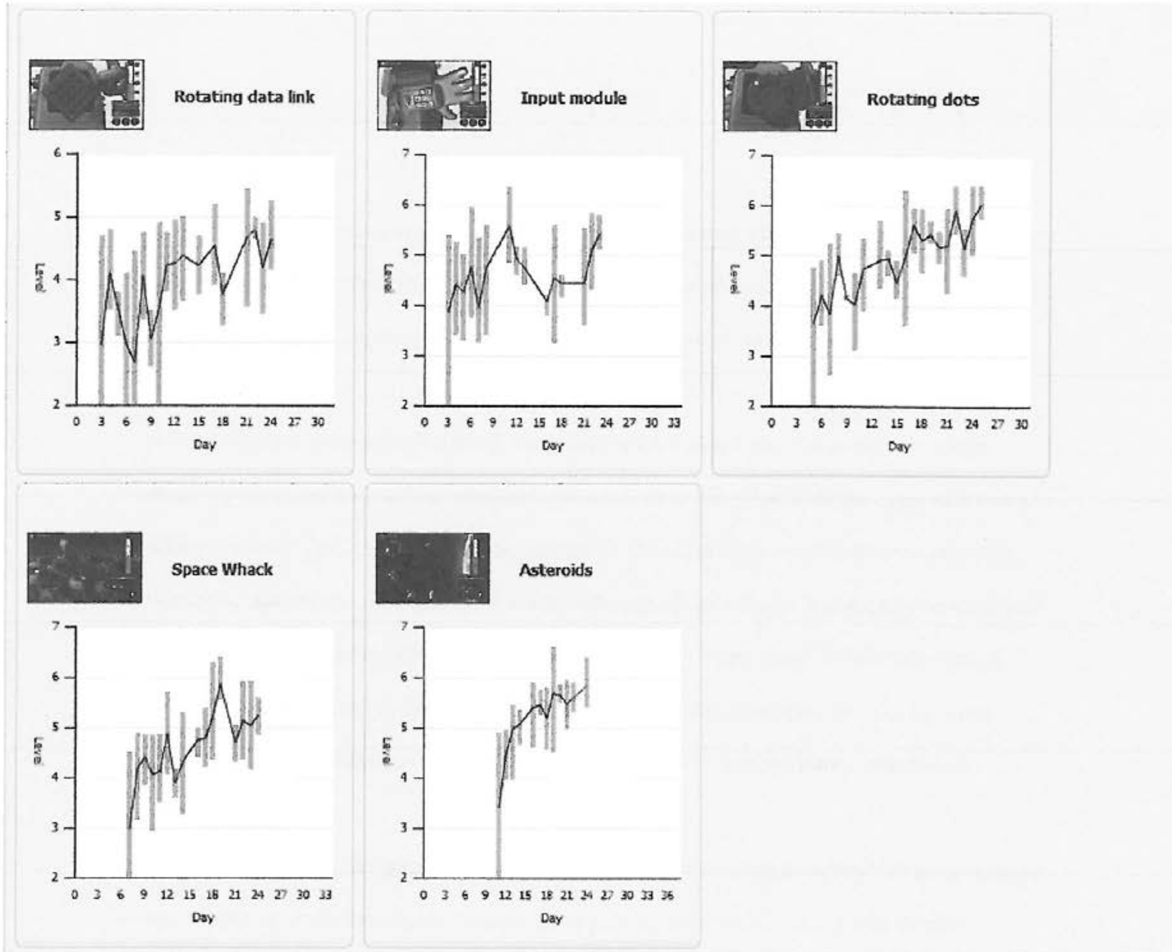
The graphs below show a summary of your development in various exercises.

The black line shows your average level.

The grey bars display the lowest and highest level on each exercise for each day.

User ID: u94180




Rotating data link
Input module
Rotating dots
Space Whack
Asteroids
Level
Day

APPENDIX: Sentence repetition task, stimuli list

List 1

1. The small, white kitten hid under the bed.
2. Did you remember to do your homework?
3. The toy was not put away by the girl.
4. Didn't the teacher give them homework?
5. Does anyone know where the principal is?
6. The children played outside even though it was raining.
7. The milk was spilled by the cat.
8. My brother is the soccer player who scored the goal.
9. The girl drew a picture of the mountains.
10. If the snow doesn't stop, school will be canceled tomorrow.

List 2

1. The boy fell on the ice.
2. Are the students going outside for recess?
3. The big, black cat hissed at me.
4. The dogs weren't allowed in the house.
5. Did your friend give you a present for your birthday?
6. Does anyone have a pencil that I can borrow?
7. The window was opened by the teacher.
8. The boy who is standing near the door is my best friend
9. As soon as school was finished, the girl ran home.
10. The man who drives the school bus is my father.

List 3

1. The boys caught fish in the lake.
2. Didn't those girls win the soccer tournament?
3. My book was taken from my desk at school.
4. The young, brown puppy slept in my bed.
5. We couldn't go to the park because it was getting dark.
6. A dollar was found by the girl on the playground.
7. My friend rode his bike to school even though it was cold.
8. The kindergartner cannot walk to school by himself.
9. The boy bought a book for his friend who likes short stories.
10. I must return my library book and finish my homework.

List 4

1. The tractor was driven by the farmer.
2. The girl cut herself while helping her mom cook.
3. The dog was not taken on a walk by the boy.
4. Does anyone know what the math homework is?
5. The door was not closed by the girl when she left the house.
6. The girl didn't come to school because she was sick.
7. The teacher could not find the assignments that the students turned in yesterday.
8. After the girl finished her lunch, she went outside to play.
9. The computer was given to me by my parents.
10. The class that reads the most books will win a prize.