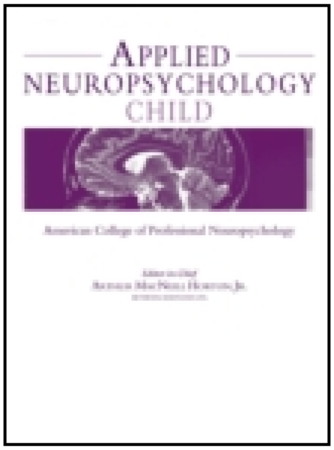

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Cogmed WM Training: Reviewing the Reviews

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Does Cogmed working-memory training (CWMT) work? Independent groups of reviewers have come to what appears to be starkly different conclusions to this question, causing somewhat of a debate within scientific and popular media. Here, various studies, meta-analyses, and reviews of the Cogmed research literature will be considered to provide an overview of our present understanding regarding the effects of CWMT. These will particularly be considered in light of two recent critical reviews published by Melby-Lervåg and Hulme (2013) and Shipstead, Hicks, and Engle (2012) and their arguments and conclusions assessed against current available evidence. Importantly we describe how the conclusions drawn by Melby-Lervåg and Hulme appear to contradict their own findings. In fact, the results from their meta-analysis show highly significant effects of working-memory (WM) training on improving visuospatial WM and verbal WM (both $ps < .001$). In addition, analyses of long-term follow-ups show that effects on visuospatial WM remain significant over time (again at $p < .001$). Thus, the analyses show that WM is indeed improved using WM training, and the highest effect sizes are achieved using CWMT (compared with other training programs). We also conclude that there is current evidence from several studies using different types of outcome measures that shows attention can be improved following CWMT. In a little more than a decade, there is evidence that suggests that Cogmed has a significant impact upon visual-spatial and verbal WM, and these effects generalize to improved sustained attention up to 6 months. We discuss the evidence for improvements in academic abilities and conclude that although some promising studies are pointing to benefits gained from CWMT, more controlled studies are needed before we can make strong and specific claims on this topic. In conclusion, we find that there is a consensus in showing that WM capacity and attention is improved following CWMT. Due to the importance of WM and attention in everyday functioning, this is, on its own, of great potential value.

Key words: *ADHD, attention, Cogmed, working memory*

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BACKGROUND

Working memory (WM) is a core cognitive function known to relate to a number of other cognitive functions and skills, such as reasoning, attention, reading, and mathematical abilities (Dumontheil & Klingberg, 2012; Gathercole, Pickering, Knight, & Stegmann, 2004; Geary, Hoard, Byrd-Craven, & DeSoto, 2004; Swanson, Ashbaker, & Lee, 1996; Swanson, Sáez, & Gerber, 2006). The capacity of an individual's WM is limited, as apparent by the constraints on the amount of information one can keep in mind at a single point in time. Whereas this capacity limit has traditionally been considered to be fixed for a particular individual, the latest decade has given rise to a wave of research studies that strongly question this old view. In the forefront of this field have been the studies carried out by Klingberg and his colleagues, showing that WM capacity can be increased using intensive training with computerized WM tasks (Klingberg, 2010; Klingberg et al., 2005; Klingberg, Forssberg, & Westerberg, 2002). This WM training program is now distributed by Cogmed (Pearson), and the following review will focus on the claims that have been made for and against the program and will summarize the evidence that exists to back it up. In particular, we will address the points of concern brought forward in two recent reviews by Shipstead, Hicks, and Engle (2012) and Melby-Lervåg and Hulme (2013) regarding effects on WM capacity, attention, reasoning, and academic abilities.

THEORETICAL REASONING BEHIND WM TRAINING

In the article by Melby-Lervåg and Hulme (2013), the authors claim that WM training, and in particular Cogmed WM training (CWMT), does not seem to rest on a good theoretical account for underlying mechanisms, but: "Rather, these programs seem to be based on what might be seen as a fairly naïve 'physical-energetic' model such that repeatedly 'loading' a limited cognitive resource will lead to it increasing in capacity, perhaps somewhat analogously to strengthening a muscle by repeated use" (Melby-Lervåg & Hulme, 2013, p. 270). This claim is surprising considering the large research literature that exists regarding neural plasticity and the mechanisms with which the brain adapts to demands from the environment. In the very first study published by Klingberg and colleagues on the WM training program that is now CWMT (Klingberg et al., 2002), design of the training program was described to be inspired by previous training studies that had been successful in enhancing sensory discrimination and demonstrated cortical plasticity in sensory and motor cortices. From these, Klingberg and colleagues (2010) adapted two key principles: the intensity and duration of training. Numerous studies had already established that WM performance could be improved by neurochemical manipulation, as is, for example, evident from observations of improved WM following intake of stimulant medication (Mehta, Goodyer, & Sahakian, 2004; Solanto, 1998). In addition, support for the idea that WM could be improved using nonpharmacological methods was found in a study in which macaque monkeys received training on a WM task for several weeks, and as a result, changes in neural activity in the principal sulcus and the prefrontal cortex were observed (Rainer & Miller, 2000). Thus, the Klingberg et al. (2002) study was pioneering in introducing a new approach to cognitive enhancement in humans, but the idea that the brain is plastic was not new, or very controversial for that matter. Possible mechanisms underlying the effects from WM training on a neural level have been discussed further in numerous papers; for example, Klingberg has argued that simple Hebbian learning can explain how repeated activation (e.g., through training) would improve WM capacity by strengthening the synaptic connectivity between neurons in the WM-related network (Klingberg, 2011). With all the research showing the brain to be plastic, a rather more surprising suggestion would be to assume that the network underlying WM is somehow special in that it would not be affected by the demands that are placed upon it by the environment. The work by Klingberg and colleagues was groundbreaking in taking knowledge from the field of neuroscience and applying it in creating a neuropsychological training tool, thereby showing that WM can be improved using a nonpharmacological intervention and that these improvements can spread to mitigate inattentive symptoms. Built into the model of CWMT are dual notions of adaptation and the active management of motivation. These aspects have theoretical components but are also complicated and play a critical role, especially in children with attention-deficit hyperactivity disorder (ADHD). As noted by Diamond and Lee (2011) in their review of tasks that improve executive functioning in children ages 4 to 12, adaptively structured tasks are a critical component for tasks that result in improvement. The theory behind adaptation is that as a trainee completes Cogmed, if he (or she) makes an error, then the task will get slightly easier in either presentation sequence or number of items to be recalled. The inverse is also true. If a person in training gets a correct answer, the next item will be slightly more difficult, so an algorithm will adjust the level of difficulty of items presented.

IS CWMT EFFECTIVE IN IMPROVING WM CAPACITY?

In 2011, Morrison and Chein published a review aptly titled "Does Working Memory Training Work? The Promise and Challenges of Enhancing Cognition by Training Working Memory." They came to the following conclusion regarding "core WM training" (Cogmed and other such programs that present a number of WM training tasks to develop WM capacity): "... results of individual studies encourage optimism regarding the value of WM training as a tool for general cognitive enhancement" (Morrison & Chein, 2011, p. 46). Similarly, Diamond and Lee (2011) specifically described Cogmed as both the most researched approach of computerized training and "one repeatedly found to be successful" and concluded that Cogmed improves WM and executive functions. Yet other reviewers, including Melby-Lervåg and Hulme (2013) and Shipstead et al. (2012), came to what seem, on the surface, to be starkly different conclusions. Melby-Lervåg and Hulme argued that there is not convincing evidence of generalization of WM training when considering the field of WM training as a whole. Similarly, Shipstead et al. came to a strongly critical conclusion in which they challenged what they consider to be specific claims made by Cogmed in particular. It is important to review why they came to these conclusions.

First, in the meta-analysis by Melby-Lervåg and Hulme (2013), 30 different WM training studies were included, 8 of which were studies using Cogmed. The authors provided some generally accepted observations with regard to WM training: WM is important for everyday function; WM is impaired in diverse clinical populations; and there is a need for more randomized, placebo-controlled studies of WM training. Close scrutiny of their other conclusions reveals that they did acknowledge that WM training does have some effects. Including 18 different effect sizes from studies using different WM training programs, Melby-Lervåg and Hulme's analysis revealed robust effect sizes across studies showing improvements on visuospatial WM tasks, and together, these results are highly significant ($p < .001$). The results also showed that the type of training performed is important because the intervention program is the only significant moderator of training effects and larger improvements are observed for CWMT compared with the other training programs. Similar results were found for improvements on verbal WM, with large effect sizes that are overall highly significant ($p < .001$). Again, numerically larger effect sizes were observed from studies using CWMT compared with other training programs, although in this case, this did not reach significance. The authors concluded: "WM training programs produced reliable short-term improvements in WM skills" (Melby-Lervåg & Hulme, 2013, p. 270). This point would appear largely in agreement with conclusions reached by Morrison and Chein (2011).

Much of the critique provided by Shipstead et al. (2012) is based on a theoretical discussion of the distinction between single and complex span tasks, with the authors arguing that only the latter are valid measures of WM. This is based on differences between the two

TABLE 1
Studies Showing Generalized Effects of Cogmed WM Training

Study	*Study Design*	*Sample*	*Measures*
Klingberg et al., 2005	Randomized, controlled trial, double-blinded	Children with ADHD	*Diagnostic and Statistical Manual of Mental Disorders*-Fourth Edition Parent Rating, Conner's Parent Rating Scale
Brehmer et al., 2012	Randomized, controlled trial, double-blinded	Typical adults	Paced Auditory Serial Addition Task (PASAT)
Green et al., 2012	Randomized, controlled trial, double-blinded	Children with ADHD	Restricted Academic Situations Task
Beck et al., 2010	Randomized, waitlist control	Children with ADHD	Conner's Parent Rating Scale, BRIEF Parent & Teacher Form
Mezzacappa & Buckner, 2010	Pilot	Children with ADHD	Teacher ADHD-RS-IV
Gibson et al., 2011	Randomized, active control	Children with ADHD	DuPaul ADHD Scale-Teacher and Parent
Westerberg et al., 2007	Randomized, passive control	Adults who have had a stroke	PASAT & RUFF 2&7
Lundqvist et al., 2010	Randomized, waitlist control	Adults with ABI	PASAT
Thorell et al., 2009	Randomized, active control, double-blinded	Typical preschoolers	Auditory CPT

ABI = acquired brain injury; CPT = Continuous Performance Test; RUFF 2&7 = The Ruff 2 and 7 Selective Attention Test (Ruff et al., 1992).

TABLE 2
Cogmed Studies and the Tests Used to Establish an Improvement in WM

Study (Year)	*Sample (Years Old [YO])*	*Test*
Bergman Nutley et al., 2011	Typical 4 YO	Odd One Out (AWMA)
	Typical 4 YO, half dose	Odd One Out (AWMA)
Thorell et al., 2009	Typical 4–5 YO	Span board (back +front)
	Typical 4–5 YO	Span board (back +front)
Klingberg et al., 2005	ADHD 7–12 YO	Span board (back +front)
Klingberg et al., 2002	ADHD 7–15 YO	Span board (back +front)
Kronenberger et al., 2011	Deaf (w/CI) 7–15 YO	Span board (back)
Holmes et al., 2010	ADHD 8–11 YO	Mr. X (AWMA)
Mezzacappa & Buckner, 2010	ADHD 8–10.5 YO	Finger Windows (WRAML)
Dahlin, 2011	Special Ed needs 9–12 YO	Span board (back)
Holmes et al., 2009	Poor WM 10 YO	Composite score (AWMA)
Roughan & Hadwin, 2011	SEBD ≈ 13 YO	Composite score (Span board & Digit Span)
Løhaugen et al., 2011	Preterm (ELBW) 14–15 YO	Span board (back)
	Typical 14–15 YO	Span board (back)
Brehmer et al., 2012	Typical 20–30 YO	Span board (back)
	Typical (aging) 60–70 YO	Span board (back)
McNab et al., 2009	Typical 20–28 YO	Span board (back)
Lundqvist et al., 2010	ABI 20–65 YO	Span board (back)
Westerberg et al., 2007	Stoke 34–65 YO	Span board (back + front)
Brehmer et al., 2012	Typical (aging) 60–70 YO	Span board (back)

CI = cochlear implant; SEBD = Severe Emotional Behavioral Disorder; ELBW = Extremely Low Birth Weight, i.e., less than 1000 grams; ABI = acquired brain injury; AWMA = Automated Working Memory Assessment Test; WRAML = Wide Range Assessment of Memory & Learning.

types of tasks and how these relate to other cognitive functions, in particular reasoning ability. Although this distinction seems to be of importance for verbal tasks, the same cannot be said for visuospatial WM tasks (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002; Unsworth & Engle, 2005). Furthermore, Shipstead et al. failed to acknowledge that improvements after CWMT have been shown on both single and complex WM tasks (see Table 2, which provides a list of the outcome measures used to measure WM capacity in various studies using CWMT). Thus, this distinction seems to bare little relevance outside of a theoretical discussion. The fact that training on mainly single span tasks has been shown to transfer to more complex WM tasks of different designs speaks against any practical relevance of this issue.

Long-Term Effects on WM Following CWMT

As stated, Melby-Lervåg and Hulme (2013, p. 281) concluded that "WM training programs produced reliable short-term improvements in WM skills"; however, they did not clearly define "short-term." Several studies of Cogmed with a follow-up duration from 3 months to 6 months have shown that effects persist. More importantly, the meta-analysis underlying these conclusions to be drawn by Melby-Lervåg and Hulme did, in fact, show significant sustained effects on visuospatial WM with a moderate effect size and high significance at $p < .001$. Despite these results, Melby-Lervåg and Hulme appeared reluctant to trust their own analyses and offered the alternative explanation that because results from one study showed improvements at follow-up measures but did not show immediate WM improvements, these findings are not reliable. The authors argued that such a pattern of findings is unlikely to reflect a true improvement because the effect of training is unlikely to increase in size after training has been completed. We would argue that this is a simplistic interpretation, and one can reasonably argue the opposite. Based on our knowledge that WM is highly taxed in everyday situations, especially in school settings, one can envision how following WM training, improved WM capacity would allow children to participate in educational activities to a more advanced level than before the training. This new cognitive engagement would allow for more frequent natural challenges of their WM capacity, thus leading to a continuation of the WM expansion even after WM training has been completed. Thus, WM training can be seen as a catalyst of WM improvements. The impact of the change in how cognitive capacities can be utilized and maximized in everyday life might be particularly apparent in a sample of severely impaired children such as in the study provoking this skepticism (Van der Molen, Van Luit, Van der Molen, Klugkist, & Jongmans, 2010). So far, these must be viewed as speculations, but it highlights the point that any strong conclusions drawn at this point, arguing either for or against the findings, would be premature. We note that there is still a need for more studies with extended follow-up for us to gain a fuller understanding of what factors predict long-term effects and whether repeated training should be recommended. Also, it might be useful to gain perspective by comparing these standards to an example of a clinical subpopulation that commonly has WM deficits: children with ADHD. Consider the present status of treatment for this subgroup. Note that the effects of the standard treatment of ADHD, stimulant medications, last a few hours, maybe 12 hr at most in terms of direct impact. In this context, 6 months of effects is rather noteworthy, an effect that lasts approximately 360 times as long as the standard treatment. This should be viewed in the context of a number of parents who find stimulant treatment of ADHD as disconcerting for their children for a number of reasons. Additionally, there are no known adverse side effects from Cogmed training.

To summarize, Cogmed has indeed demonstrated reliable immediate improvements in WM capacity in samples of typically developing children (Bergman Nutley et al., 2011; Holmes & Gathercole, 2013; Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009) and adults (Brehmer, Westerberg, & Backman, 2012; McNab et al., 2009; Olesen, Westerberg, & Klingberg, 2004), children with ADHD (Beck, Hanson, Puffenberger, Benninger, & Benninger, 2010; Green et al., 2012; Holmes et al., 2010; Klingberg et al., 2002, 2005; Mezzacappa & Buckner, 2010), children with poor WM (Holmes, Gathercole, & Dunning, 2009), children with cochlear implants (Kronenberger, Pisoni, Henning, Colson, & Hazzard, 2011), children born at very low birth weight (Grunewaldt, Lohaugen, Austeng, Brubakk, & Skranes, 2013), adolescents born at extremely low birth weight (Lohaugen et al., 2011), pediatric cancer survivors (Hardy, Willard, Allen, & Bonner, 2013), and brain-injured adults (Westerberg et al., 2007). Further, Cogmed studies have shown that both visuospatial and verbal WM improvements have been sustained at follow-up at 3 months (Klingberg et al., 2005) and 6 months (Dahlin, 2011; Holmes et al., 2009, 2010).

DOES CWMT LEAD TO IMPROVEMENTS IN OTHER COGNITIVE FUNCTIONS (I.E., DOES IT TRANSFER)?

Melby-Lervåg and Hulme (2013) concluded that "...there was no convincing evidence of the generalization of WM training to other skills (nonverbal and verbal ability, inhibitory processes in attention, word decoding, and arithmetic)" (p. 270). Because similar conclusions were drawn in the review by Shipstead et al. (2012) in these areas of transfer, we will now review these topics individually.

Attention

Although Shipstead and colleagues (2012) acknowledged existing evidence showing improvements in objective measures of "attentional stamina" following CWMT, the authors argue that the Stroop task would be a better outcome measure for attention. It seems surprising that both reviews discussed here focus on the Stroop task because this is usually not considered a measure of attention primarily, and in particular not a measure of sustained attention, which is the kind of attention that is most closely linked to WM. Rather, the Stroop task is considered to measure focused or selective attention, the ability to shift and to inhibit responding (Baron, 2004). It is worth noting that selective attention has not been an area in which Cogmed has made any specific claims. Yet, the reviewers chose to focus on this measure rather than more ecologically valid ratings of attention in everyday functioning. Still, close reading of the results from Melby-Lervåg and Hulme's (2013) meta-analysis shows that effects on the Stroop task have an overall small-to-moderate effect size that is significant at $p < .01$. Thus, it makes their conclusion in the abstract appear very puzzling to say the least: "...there was no convincing evidence of the generalization of working memory training to other skills (nonverbal and verbal ability, inhibitory processes in attention, word decoding, and arithmetic)" (Melby-Lervåg & Hulme, 2013, p. 270). The authors mention the small number of effect sizes included ($n = 10$) as a reason to doubt the results. However, with this same reasoning, the majority of their analyses of generalization must be judged as underpowered, and therefore, their negative findings should also be interpreted cautiously (verbal ability, $n = 8$; word decoding, $n = 7$; and arithmetic, $n = 7$). Other design and methodological concerns will be discussed later.

Similarly and intriguingly, Shipstead et al. (2012) appear to concede that Cogmed improves sustained attention, but they appear to dispute the significance of that. They seem to make a begrudging concession and then suggest that essentially any other training task would have had the same effects: "There is evidence that Cogmed training will improve 'attentional stamina' (as claimed in the opening quotes). Whether this is related to increased WM capacity, or is a product of completing a month of training on an attention-demanding task (i.e., any training task will do) is unclear" (Shipstead et al., 2012, p. 189). However, such effects would be controlled for by including an active control group as many of the studies that have active control groups arguably are training on a task that is similar to many commonly used tests of sustained attention (involving continuously responding to a single stimulus). This distinction shows that the WM load of the tasks makes a significant difference. Shipstead et al. follow this contention with a somewhat tangential concern again to seemingly nullify the concession: "Thus, whereas this training program may increase the time that a person can apply attention to a specific task, there is no reasonable evidence to suggest it will improve attention as it relates to selecting appropriate information or controlling impulses" (p. 189). This appears to suggest the notion that "selective attention" would be a more worthy target of intervention and effect than would "sustained attention." However, neither research nor reason supports this claim. Children whose minds wander in class and who have difficulty listening or watching for extended periods exhibit difficulties with sustained attention. Parents and teachers of such children know that their rather limited ability to keep their attention on a specific task creates substantial problems for daily living and academic achievement. For example, sustained attention has been found to be a predictor of academic readiness among preschoolers (Edley & Knopf, 1987). Steinmayr and colleagues found that among 11th- and 12th-grade students ($n = 231$) in Germany, sustained attention was critical for this age group's academic achievement (Steinmayr, Ziegler, & Träuble, 2010). To suggest that increased "attentional stamina" for such people is without clinical, academic, and practical importance is untenable.

Furthermore, it is worth noting that a number of studies have used parental ratings of attention-related behavior before and after training, but these studies have been left out from both reviews. Such ratings have the obvious advantage of high ecological value—that is, they measure effects of the training in situations that matter for the child's everyday life. Spencer-Smith and Klingberg (under review) conducted a recent meta-analysis in which they found a significant overall improvement for parent-rated symptoms of inattention. This suggests that CWMT can impact attention and that this transfers to function in everyday life.

Academic Performance

Because WM capacity is known to be important for academic achievement (Gathercole et al., 2004), a reasonable assumption is that for students in which WM is a deficit or limiting factor for their academic achievement, improvement in WM capacity may have benefits in academic functioning.

This hypothesis is based on a few theoretical underpinnings. First, it rests on an assumption that low WM is a causal factor of low academic performance. That means that the low WM capacity is a bottleneck that prohibits optimal capacity to be reached on academic tasks. Second, low WM capacity might decrease the ability to learn, either on its own or through a connection with poor attention. Both of these would suggest that effects from CWMT on academic abilities might gradually appear over time. If, for example, a child has problems learning mathematical abilities and poor WM is found to be a causal factor, increasing WM will likely not be sufficient on its own (CWMT does not include any teaching of mathematical skills or theory). Rather, an improved WM capacity could increase the child's ability to learn mathematics better after training, and the mathematical abilities would therefore be expected to increase over time. Furthermore, academic abilities are complex and clearly rely on a number of cognitive functions and skills in addition to WM, and developing these abilities is therefore dependent on the development of a number of cognitive capacities and appropriate educational exposure. Considering this complexity, we hypothesize that effects of CWMT on academic abilities will be small to moderate. Statistically, this means that large samples are required to detect such effects with any reasonable power (meaning how confidently one can interpret a lack of effect). More controlled studies assessing CWMT on academic performance are needed as is also reflected in Melby-Lervåg and Hulme's (2013) meta-analysis in which there is only one study using CWMT included in each analysis of assessments related to academic abilities. These results can therefore not be generalized to CWMT. There have, however, been some encouraging studies looking at CWMT and classroom-relevant tasks, as well as academic and learning abilities that were not included in the meta-analysis. For example, using a classroom-analogous task, Holmes et al. (2009) found an increase in the capacity to follow instructions both at the end of the program and 6 months later. Improvement in reading comprehension was noted by Dahlin (2011) in her study of children in a special education class. Beck et al. (2010) found improved executive functions as rated by parents and teachers in initiating activities and in planning, as well as improved organization and WM as rated by parents alone. Løhaugen et al. (2011) found improved verbal learning for adolescents born at extremely low birth weight. Kronenberger et al. (2011) in a pilot study (without a control group) found that hearing-impaired children with cochlear implants were able to significantly improve upon sentence repetition at the end of the program and at 6 months follow-up. Also, Green et al. (2012) found that children with ADHD significantly improved their behavior on a restricted academic situations task. Recently, Holmes and Gathercole (2013) published the largest CWMT study looking at academic performance. This study showed that 50 children who trained with CWMT as part of their classroom activity improved not only on measures of WM, but also on academic achievements in both English and mathematics across the academic year compared with a matched control group. These studies are promising in suggesting that CWMT might have a positive impact on children who struggle with their academic performance.

Reasoning Ability

Both the reviews from Shipstead et al. (2012) and Melby-Lervåg and Hulme (2013) focus substantially on supposed claims that Cogmed advertises their WM training as a method for improving reasoning, or fluid intelligence. For example Shipstead et al. writes in the first sentence of the abstract: "Cogmed WM training is sold as a tool for improving cognitive abilities, such as attention and reasoning" (p.185). This focus is unfortunate as these claims are outdated and simply not true. Still, Melby-Lervåg and Hulme do report significant effects on nonverbal reasoning in their meta-analysis (mean effect size was small but significant at $p = .02$). Again, this makes one question how they came to the strong conclusion that no evidence of generalization was observed. The authors reported a large difference in findings between studies and suggested that results are sensitive to study design. This is something that is also true when looking exclusively at studies using CWMT. Although some early studies of CWMT did find improvement in fluid intelligence (Klingberg et al., 2002, 2005), some later studies have not replicated these findings (Bergman Nutley et al., 2011; Holmes et al., 2009). Thus, evidence of CWMT improving reasoning ability is conflicting, and it is currently poorly understood what factors influence these differences in findings. This situation is something that is acknowledged by Cogmed, and therefore, because findings on reasoning were not replicated, Cogmed removed such claims from their Web site and marketing material. This is apparent by Shipstead et al. referring to an old version of the Cogmed Web site (they do not state when they visited the Web site but refer to a version archived elsewhere in 2011). Melby-Lervåg and Hulme (2013) fail to provide any proper reference to where Cogmed's apparent claims can be found (instead they provide a general reference to Cogmed's start page).

A NOTE ON COGMED'S CLAIMS AND RESEARCH STRATEGIES

Cogmed does encourage independent research to be done on CWMT, and all completed and ongoing research studies are presented on the Cogmed Web site (http://www.cogmed.com/research). At the time of writing, there are more than 30 studies published and more than 60 studies ongoing at universities all over the world assessing the effects of CWMT, and all researchers are completely free to publish their results, whatever they may be, and without involvement of Cogmed. Because WM training is a growing field, much knowledge is still to be gained regarding its effects, and as more knowledge is gained, Cogmed works hard on updating practices, recommendations, and claims that are being made. This continuous work is apparent by the removal of all previous claims regarding effects on reasoning ability. Pearson provides an actual list of claims related to Cogmed that is worth reviewing for more details. It is titled "COGMED Research Claims and Evidence 1.3" and can be found at http://www.cogmed.com/research (Note: The numbering of the document as "1.3" indicates the version of the document, which will continue to be edited as research findings warrant such edits). Staff members who work with Cogmed are continuously informed of the current state of evidence and claims that can be made, and they are instructed to use them carefully. So, the notion that Cogmed is sold as a tool for improving reasoning or fluid intelligence is simply not true.

DESIGN & METHODOLOGY PROBLEMS OF MELBY-LERVÅG AND HULME (2013) RELATED TO COGMED

Finally, a note about the methods used by Melby-Lervåg and Hulme (2013) and how these impact our ability to interpret the results is warranted. Due to strict inclusion criteria, this meta-analysis includes a limited number of WM training programs in their analysis. The most problematic issue related to Cogmed is that only 8 out of 30 studies were studies of Cogmed. The other research pertained to other programs. As such, one unequivocal conclusion is that their meta-analysis is not simply about Cogmed. Numerous studies supportive of Cogmed's efficacy were excluded due to what might be considered overly restrictive criteria. Arguments were made as a pretext to exclude certain studies including those with relevance to theoretical development such as imaging studies and studies using behavioral rating data. Additionally, studies were excluded because they did not report data on the preferred targeted transfer measures, which were operationally defined by Melby-Lervåg and Hulme, not the original investigators. Thus, there was an exclusion of studies with otherwise appropriate designs (e.g., Løhaugen et al., 2010).

Various training program types were combined and were categorized into groups based on arbitrary definitions of moderator variables: Various training programs and protocols were included as "WM training" such as updating training, simple and complex span training, and strategy training while listening to stories. The problem with these combinations is not just that the approaches of these training programs differ, but so do their intensity and the adaptive algorithms applied. Exact design and timing of the stimuli in each program also vary considerably. These approaches cannot reasonably be equated with CWMT, nor should the conclusions from such a grouping of studies apply.

Other methodological concerns included using a diverse combination of sample populations and ignoring the distinction between individuals with and without WM deficits. Both children younger than 10 years old and adults older than 51 years old were included. Some of these concerns are among their stated limitations in the Melby-Lervåg and Hulme (2013) review itself. However, these are not minor limitations. Arguably they call into question the conclusions of these reviewers. In spite of these clear and substantial limitations, the authors arrive at a rather strong negative conclusion, yet with so few Cogmed studies, one would think that cannot logically be applied to Cogmed. Furthermore, in their review, Melby-Lervåg and Hulme suggest that their "current findings cast doubt on both the clinical relevance of WM training programs and their utility as methods of enhancing cognitive functioning in typically developing children and healthy adults" (p. 270). This sweeping generalization of a conclusion appears unwarranted by the data showing significant effects on WM and several measures of transfer. Furthermore, if you "lump" together different age groups, different clinical conditions, and different degrees of WM impairment, then it is probable that any true differences in WM improvement may be lost in the data. The benefits to children with differing clinical presentations will not emerge from the data, as there is too much variability. This is beside the fact that there were substantially different approaches to training WM used in these studies.

ADHD AND CWMT

Chacko and colleagues (2013) recently published a review concerning the subgroup of children with ADHD and the efficacy of Cogmed using evidence-based criteria as outlined by the Society for Clinical Child and Adolescent Psychology. This is reasonable given the prominence of WM deficits among this group and the high prevalence of ADHD in Western populations. They note that the two studies included that were randomized and controlled showed that Cogmed resulted in neuropsychological outcomes and parent-rated ADHD symptom reduction compared with a waitlist and a placebo-controlled study. They also note that a third study showed improvement on a restricted academic performance task but not on parent-related ADHD. These data, so far, appear to support an argument for the efficacy of Cogmed for children with ADHD. However, Chacko et al. (2013) note a study that did not reveal benefits of CWMT (Gray et al., 2012). The inclusion of this study in the generic group of children with ADHD is questionable in that these children are actually severely learning-disabled in addition to having a diagnosis of ADHD.

Chacko et al. (2013) acknowledged that the group of students in the Gray et al. (2012) study was rather severely learning-disabled, but they argued that the limits of this sample do not "negate the findings of a lack of effects of CWMT" (p. 12). One might argue that this study may have come close to finding the limits of the effects of Cogmed. This apparent limit might relate to the degree of impairment, which might be reflecting the degree of neuroplasticity. Similar findings were presented by Söderqvist and colleagues, who reported that the amount of improvements seen during training was related to baseline capacity (possibly reflecting degree of impairment) in a sample of children with intellectual disability (Söderqvist, Nutley, Ottersen, Grill, & Klingberg, 2012).

Chacko et al. (2013) did note that these results bring to the surface an important issue, which is the possibility that severity of the disorder for different populations may limit the effects. Even when one simply considers the difference in intensity between inpatient and outpatient behavioral treatment and/or students who are in mainstream schools versus those who need to attend specialized schools, there is a notable difference in the behavioral treatment that is delivered to them. These groups of patients are substantially different in their therapeutic needs. So, if one were to consider the level of intensity of intervention at such facilities, one would argue that a more "routine" intervention would simply not suffice. Why would the same logic not apply to an intervention like Cogmed? Might it be the case that the intensity or duration of CWMT for groups with more severe impairments may need to be varied as well? For example, this group may need to do CWMT for a longer period of time. Possibly the most persuasive argument for a reexamination of the researched effects of Cogmed is the lack of a long-term impact of the "gold standard" of ADHD treatment reported by Molina et al. (2009). Molina and colleagues conducted the 6- and 8-year follow-up Multi-Modal Treatment of ADHD study with what is considered to be the "gold standard" of treatment of ADHD—a combination of prescription medications and excellent and intense behavioral treatment. They found notably disappointing results at 6 years and 8 years. These results pose a substantial problem for the traditional treatment of ADHD and are a critical consideration when one considers "clinical utility" of innovations like Cogmed. In fact, these authors themselves call for targeted innovations, arguably like Cogmed, to improve the functioning of adolescents with ADHD. Additionally, Molina et al. concluded that the time period for the best impact of prescription medication was about a 2-year frame in which medication had added benefit, but not beyond that. One begins to wonder whether a combination of complementary treatments might be warranted. CWMT will in most cases not provide a full replacement for medication, but it is likely that combining CWMT with other interventions such as medication will enhance the benefits. This idea is supported by findings from a study by Holmes et al. (2010) in which CWMT in a sample of children with ADHD was found to improve WM performance above and beyond the effects that were observed from stimulant medication treatment alone. These findings points to an exciting future of investigating how WM training can be tailored to best fit individual capacities and needs. It is likely that some individuals or clinical groups would benefit from CWMT in combination with other interventions, or that they would benefit more from an altered training protocol with, for example, extended training time.

CONCLUSION

It is in the context of ADHD standard treatment today that one should evaluate the effects of Cogmed. A significant point of theory is that WM has been consistently found to be related to academic achievement (Swanson et al., 2006). This is a critical plank of the theoretical underpinnings of why WM training matters at all. Given the more limited impact of traditional ADHD treatment upon academic functioning, this has clinical and academic salience.

We conclude by noting that numerous studies have established the effectiveness of CWMT in improving WM and attention, and these effects have also been found significant when combining evidence in objective meta-analyses. There is some support for improvement in academic abilities and reasoning ability, but more research is needed to better understand what factors influence these improvements. It is possible that the ongoing 65 studies of Cogmed may help to clarify this support.

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