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A randomized clinical trial of Cogmed Working Memory Training in school-age children with ADHD: A replication in a diverse sample using a control condition

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Abstract

Background—Cogmed Working Memory Training (CWMT) has received considerable attention as a promising intervention for the treatment of Attention-Deficit/Hyperactivity Disorder (ADHD) in children. At the same time, methodological weaknesses in previous clinical trials call into question reported efficacy of CWMT. In particular, lack of equivalence in key aspects of CWMT (i.e., contingent reinforcement, time-on-task with computer training, parent-child interactions, supportive coaching) between CWMT and placebo versions of CWMT used in previous trials may account for the beneficial outcomes favoring CWMT.

Methods—Eighty-five 7- to 11-year old school-age children with ADHD (66 male; 78%) were randomized to either standard CWMT (CWMT Active) or a well-controlled CWMT placebo condition (CWMT Placebo) and evaluated before and 3 weeks after treatment. Dependent measures included parent and teacher ratings of ADHD symptoms; objective measures of attention, activity level, and impulsivity; and psychometric indices of working memory and academic achievement (Clinical trial title: Combined cognitive remediation and behavioral intervention for the treatment of Attention-Deficit/Hyperactivity Disorder; http://clinicaltrials.gov/ct2/show/NCT01137318).

Results—CWMT Active participants demonstrated significantly greater improvements in verbal and nonverbal working memory storage, but evidenced no discernible gains in working memory storage plus processing/manipulation. In addition, no treatment group differences were observed for any other outcome measures.

Conclusions—When a more rigorous comparison condition is utilized, CWMT demonstrates effects on certain aspects of working memory in children with ADHD; however, CWMT does not

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Supporting Information
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Table S1: Observed means and outcome measures
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appear to foster treatment generalization to other domains of functioning. As such, CWMT should not be considered a viable treatment for children with ADHD.

Keywords

ADHD; treatment; working memory; cognitive training

Introduction

Treatments focused on improving working memory in children with Attention-Deficit/Hyperactivity Disorder (ADHD) have received considerable attention over the past few years (e.g., Klingberg, 2010), as working memory deficits have been linked to the core behavioral characteristics of the disorder (Rapport, Chung, Shore, & Isaacs, 2001), most notably inattention. Moreover, impairments in working memory have been associated with patterns of academic underachievement (e.g., Swanson & Jerman, 2007; Swanson, Jerman & Zheng, 2008) which often co-occur in children with ADHD. Given these findings, it has been posited that efforts to target and improve working memory can have a significant and enduring impact on ADHD symptoms and key associated impairments (Klingberg et al., 2010).

Cogmed Working Memory Training (CWMT; www.cogmed.com) is a computerized training program designed to improve working memory by effectively increasing working memory capacity over a five-week training period through targeting both the storage and storage plus processing/manipulation components of verbal and nonverbal working memory. The specific therapeutic component of CWMT focuses on improving working memory through the use of a game-like interface where trials are titrated to the capacity of the individual using an adaptive, staircase design that adjusts the difficulty of the program on a trial-by-trial basis. That is, correct trials are followed by successive trials with heightened working memory demands, whereas incorrect trials result in subsequent trials with diminished working memory load. In addition, several components of CWMT focus on supporting the user's engagement to the CWMT intervention. Specifically, contingent reinforcement is integrated within the program (e.g., earning small rewards for successful completion of a training-week). Moreover, each individual's training is supervised by a training aide (typically a parent or guardian when CWMT is implemented at home) and a certified CWMT coach, who is able to track closely (via online access) each individual's performance. During CWMT, the training aide is responsible for supporting the user through reinforcing on-task behavior, effort, and completion of CWMT by providing praise and encouragement. The CWMT coach supports the training aide and the user via a detailed training review and efforts to problem-solve motivational and logistical (e.g., scheduling) obstacles to adherence.

Several randomized clinical trials of CWMT have been conducted in children and adolescents with ADHD over the past several years (Beck et al., 2010; Gray et al., 2012; Green et al., 2012; Klingberg et al., 2005). In the first randomized clinical trial of CWMT, Klingberg and colleagues (2005) randomized a sample of 53 children with ADHD to either CWMT or to a non-titrating, low-level working memory version (i.e., placebo) of CWMT. Results demonstrated the effects of CWMT on various aspects of trained (i.e., outcomes resembling tasks similar to those utilized in CWMT) and non-trained cognitive tasks (e.g., Stroop Task). Results also demonstrated improvements in parent-rated inattention and hyperactivity/impulsivity at post-treatment. No statistically significant effects of CWMT were observed on teacher-rated symptoms of inattention or hyperactivity/impulsivity, or on an objective measure of motor activity.

The above-referenced findings were largely replicated in two subsequent randomized clinical trials. Beck and colleagues (2010) reported that, compared to an age matched, adolescent wait-list group, participants in the CWMT condition demonstrated improved parent-rated working memory and diminished inattention symptoms/problems at post-treatment. No statistically significant effect of CWMT was observed on parent-rated ADHD hyperactivity/impulsivity symptoms or on any teacher-rated outcomes. More recently, Green and colleagues (2012) reported that, relative to those assigned to the placebo-version of CWMT (identical to that used in Klingberg et al., 2005) children assigned to the active form of CWMT experienced significant benefits on trained working memory tasks and on observed behaviors during an analogue academic task. However, perhaps owing to the relatively small sample size and therefore limited power to detect group differences on certain outcomes, CWMT was not found to improve parent-rated ADHD symptoms.

Finally, in a randomized clinical trial of 60 adolescents with severe Learning Disorders (LD) and ADHD, Gray and colleagues (2012) evaluated CWMT compared to an intensive computerized academic instruction program. Results demonstrated effects of CWMT on two of the three trained working memory tasks. No differences were found on non-trained cognitive tasks. Moreover, CWMT had no incremental effect on parent- or teacher-rated ADHD behavior, and no treatment effects were found on academic measures.

Collectively, the results of four randomized clinical trials suggest consistent effects of CWMT on trained working memory outcomes but mixed findings for other cognitive outcomes and parent/teacher-rated ADHD symptom outcomes (e.g., setting specific behavioral improvements). Importantly, there has been considerable scrutiny regarding the purported benefits of CWMT on empirical, conceptual, and methodological grounds (Chacko et al., 2013; Hulme & Melby-Lervag, 2012; Shipstead, Hicks, & Engle, 2012). One particular issue is the apparent lack of equivalence between the active and placebo versions of CWMT utilized in supportive studies of CWMT (i.e., Green et al., 2012; Klingberg et al., 2005) Specifically, although the placebo condition utilized in supportive studies of CWMT was reported to achieve equivalent parent involvement as the training aide, child exposure to computer training, and time on task, it has arguably fallen short of achieving such objectives (Chacko et al., 2013). More specifically, the overall active training time (i.e., time spent performing the computerized training tasks) was not matched between the CWMT active and placebo conditions (Pearson, personal communication, November 22, 2011), resulting in a placebo condition that required considerably less time (and effort) to complete than the CWMT Active condition. Importantly, a more rudimentary and more time-limited intervention diminishes the amount and quality of interactions the training aide (i.e., parent) has with their child during training as well as the quantity and quality of support provided by the CWMT coach to the parent. These differences are notable, as supportive interactions between the parent and child constitute an important aspect of CWMT (Holmes et al., 2010) and can have direct benefits on improving behavior of children (Harwood & Eyberg, 2006). Additionally, the increased involvement of the CWMT coach in the active condition should not be underestimated; the therapeutic benefits of increased support and collaborative problem-solving with parents—an important role of the CWMT coach—has been shown to improve parent-ratings of ADHD symptoms in other studies (e.g., Sonuga-Barke et al., 2001). Clearly, methodologically rigorous studies are needed to more appropriately evaluate CWMT as a treatment for ADHD in children.

The purpose of this study was to replicate previous studies of CWMT (i.e., Green et al., 2012; Klingberg et al., 2005) using more rigorous methodology and a more psychiatrically and socioeconomically diverse sample of children with ADHD. This was accomplished through evaluating the efficacy of CWMT (CWMT Active) compared to a well-controlled placebo version of CWMT (CWMT Placebo) in a sample of school-age children with

ADHD across various key outcomes (i.e., working memory; parent- and teacher-rated ADHD symptoms, objective measures of attention, activity level, and impulsivity; and academic achievement). Given the adaptive working memory training component of CWMT Active, it was hypothesized that, compared to CWMT Placebo, CWMT Active would result in significant improvements in trained (i.e., outcomes that are similar to those trained during CWMT) as well as untrained (i.e., outcomes that are dissimilar to those trained during CWMT) working memory outcomes. Moreover, given the relationships between working memory, inattention, and academic achievement, it was hypothesized that, compared to CWMT Placebo, CWMT Active would result in significant improvements in ADHD inattention symptoms, objective measures of attention, and academic achievement. Moreover, in line with previous research, we hypothesized that the effects of CWMT Active would be observed on parent but not teacher ratings.

Method

Participants

Children and their families were recruited through community advertisements for a clinical trial of ADHD (Title: Combined cognitive remediation and behavioral Intervention for the treatment of ADHD; http://clinicaltrials.gov/ct2/show/NCT01137318). Inclusion criteria included: 1) children between the ages of 7–11 years; 2) a diagnosis of ADHD through consensus diagnosis based on parent and teacher ratings on the Disruptive Behavior Disorder Rating Scales (DBD; Pelham, Gnangy, Greenslade, & Milich, 1992) and impairment using the Impairment Rating Scale (Fabiano et al., 2006); and a semi-structured interview with the parent using the Kiddie-SADS (Kaufman et al., 1997); 3) fluency in English (parent and child), and; 4) internet access at home. Children were excluded if 1) there was evidence of a pervasive developmental disorder based on previous diagnosis and/or elevated sores on the Child Autism Rating Scale (Schopler, Reichler, & Renner, 1988) rated by the evaluator at intake, or psychosis; 2) the child or parent presented with emergency psychiatric needs that required immediate services (e.g., suicidal or homicidal intent), and; 3) if the child had an estimated Full Scale IQ below 80 based on two subtests of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler et al. 1999). Socioeconomic Status (SES) was measured using the Nakao and Treas Socioeconomic Prestige Index (1994). Higher scores indicate higher SES. The higher value of mother or father was taken to represent the family SES at baseline. Diagnoses for comorbid oppositional defiant disorder (ODD) and conduct disorder (CD) were evaluated through information collected on the DBD and the Kiddie-SADS. Table 1 details the family and clinical characteristics of the study sample by treatment group.

Intervention Conditions

CWMT Active—CWMT Active is a computerized training program that targets both the storage and storage plus processing/manipulation components of verbal and nonverbal working memory through training which takes place in approximately 30–45 minute increments over five days per week (25 training-days total). CWMT Active trials are titrated to the capacity of the individual using an adaptive staircase design that adjusts the difficulty of the program on a trial-by-trial basis. Each individual's training is supervised by a training aide (typically a parent or guardian) and a certified CWMT coach, who is able to track closely (via online access) each individual's performance and provide support to the family through weekly coaching interactions (by phone).

CWMT Placebo—The CWMT Placebo condition included a low-level (placebo) working memory training program that was identical to CWMT Active with respect to the types of training games utilized and the number of training trials per session (i.e., 90 trials). Unlike the active condition, difficulty level was not scaffolded according to each user's performance parameters in the placebo condition. As with CWMT Active, parents in the CWMT Placebo served as training aides, and each family was supported by a coach who utilized comparable support procedures.

Measures

Process Measures

Compliance: As has been reported in previous studies (Klingberg et al., 2005), compliance was defined as completing ≥ 20 of the 25 trainings within a 5-week period. Using this algorithm, each child was categorized as compliant or noncompliant to treatment.

Treatment Time Modification: To ensure that active treatment time (i.e., the amount of time a child spent directly involved in computerized working memory exercises) was within intended limits for both the CWMT Active and Placebo conditions, active training time was modified (i.e., increased or decreased) by the coach when necessary. More specifically, as suggested by Cogmed, the active training time was targeted to be between 30–45 minutes per session. If the active training time was outside of this range (below or above) for three consecutive training days, a request was made by the coach to Cogmed to modify the active training time to be between 30–45 minutes by adding or reducing trials to each CWMT exercise. Active training time was monitored throughout the study, and modifications were made when necessary.

Improvement Index: An Improvement Index score was calculated for participants in CWMT Active. This score, which is a built-in compliance/progress measure, was calculated by subtracting the Start Index (results of day 2 and 3 of training) from the Max Index (results from the two best training days). Higher Improvement Index scores indicated greater compliance and progress with CWMT. An Improvement Index of 17 has been noted to represent successful improvement following completion of CWMT Active (Gray et al., 2012).

Outcome Measures

Parent and teacher report of ADHD symptoms: ADHD symptoms were measured using the Disruptive Behavior Disorders Rating Scale (DBD; Pelham et al., 1992). The DBD is a 45-item measure that asks parents and teachers to rate symptoms of ADHD, ODD, and CD on a four-point scale (i.e., Not at all, Just a little, Pretty Much, or Very Much), with higher scores indicating a greater frequency of problems. The sum of individual items for the inattentive symptoms and for the hyperactive-impulsive symptoms was calculated separately and used as outcome measures. Cronbach Alphas range from .82 for the Inattentive score to .84 for the Hyperactivity/Impulsivity score. (See Table 2; See also online-only supplementary Table S1)

Working memory: The Automatic Working Memory Assessment (AWMA; Alloway, 2007) was used as an objective, computer-based measure of working memory. Four span tasks from the AWMA were completed to assess nonverbal storage (Dot Matrix) and storage plus processing/manipulation (Spatial Recall), and verbal storage (Digit Recall) and storage plus processing/manipulation (Listening Recall) aspects of WM. Standard scores for each of the subtests were generated by the AWMA and used as outcome measures. Test re-test reliabilities have ranged from .80–.86 for the four AWMA subtests.

Objective assessments of attention, activity level, and impulse control: Motor activity was recorded throughout the evaluations using two acceleration-sensitive devices with solidstate memory that store movements per minute (Reichenbach, Halperin, Sharma & Newcorn, 1992). Actigraphs were placed on the non-dominant ankle and waist, and the mean of the median activity counts for the two actigraphs was calculated. Test-retest reliability was reported as .84. The A-X Continuous Performance Test (Halperin, Sharma, Greenblatt, & Schwartz, 1991) generates objective measures of inattention and impulsivity. Letters are presented individually for 200 milliseconds with a 1.5 second interstimulus interval. The child responds when s/he sees an “A” followed by an “X”. A total of 400 letters are presented, and the entire task lasts approximately 12 minutes. The number of omission errors and commission errors were used as outcome measures. Reported reliabilities range from .65–.74 in previous analyses.

Academic Achievement: Wide Range Achievement Test 4 Progress Monitoring Version (WRAT4-PMV; Roid & Ledbetter, 2006) is an adaptation of the WRAT4 designed to be a reliable and efficient tool for monitoring academic progress. Brief 15-item tests are administered to evaluate four basic skill areas: Word Reading, Sentence Comprehension, Spelling, and Mathematical Computation. Each WRAT4-PMV level consists of four parallel forms that are psychometrically equivalent; thus a different form was used at each of the two assessment points. Raw scores were converted into Level Equivalent Scores which are standardized to allow for comparison across grade and age. Alpha coefficients for the subtests range from .74–.81.

Procedure

At study intake, parents and children were informed of randomization to one of two computerized programs to target working memory. No information was provided to the parents, children, or teachers regarding the relative benefits of the two programs. As such, these individuals were blind to study group assignment. Following parent consent and child assent, a semi-structured interview was completed by a clinician with the parents to ascertain psychiatric diagnoses, including ADHD. During this assessment, which occurred approximately 2–4 weeks prior to the start of treatment, parent and teacher rating scales were completed, as was the child’s initial evaluation (see above). As was the case during previous trials of CWMT (e.g., Klingberg et al., 2005), post-treatment assessments and rating scales were completed approximately three weeks after the final training day for each participant. All assessments were conducted by research staff who were blind to participant treatment randomization. Study procedures were approved by the University’s Institutional Review Board.

Participants were randomly assigned to treatment condition (CWMT Active= 44; CWMT Placebo= 41; see Figure 1 for CONSORT diagram) by a senior research staff (blind to participant profile) based on a random permutation calculator (http://www.webcalculator.co.uk/statistics/rpermute3.htm). Following randomization, research staff, all certified by Pearson as CWMT training coaches, were assigned cases and received an equal number of CWMT Active and CWMT Placebo cases. All families participated in a start-up session which introduced the basic features of CWMT and established a schedule for implementing the intervention and for weekly coaching calls. In addition, all families and their coaches developed an individualized incentive system that focused on rewarding on-task behavior during training. This reward system, implemented for both conditions, augmented the standard CWMT incentive system (i.e., earning stickers) with contingent daily, weekly, and end-of treatment rewards that were selected by the child and agreed upon by the parent (e.g., picking a snack for lunch, dessert for dinner, extra television time, etc.). This simple enhancement was made to maximize compliance given the expected high rates of comorbid oppositional problems in the sample. All coaches completed a weekly fidelity and integrity questionnaire, developed specifically for this study to: (i) identify potential challenges to treatment compliance, (ii) establish an algorithm to titrate total training time, (iii) operationalize feedback and support across participants in the two treatment conditions during weekly coaching calls, and (iv) problem-solve challenges in performance and compliance. Treatment was supervised by senior staff (AC, ACB, & DJM) that verified data and monitored coaching calls so that participants in both conditions received equal support from their coaches throughout the training period. All training was conducted at home and was scheduled to be completed over a five-week period based on the family's schedule.

Statistical Analyses

An Intent-To-Treat (ITT) approach was used to compare treatment effects of the two treatment conditions. Mixed effects regression was used for each outcome over time using SuperMix software (Hedeker, Gibbons, du Toit, & Cheng, 2008). Also known as multilevel linear modeling, this analytic approach allowed parameters (intercepts and slopes) for measurements over time within cases to vary between cases. The correlations between measurements within cases were also accounted for. Finally, this type of modeling allowed for different times and numbers of measurements within cases, which is an appropriate method for modeling longitudinal change involving data where there is attrition over time with the assumption that the missing data are at least missing at random. This assumption was considered appropriate given that the data met distributional properties of missing at random (e.g., Jaeger, 2006).

Mixed effects linear regression was used to model each continuous outcome as a function of a time dummy (time=1 for post-test, = 0 for pre-test), group (CWMT Active=1, CWMT Placebo = 0) and time-by-group interaction. Intercepts were allowed to vary randomly within each model. All pre-treatment assessment data were analyzed to determine if there were significant differences between groups on these variables. Analyses determined no differences between groups on any outcome variable at baseline (all $p > .05$). Linear contrasts were subsequently used to test for significant differences between the CWMT Active and CWMT Placebo on each outcome variable at post-treatment (all outcome variables), as well as within-group changes in outcomes over time from pre-treatment to post-treatment. Between-group linear contrasts that compare outcomes at post-treatment are reported. Given that there were multiple outcome measures, a Sidak-Bonferroni correction was used for all analyses with a family wise alpha level of .05. This resulted in an alpha level of .013 for parent ratings, .017 for teacher ratings, .013 for AWMA measures, .017 for objective measures of attention, activity level and impulse control, and .013 for WRAT-PMV outcomes. Lastly, Cohen's *d* effect size was obtained by dividing the improvement in the experimental condition subtracted from the improvement in the control condition divided by the pooled baseline standard deviation of the sample.

Results

Compliance—Of the 44 participants assigned to CWMT Active, 35 (80%) met compliance criteria (≥ 20 training days within five weeks). Of the 41 participants assigned to CWMT Placebo, 31 (77%) met compliance criteria. Overall, compliance to treatment was high, given that this was a home-based, parent-supported intervention that included a substantial proportion of participants with comorbid ODD.

Treatment Time Modification—Five participants (11%) in CWMT Active required increases in training time. Thirty-two participants (78%) in the CWMT Placebo condition required increases in training time, 18 (56%) of which required at least two increases to their active training time. Active training time for participants in CWMT Active was within established parameters (Mean = 39.1 minutes SD= 6.85 minutes). Despite titration efforts, mean active training time for participants in CWMT Placebo (Mean = 26.0 minutes SD= 4.47 minutes) was lower than the 30 minute suggested minimum for CWMT Active, and differed significantly from active training time of CWMT Active participants (p= 0.0001).

Index Improvement—Thirty-seven (84%) of the total CWMT Active condition participants met the Improvement Index criterion (≥ 17). Of the 35 participants in the CWMT Active condition who were compliant to treatment, 31 (89%) met the Improvement Index criterion.

Outcome Measures

Parent and teacher report of ADHD Symptoms—A significant main effect of time was observed for parent reported ADHD symptoms domains, with participants across groups showing a diminution in severity over time; no analogous findings were observed for teacher rated ADHD inattention (b = −1.05629, SE=1.15328, Z= −0.91590, p= 0.35972) or hyperactivity/impulsivity (b = −1.37713, SE= 0.90675, Z= −1.51875, p= 0.1288) symptoms. However, there were no significant differences found between CWMT Active and CWMT Placebo on either parent inattention (b = 1.9845, SE= 1.1726, Z= 2.9716, p= 0.2030, d= −.24), parent hyperactivity/impulsivity (b = 1.8828, SE= 1.1573, Z= 3.1822, p= 0.2015, d= −.24) or teacher reports of inattention (b = 1.8390, SE= 1.4909, Z= 1.2335, p= 0.2174, d= −.03) or hyperactivity/impulsivity (b = 1.9399, SE= 1.5390, Z= 1.2605, p= 0.2075, d= .07).

Working memory—There was a significant effect of time on AWMA performance. Significant differences between treatment conditions were found for measures of nonverbal (Dot Matrix; b=17.0705, SE=3.8200, Z= 4.4688, p= 0.00009) and verbal (Digit Recall; b=9.1746, SE=3.2691, Z=2.8065, p=0.0050) storage such that CWMT Active participants demonstrated significantly greater improvements relative to those in the CWMT Placebo condition (d= 1.17 for Dot Matrix; d= .28 for Digit Recall). In contrast, no significant differences were found between treatment conditions on measures of nonverbal (Spatial Recall; b =7.2867, SE=3.6856, Z=1.9771, p= 0.048, d=.29] or verbal (Listening Recall; b =1.1095, SE=3.1913, Z=.3477, p= 0.7281, d=.07) complex working memory (storage plus processing/manipulation).

Objective assessments of attention, activity level, and impulse control. There was no effect of time on objective assessments of attention (b = −1.45264, SE= 1.02726, Z= −1.41409, p= 0.15733), activity level (b = −1.39418, SE= 21.9980, Z= −0.6338, p= 0.94947), and impulse control (b = 9.43111, SE= 7.04932, Z= 1.33787, p= 0.18094). No significant differences were observed between treatment conditions on objective measures of inattention (CPT omission errors; b = −0.3825, SE= 1.3720, Z= −0.2788, p= 0.7804, d= .07), impulsivity (CPT commission errors; b = −7.6023, SE= 7.6468, Z= −0.9942, p= 0.3201, d=−.02), or activity level (actigraph data; b = 27.7427, SE= 25.5245, Z= 1.0869, p= 0.2771, d=−.18).

Academic Achievement—There was a significant effect of time on academic achievement scores. However, no significant differences were found between treatment conditions on Word Reading (b = −2.7296, SE= 5.5154, Z= −0.4949, p= 0.6207, d= −.05), Sentence Completion (b = 5.6363, SE= 4.7126, Z= 1.1960, p= 0.2317, d= .31), Math Computation (b = 5.2215, SE= 5.2113, Z= 1.0020, p= 0.3164, d= .10) or Spelling (b = 1.2851, SE= 6.1769, Z= 0.2081, p= 0.8352, d= .13) achievement scores at post treatment.

Discussion

The purpose of this study was to determine the benefits of CWMT compared to a well-controlled placebo version of CWMT on various outcomes in a diverse sample of school-age

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children with ADHD. Results indicated that CWMT Active did not result in significantly greater improvements compared to CWMT Placebo condition on parent- or teacher-rated ADHD symptoms, objective measures of inattention, activity, and impulsivity, measures of verbal and nonverbal working memory manipulation, and academic achievement. Compared to CWMT Placebo, CWMT Active did result in greater improvements on measures of verbal and nonverbal simple working memory (storage). We discuss below issues with attaining equivalence of treatment components between the two treatment conditions, followed by a discussion of how findings contribute to our understanding of CWMT as a treatment for ADHD in school-age children.

Active training time was significantly lower in CWMT Placebo compared to CWMT Active, which consequently likely led to decreased parent-child supportive interactions, and less content discussed during CWMT coaching calls. The lower active training time was likely due to the nature of the titration procedure. Specifically, three consecutive days where the participant was outside the 30–45 minute active training time window were required prior to submitting a request to Cogmed to modify the number of training tasks to achieve the appropriate active training time. In addition, modifications by Cogmed would typically be implemented one to three days after a given request. As such, some participants trained for up to a week before the intended adjustments were made. Importantly, when compared to other studies that have utilized the CWMT Placebo condition (Green et al., 2010; Klingberg et al., 2005), active training times were more equivalent between the CWMT Placebo and CWMT Active in this study. Importantly, this increased active training time in CWMT Placebo allowed for greater child exposure to computer training, greater parent-child interactions, and increased content for discussion during weekly CWMT coaching calls relative to other studies.

Contrary to what has been reported in previous studies (Klingberg et al., 2005), no significant differential impact of CWMT Active versus Placebo was observed for parent-reported ADHD symptoms; however, our results comport with those of prior controlled trials (Beck et al., 2010; Gray et al., 2012; Klingberg et al., 2005), which did not find effects of CWMT on teacher-rated ADHD symptoms. Collectively, these findings suggest caution in attributing improvements in ADHD symptomatology found in earlier studies to CWMT. When tighter controls were employed in the CWMT Placebo condition, we found no benefits of CWMT on ADHD symptoms.

CWMT appears to have robust effects on certain aspects of working memory, which were also evident in earlier studies (see Chacko et al., 2013). Specifically, relative to participants in CWMT Placebo, participants in CWMT Active had improved performance on the AWMA Dot Matrix and Digit Recall subtests as a function of treatment. However, such findings are not surprising given the similarity between the working memory tasks used during CWMT training and the AWMA Dot Matrix and Digit Recall tasks (i.e., simple, sequential, not-self-ordered, span tasks indexing involving only working memory storage). These “near transfer” effects are noted as expected effects of CWMT, particularly when outcome measures are very similar to CWMT training tasks themselves. Unlike these trained tasks, CWMT Active had no significant differential effect on non-trained outcome measures (i.e., AWMA Spatial Recall or on the AWMA Listening Recall). This suggests, as some have already posited (Shipstead, et al., 2012), that benefits of CWMT appear to be most closely related to transfer of training effects rather than generalization of training to more complex areas of working memory involving storage plus processing/manipulation.

Both treatment groups improved with treatment on measures of academic achievement, with no incremental benefit of CWMT Active on these outcomes. These findings are similar to those of Gray et al. (2012), who found no incremental benefit of CWMT Active compared to an intensive math intervention on academic achievement outcomes. This suggests that CWMT per se may not have specific effects on measures of academic achievement, at least in the short term.

Limitations

There are notable limitations to this study. Equivalence of active training time between treatment conditions was not fully obtained. Given the aims and hypotheses of the study, this difference was likely to favor CWMT Active; however, an incremental benefit of CWMT Active was largely not observed. Greater equivalence of therapeutic components would be hypothesized to further diminish differences between CWMT Active and CWMT Placebo. Furthermore, given that no wait-list control condition was utilized, we do not know the extent to which these findings relate to parent expectancy effects. In addition, longer-term follow up assessments are needed and may be particularly useful for outcomes such as academic achievement that may demonstrate continued benefits of treatment over longer periods of time.

Clinical Implications

Our findings suggest that CWMT has a specific and facilitating effect on select working memory training components. However, there appear to be no incremental benefits of CWMT relative to a well-matched placebo condition on parent and teacher ratings of ADHD symptoms, objective measures of attention, hyperactivity and impulsivity, or academic achievement. Collectively, these findings, together with other recently published data, suggest that CWMT should not be used as a treatment for ADHD in children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key Points

- Working Memory (WM) has been linked to symptoms of Attention-Deficit/Hyperactivity Disorder (ADHD), particularly inattention symptoms.
- Cogmed Working Memory Training (CWMT) is an intervention focused on improving WM.
- CWMT has been studied as an intervention for ADHD, with mixed data supporting the efficacy of CWMT.
- Due to methodological limitations of studies, it is unknown the extent to which CWMT results in improved outcomes for children with ADHD.
- The current findings indicate that CWMT results in benefits on select WM outcomes but does not have effects on ADHD symptoms or key areas of functional impairment (i.e., academic achievement).

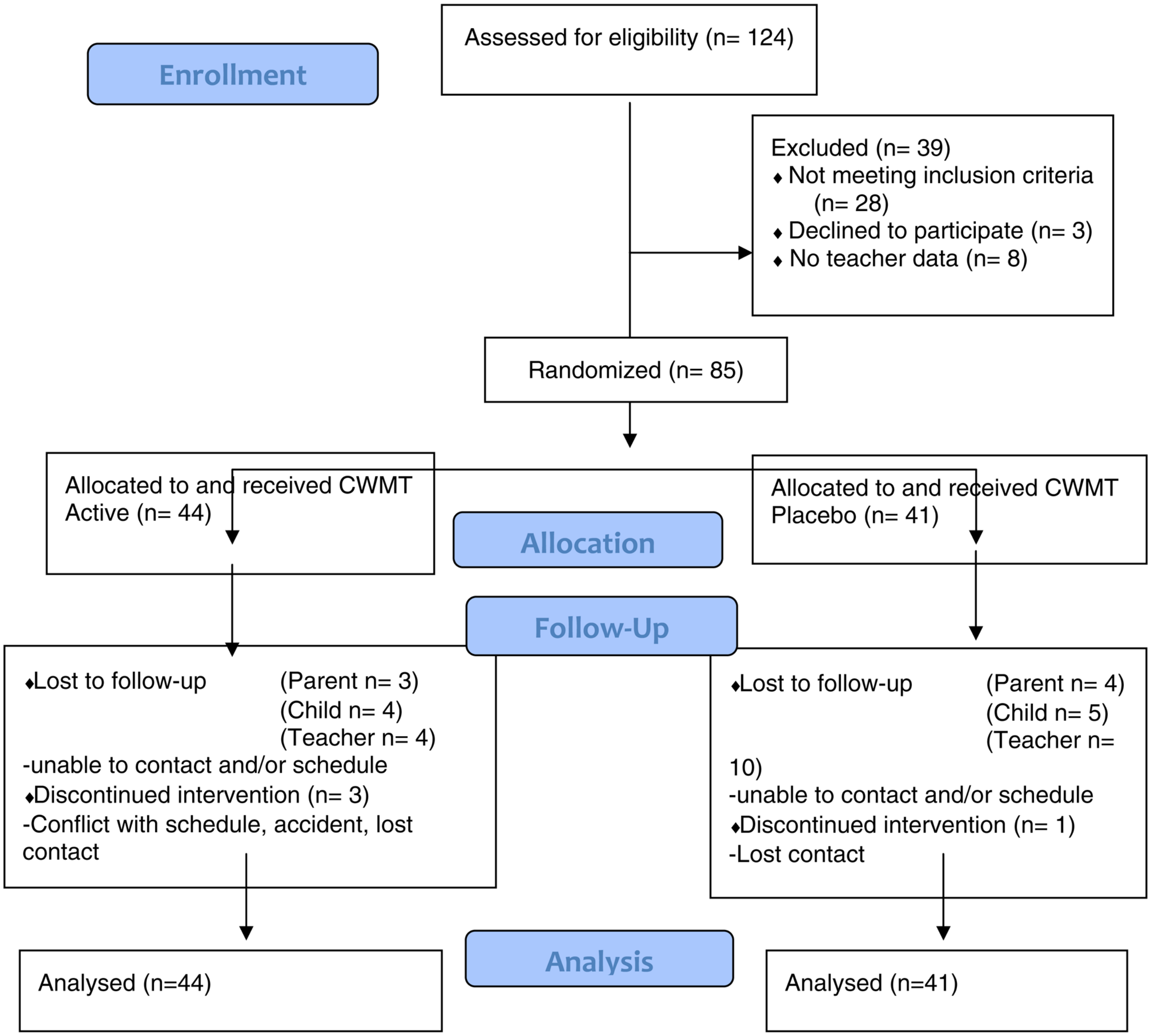

Figure 1.
CONSORT Flow diagram

Table 1

Demographic and Clinical Characteristics by Treatment Group

	CWMT Active (n=44)	CWMT Placebo (n=41)
Age, mean (SD) in years	8.4 (1.4)	8.4 (1.3)
Sex, No Males. (%)	36 (81)	30 (73)
Full-Scale IQ, mean (SD)	104.2 (20.9)	104.6 (13.4)
Medicated for ADHD, No. (%)	12 (27)	13 (32)
ADHD Subtype, No. (%)		
Combined	29 (66)	24 (59)
Inattentive	15 (34)	17 (41)
Comorbid ODD, No. (%)	22 (50)	16 (39)
Comorbid CD, No. (%)	4 (9)	6 (15)
Ethnicity, No. (%)		
Hispanic or Latino	15 (34)	13 (32)
Not Hispanic or Latino	28 (64)	27 (66)
Race, No. (%)		
American Indian	1 (2)	1 (2)
Asian	6 (14)	7 (17)
Caucasian	22 (49)	15 (37)
African American/Black	6 (14)	8 (20)
Other	9 (20)	10 (24)
Marital Status, No. (%)		
Married	27 (61)	28 (68)
Married but Separated	3 (7)	3 (7)
Divorced	7 (16)	2 (5)
Never married/Single	7 (16)	8 (19)
Socio-economic Index, Mean (SD); Range	55 (17); 28–87	59 (19); 22–97

Note: No significant differences between participants in both treatment condition groups on all demographic and psychiatric variables.

Table 2

Test of Groupwise (Active vs. Placebo) Treatment Differences

Outcome Variable	Treatment Effect	Standard Error	Z-statistic	p-value	Effect Size (Cohen's *d*)[a]
Parent DBD-IN	1.9845	1.1726	2.9716	0.2030	**−.24**
Parent DBD-HI	1.8828	1.1573	3.1822	0.2015	**−.24**
Teacher DBD-IN	1.8390	1.4909	1.2335	0.2174	**−.03**
Teacher DBD-HI	1.9399	1.5390	1.2605	0.2075	**.07**
AWMA-Dot Matrix	17.0705	3.8200	4.4688	0.0000*	**1.17**
AWMA-Spatial Recall	7.2867	3.6856	1.9771	0.0480	**.29**
AWMA-Digit Recall	9.1746	3.2691	2.8065	0.0050*	**.28**
AWMA-Listening Recall	1.1095	3.1913	0.3477	0.7281	**.07**
Actigraph	27.7427	25.5245	1.0869	0.2771	**−.18**
CPT-Omission Errors	−0.3825	1.3720	−0.2788	0.7804	**.07**
CPT-Commission Errors	−7.6023	7.6468	−0.9942	0.3201	**−.02**
WRAT-4-PMV Word Reading	−2.7296	5.5154	−0.4949	0.6207	**−.05**
WRAT-4-PMV Sentence Completion	5.6363	4.7126	1.1960	0.2317	**.31**
WRAT-4-PMV Math Computation	5.2215	5.2113	1.0020	0.3164	**.10**
WRAT-4-PMV Spelling	1.2851	6.1769	0.2081	0.8352	**.13**

Note: DBD-IN: Disruptive Behavior Disorder Rating Scale Sum of Inattention Symptoms; DBD-HI: Disruptive Behavior Disorder Rating Scale Sum of Hyperactive/Impulsive Symptoms; AWMA; Automatic Working Memory Assessment; CPT: A-X Continuous Performance Test; WRAT-4-PMV: Wide Range Achievement Test-Fourth Edition Performance Monitoring Version.

[a]CWMT Active condition is the reference category for calculations. Positive effects sizes represent a beneficial effect of CWMT Active relative to the CWMT Placebo. Negative effect sizes represent a beneficial effect of CWMT Placebo relative to the CWMT Active.

*family wise alpha $p < .05$