Effectiveness of Working Memory Training on Children and Adolescents Comorbid with ADHD and Other Externalizing Disorders

A Senior Honors Thesis

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Introduction

Attention deficit/hyperactivity disorder (ADHD), a prevalent psychopathological condition, can be characterized by a number of symptoms pertaining to inattention, hyperactivity, and impulsivity (American Psychiatric Association, 1994). The prevalence of ADHD in school aged children is estimated to be about 3-6% (Goldman, Genel, Bezman, & Slanetz, 1998). ADHD is categorized by three subtypes, a predominantly inattentive type, a predominantly hyperactive-impulsive type, and a combined type. Behaviors such as making careless mistakes, trouble organizing tasks, forgetfulness, and becoming easily distracted are common among individuals diagnosed with inattentive type ADHD (American Psychiatric Association, 1994). Individuals categorized with hyperactive-impulsive type ADHD may talk excessively, display a high rate of fidgeting, frequently interrupt, run and climb in situations when it is not appropriate, and exhibit a difficulty waiting for one's turn (American Psychiatric Association, 1994). In addition to these symptoms, children diagnosed with ADHD often display deficits in executive functioning (Barkley, 1997; Kuntsi, 2001; Mariani & Barkley, 1997; Rapport & Chung, 2000; Klingberg, 2002).

Although there is no single definition of executive functioning, it may be described as meta-cognitive processes controlled by neurological mechanisms in the frontal cortex, that allow functional organization, planning, execution, and regulation of goal-directed behavior (Oosterlaan, Scheres, & Sergeant, 2005). Working memory, one facet of executive functioning, pertains to the ability to hold and manipulate information during a short delay and in the face of distractions (Engle & Kane, 2004; Cowan, 2001). Across attention shifts and between the processing of irrelevant stimuli, original stimulus information stays available to an individual by remaining in working memory (Engle & Kane, 2004). For example, a child is told to put their homework and lunch in their book bag and put on their shoes. The list of instructions is held and manipulated using working memory. A child with poor working memory, such as a child diagnosed with ADHD, may put their homework into their book bag and then on the way to get their lunch from the counter, see a toy, and stop to play. Meanwhile, the child's working memory will stop holding the list of tasks, the child will forget what they are supposed to be doing, and will have to be reminded again.

The temporary storage and manipulation of information, by working memory systems, is involved in many higher cognitive functions (Smith & Jonides, 1999). For example, Smith and Jonides (1999) state that an individual's ability to inhibit behaviors, plan, reason, comprehend and regulate emotions is related to working memory abilities. Deficits of cognitive functions, such as the ability to inhibit behaviors, are symptomatic of children with ADHD (American Psychiatric Association, 1994). Several past studies have explored this relationship and found that behaviors connected to ADHD, such as forgetfulness and interrupting others, are thought to be associated with deficits in executive functioning, specifically working memory (Barkley, 1997; Castellanos & Tannock, 2002; Rapport, 2000; Westerberg, 2004)

One model of working memory states that working memory processes information through two independent subsystems, a phonological loop and a visuospatial scratchpad, which are controlled by a single attention controller; the central executive (Baddeley, 2007). Visuospatial abilities pertain to the storage and manipulation of information seen visually. Phonological abilities pertain to the storage and manipulation of both information that is heard and information that is seen visually and then transformed into phonological code. Both subsystems are equipped with an input processor, buffer for the temporary storage information, and a rehearsal mechanism which helps maintain processed information (Baddeley, 2007). The two subsystems are directed and coordinated by the central executive . Poor visuopatial and phonological abilities pertain to a decreased ability to process information that is either seen or heard.

Children with ADHD often display working memory deficits in the visuospatial and phonological domains (Martinussen, 2005; Rapport, 2008a, 2009). Rapport measured phonological and visual recall in individuals, 8-12 years old, diagnosed with ADHD and compared them to typically developing children (Rapport, 2008a). In the visuospatial task, participants were asked to recall the serial position of a series of dots. In the phonological task, participants were given a series of numbers and one letter on a computer screen and then were asked to recall the numbers in order from smallest to largest and recall the letter last. Through the use of both the phonological and visuospatial subsystems, typically developing individuals were able to recall up to 6 stimuli (Rapport, 2008a). However, individuals in the ADHD group were only able to recall up to 4 stimuli using the phonological subsystem and less than 2 stimuli using the visuospatial subsystem (Rapport, 2008a). The inability to recall a greater number of stimuli suggests an underlying impairment in the buffer (storage/rehearsal loop) functioning in both subsystems, among participants with ADHD (Rapport, 2008a).

The increasing number of ADHD diagnoses in the United States has guided research to explore various treatments. Specifically, improving working memory has been explored as a possible treatment for ADHD symptoms. Cognitive systems associated with working memory are said to be “plastic”, which means the systems can undergo change (Westerberg & Klingberg, 2007). Additionally, the relationship between ADHD and working memory deficits suggests that by improving working memory the effects and severity of ADHD symptoms may be decreased (Klingberg, Forssberg, & Westerberg, 2002).

In a preliminary study, Klingberg et al., (2005) examined the effects of organized working memory training on a variety of tasks requiring the use of working memory, using primarily visual-spatial and verbal tasks. Treatment effects were evaluated through a randomized, controlled, and double-blind trial involving 53 children with either combined subtype ADHD or predominantly inattentive subtype. The participants in this study were referred to the study by professionals but were not clinically diagnosed by the study's researchers. None of the participants met criteria for oppositional defiant disorder or conduct disorder. In the study a computerized program (Cogmed America Inc.), which required systematic practice of working memory, was used to enhance working memory, response inhibition, and reasoning in children with ADHD. Before and after the completion of the working memory program, participants were assessed using several inventories that measured verbal working memory, visuospational working memory, response inhibition, nonverbal reasoning ability, and ADHD symptoms. Specifically the span board task from the WAIS-RNI (Wechsler, 1981) was used to measure visuospatial working memory, the digit-span task from the WISC-III (Wechsler, 1991) was used to measure verbal working memory, the Stroop inference task was used to measure response inhibition (Lezak, 1995), and Raven's Colored Progressive Matrices (Raven, 1995) to measure nonverbal reasoning ability.

Results showed that, when compared with a control group, participants with ADHD displayed improvements in several areas of working memory functioning following completion of the working memory training (Klingberg et al., 2005). The control group received training using a program without an algorithm, explained later, that keeps working memory engaged. Specifically, participants in the experimental group, who did complete the training using an algorithm, showed improvement in areas of visuospatial working memory, response inhibition, verbal working memory, and complex reasoning (Klingberg et al., 2005). Participants, based on parent ratings, were also found to display lower scores on measures of ADHD symptoms subsequent to receiving the treatment (Klingberg et al., 2005). A significant treatment effect was discovered after treatment as well as during 3 month follow up studies (Klingberg et al., 2005). Based on participant's improvements on untrained reasoning ability tasks, working memory may be associated with or considered necessary for reasoning ability (Engle, Tuholski, Laughlin & Conway, 1999; Klingberg et al., 2005). Researchers were also able to conclude that working memory may be improved through training and that the severity of symptoms related to ADHD decrease after training (Klingberg et al., 2005). However, the generalizability of the study is limited by the lack of clinical diagnosis of participants and the research's exclusion of comorbid participants diagnosed with ADHD and oppositional defiant disorder or conduct disorder.

Children with ADHD display a high rate of comorbidity (Barkley, 2002). Comorbidity is the occurrence of two or more disorders at the same time. This co-diagnosis frequently occurs between ADHD and other externalizing disorders, such as oppositional defiant disorder (ODD) or conduct disorder (CD) (Maughan, Rowe, Messer, Goodman, Meltzer, 2004). ODD can be characterized by frequent arguing with adults, refusal to comply with rules, periods of anger, and a tendency to blame others for their mistakes (American Psychiatric Association, 1994). Individuals diagnosed with CD display aggression towards others, are involved in the destruction of property, deceitfulness, theft, and violation of rules such as skipping school (American Psychiatric Association 1994). ODD and CD have been found to co-occur in about 30-50% of samples of individuals diagnosed with ADHD (Biederman, 1991; Spencer, 1999). Additional studies have found 40-90% of samples of individuals diagnosed with ADHD to be comorbidly diagnosed with ODD or CD (Jensen, 1997; Biederman, 2007). Numerous explanations for the frequent existence of this comorbidity have been explored. Several studies have found genetic factors that similarly influence CD and ADHD (Silberg, 1996; Thapar, 2000). The comorbid occurrence has also been related to environmental and familial factors (Farone, 1991). Comorbid externalizing disorders been shown to have severe adverse effects and a worse outcome than individuals with a single diagnosis (Jensen, 1997; Kuhne, 1997). In one 10 year longitudinal study it was found that individuals comorbidly diagnosed with ADHD and CD displayed significantly increased risks for psychoactive substance use disorders, smoking, and bipolar disorder (Biederman, 2008). Most relevant to this study, however, is the frequent occurrence of ODD or CD among individuals diagnosed with ADHD and the disorders relationship to working memory.

The relationship between ADHD, ODD, CD, and deficits in executive functioning has been debated in past literature. Various studies have revealed a correlation between working memory deficits and a diagnosis of ODD or CD (Moffitt, 1993; Speltz, 1999; Séguin, 1999; Morgan & Lilienfeld, 2000). The co-occurrence of working memory impairment among individuals diagnosed with ADHD and ODD may be due in part to an extensive overlap of symptoms associated with both disorders and a product of the comorbidity (Pennington & Ozonoff, 1996).

Incongruently, studies have also been unsuccessful in correlating ODD or CD diagnoses with working memory deficits. Oosterlann , Scheres, and Sergeant (2005), evaluated the notion that working memory deficiencies are specifically related to ADHD through the study of 99 children, ages 6-12 years, who were diagnosed with either ADHD, ODD or CD, or had a comorbid diagnosis of ADHD and ODD or CD. The working memory capabilities of participants diagnosed with ADHD and other externalizing disorders were measured using verbal fluency and abstract design tests. The Tower of London and the Self-Ordered Pointing Task were used to measure executive functioning in participants. These two types of tests force the participant to utilize mechanisms in the frontal cortex, and thus, involve working memory. Participants diagnosed with ADHD committed more errors than children without ADHD. Participants diagnosed with either a single diagnosis of ODD or CD or with ADHD and ODD, performed better than participants with a single diagnosis of ADHD. All participants with a diagnosis performed worse than control participants. The presence of ADHD was used to account for any deficits in children also diagnosed with ODD or CD. Based on the results of their study, Oosterlann and colleagues (2005) were able to conclude that executive functioning deficits are unique to ADHD.

In support of this notion several additional studies, using both clinical and non-clinical samples, suggest that deficits in executive functioning should primarily be considered a correlate of ADHD instead of ODD or CD (Kalff et al., 2002; Berlin & Bohlin, 2002; Sonuga-Barke et al., 2002, 2003; Thorell & Wahlstedt, 2006). Using 400 participants, Klormann and Hazel-Fernandez (1999) conducted the largest study on the presence of executive functioning deficits among individuals with either ADHD or ODD. Through the use of the Wisconsin Card Sorting Test and the Tower of Hanoi task executive functioning of participants was measured. Again executive function deficits were found only among participants diagnosed with ADHD (Klormann et al., 1999).

Using several measures of executive functioning, McBurnett, Harris, Swanson, Pfiffner, Tamm, & Freeland (1995) found executive functioning deficits to be associated with ADHD symptoms and not aggressive–defiant behavior, among a group of children between 5 and 12 years old. Past findings, using both clinically referred and population-based samples, indicated that similar deficits are primarily associated with ADHD but not primarily associated with ODD or CD (McBurnett et al., 1995; Moffitt &Henry, 1989; Nigg et al., 1998; Clark et al. 2000).

Clark, Prior, & Kinsella (2000) explored the nature of neuropsychological deficits associated with ADHD by distinguishing them from deficits found in individuals diagnosed with ODD/CD. The study compared 110 adolescents, between the ages of 12 and 15, on measures of executive functioning. Participants were split into four groups: ADHD diagnosis only group, ADHD and ODD/CD diagnoses group, ODD/CD diagnosis only group and a normal community control group. The Six Elements Test and the Hayling Sentence Completion Test were used to measure behaviors associated with executive functioning such as a participant's ability to plan and organize and to generate strategies for ongoing goal-directed behavior. The ADHD-only and ADHD combined ODD/CD groups performed more poorly on measures of executive functioning than the control and ODD/CD-only groups (Clark, 2000). Clark et al. (2000) concluded that individuals with ADHD or a combination of ADHD and ODD/CD displayed significantly more impaired ability to plan and organize information and to monitor or scrutinize their performance on tasks, when compared with age-matched controls and adolescents with ODD/CD only. Ultimately, the study indicated that deficits in executive functioning are associated with ADHD and not with CD/ODD. The notion that executive functioning deficits may be a primary area of concern for individuals with ADHD was also supported by this study (Clark, 2000).

Pennington and Ozonoff (1996) completed a meta-analysis of 18 studies that evaluated executive functioning in children diagnosed with ADHD. All studies included in the evaluation had been published in a referred journal, included a control group, and adapted the notion that the prefrontal cortices play a role in executive functioning. Across the evaluated studies a total of 60 measures of executive functioning were used to assess individuals with and without

ADHD. Of the 60 measures, participants with ADHD performed significantly worse than control groups on 40 of the measures and performed significantly better on none of the measures. Nine studies evaluated executive functioning in samples of individuals with CD and samples of individuals comorbidly diagnosed with CD and ADHD. In their review, Pennington and Ozonoff (1996) found evidence of deficits in executive functioning in samples of CD only when ADHD had not been removed. One sample, Dykeman and Ackerman (1991), revealed that a comorbid CD diagnosis did not further worsen performance on executive function measures in a sample in which all participants were diagnosed with either ADD or ADHD.

An additional diagnosis of ODD or CD may not further impair working memory. However, studies have suggested that children with ADHD and ODD often display elevated levels of ADHD symptoms (Brocki et. al, 2007). Pennington and Ozonoff (1996) speculated that deficits in executive functioning, which exist in comorbid groups, may cause the persistence of antisocial behavior and raise the severity of symptoms in populations diagnosed with both ADHD and CD. It would be helpful to explore the effects multiple diagnoses have on an individual's ability to benefit from Cogmed working memory training.

In the present study, participants received working memory training through the Cogmed computer training program, which utilizes visuospatial and phonological exercises to strengthen working memory functioning (Cogmed America, Inc.) The sample is composed of individuals diagnosed with ADHD and individuals comorbidly diagnosed with ADHD and either ODD or CD. Training sessions were completed 5 times a week for 30-45 minutes and spanned over 5 weeks. The progress of participants with a multiple diagnoses of ADHD and one other externalizing disorder was compared to the progress of participants diagnosed with ADHD and no other externalizing disorder. Past research is inconclusive as to whether children displaying multiple DSM-IV diagnoses achieve the same results from working memory training as children without multiple DSM-IV diagnoses. Based on research by Oosterlaan and others, it was expected that participants with and participants without comorbid diagnoses of externalizing disorders would show similar increments of progress after the working memory training. Both groups exhibiting similar improvement will expand the applicability of Cogmed working memory training. Additionally, this study compared the average amount of time it took both groups to complete Cogmed working memory training. Due to the more oppositional, less compliant, and less invested tendencies of individuals diagnosed with ODD it was expected that the ADHD comorbid group would spend longer working on the program than individuals from the ADHD only group.

Participants

Participants were students of a private academy in a large Midwestern city. The academy specializes in working with children with learning disabilities. To participate, each participant needed to achieve a T-score of 65 or higher on either the working memory subscale from the Behavior Rating Inventory of Executive Functioning (BRIEF) (Gioia, Isquith, Guy, Kenworthy, 2000) or the Inattention scale from the DSM-IV-TR (American Psychiatric Association, 1999). The initial sample consisted of 60 participants. However, 2 participants were unwilling to complete the initial interview, due to lack of time, and consequently were not included in the study. Six participants who did not meet criteria for a diagnosis of ADHD were not included in this study. Additionally, 7 participants were not included in the final analysis due to incompletion of post measures. Of the 45 participants, of whom 11 were female, ages ranged between 7 and 17 (M=11.32). In the sample 100% (45) of participants met the DSM-IV criteria for ADHD. Of the participants 69% (31) displayed predominately inattentive type ADHD, 29% (13) displayed combined type ADHD and 2% (1) displayed hyperactive-impulsive type ADHD. Each participant was assessed for 20 axis I disorders using the parent rated Children's Interview for Psychiatric Syndromes (P-Chips) (Weller, E.B., Weller, R.A., Rooney, Fristad, 1999a, 1999b). Of the 45 participants, 16 participants had comorbid diagnosis of ADHD and oppositional defiant disorder (ODD), 3 participants had a comorbid diagnosis of ADHD and conduct disorder. Participants also had comorbid diagnoses for other Axis 1 disorders, such as anxiety disorders and major depressive disorders. 15 participants were only diagnosed with ADHD In addition to ADHD, 8 participants were diagnosed with 2 other disorders, 4 participants were diagnosed with 3 other disorders, 2 participants were diagnosed with 4 other disorders, and 4 participants were diagnosed with 5 other disorders. The occurrence of disorders other than ADHD, ODD, and CD were not controlled for. Participants were alphabetized and then every other participant was assigned to the experimental group. After both groups received treatment, groups were combined and split according to a diagnosis of ADHD and no other externalizing disorders (*n*=26) and a comorbid diagnosis of ADHD and one other externalizing disorder (*n*=19).

Pre-Screening Measures

Working Memory scales from the BRIEF

The Working Memory scale from the BRIEF (Gioia et al., 2000) was one of two pre-screening measures used to determine a child's eligibility for the sample. The scale consists of 10 questions pertaining to the child's behavior. Parents rated a particular behavior, such as: trouble finishing tasks, trouble remembering things, and having a short attention span, as occurring never, sometimes, or often. Responses were converted to point totals and points were totaled and converted into a T-score. T-scores were used to denote the participant's level of working memory impairment. The threshold of a T-score of 65 or higher determined a participant's eligibility for the study.

Inattention Scale from the DSM-IV-TR

The inattention scale from the DSM-IV-TR (American Psychiatric Association, 1999) was used as the second of two pre-screening measures to determine a child's eligibility for the sample. The scale consisted of 9 items that specified specific behaviors, such as "often being easily distracted by extraneous stimuli" and "often having difficulties organizing tasks and activities" (American Psychiatric Association, 1999). If behavior is expressed "often" parents reply to the items with "yes". If the behavior does not occur at all or just a little parents reply to the item with "no". The number of total "yes" answers was converted into a T-score, which was used to rank the participant's level of Inattention. In order to attain a T-score of 65 at least 6 out of the 9 behaviors had to be marked as "yes".

Parent Rated Children's Interview for Psychiatric Syndromes

The occurrence of ADHD and other disorders were screened for using the Parent Rated Children's Interview for Psychiatric Syndromes (P-ChIPS) (Weller, E.B., Weller, R.A., Rooney, Fristad, 1999a, 1999b). Through a structured interview, with one of the participant's parents, the P-ChIPS were used to determine symptoms, duration, and diagnosis for a variety of DSM-IV disorders. Interviews were conducted by trained interviewers. Parents were asked a series of questions regarding their child's behavior. Interview questions comprise of short sentences which use simple language to ensure comprehension. The parent's answers were used to determine whether or not the behaviors met the criteria for diagnosis and duration of the disorder. The P-ChIPS screens for 20 Axis I disorders, such as attention-deficit/hyperactivity disorder, conduct disorder, anxiety disorders, stress disorders, eating disorders, mood disorders, elimination disorders, and schizophrenia. Psychosocial stressors, other life stressors, and psychoses were also evaluated. In an analysis of the P-ChIPS' sensitivity and specificity it was found that P-ChIPS' psychometrics in nonclinical samples is comparable with that of other structured interviews (Fristad, Glickman, Verducci, et al., 1998b). Agreement on syndrome endorsement between parent and clinician was calculated using percentage agreement. All syndromes, except simple phobia, had a 95.5%-100% agreement rate between parents and clinicians (Fristad, Glickman, Verducci, et al., 1998b). The agreement rate for simple phobia was 72.5%. In an analysis of the validity of the ChIPS, 14 of 16 of the disorder were found to have significant ($p < 0.05$) diagnostic agreement between clinicians and the ChIPS (Fristad, Cummins, et al. 1998a). The remaining 2 of 16 disorders had 98% agreement (Fristad et al, 1998a). The psychometric properties of the P-ChIPS were found to be similar to other structured interviews. Additionally, questions from the ChIPS and the P-ChIPS are the same. However, questions from the P-ChIPS reference the behavior of the child. Therefore the P-ChIPS may be assessed using psychometric data on the ChIPS.

Outcome Measures

Behavior Rating Inventory of Executive Functioning

The Behavior Rating Inventory of Executive Functioning (BRIEF; Gioia et al. 2000) may be used to evaluate executive functioning in children ages 5-18. The BRIEF is a parent and teacher rated questionnaire consisting of 86 items. Each question requires parents and teachers to evaluate the frequency of certain behaviors, with the last month, as occurring never, sometimes, or often. Each behavior pertains to 1 of 8 non-overlapping clinical scales. The 8 scales pertain to behaviors thought to be associated with executive functions. Scales are based on child ratings from 1,419 parents from rural, suburban, and urban areas, reflecting 1999 U.S. Census estimates for social economic status, ethnicity, and gender distribution. Children with developmental disorders or acquired neurological disorders were included in the sample. The 8 clinical scales, both theoretically and statistically derived, shape two expansive indexes; Behavioral Regulation and Metacognition. The Inhibit, Shift and, Emotional Control scales describe the Behavior Regulation index. The Initiate, Working Memory, Plan/Organize, Organization of Materials, and the Monitor scales describe the Metacognition index. The inhibit scale (10 items) relates to an individual's ability to control impulses and stop behavior. The shift scale (8 items) consists of behaviors that describe an individual's ability to move freely from one activity or situation to another and problem-solve flexibly. The Emotional Control scale (10 items) refers to an individual's ability to amend emotional reactions appropriately. The Initiate scale (8 items) relates to problem solving strategies, and an individual's ability to begin a task and generate ideas. The Working Memory scale (10 items) measures an individual's ability to hold and manipulate information short term. The Plan/Organize scale (12 items) relates to an individual's ability to prepare for future events and set goals. The Monitor scale (8 items) measures the ability to check one's work and assess one's performance. Each scale was developed by Gioia et al., 2000. The negativity and inconsistency of responses is measured by the 2 validity scales. Scales are evaluated using normative tables which provide T-scores, percentiles, and 90% confidence intervals organized by the age and gender of the child.

The Conners Rating Scales, short version

The Conners Rating Scale for parents (short and revised) (CPRS-R:S) (Conners, Sitarenios, Parker, Epstein, 1998a) used parent ratings to measure pre and post severity of ADHD symptoms among participants. Additionally, The Conners Rating Scale for teachers (short and revised) (CTRS-R:S) (Conners, Sitarenios, Parker, & Epstein (1998b) used teacher ratings to measures pre and post severity of ADHD symptoms among participants. CPRS-R and CTRS-R short versions are 27 item measures that assess the core constructs of ADHD in children ages 3-17. The 27 questions overlap into 1 or more of 4 subscales; Oppositional subscale (6 items), Cognitive Problems/Inattention subscale (6 items), Hyperactivity subscale (6 items), and ADHD Index (12 items). These subscales evaluate a range of significant problem behaviors that correspond with the DSM-IV's criteria for ADHD. Parents and teachers indicated the frequency of specific behaviors exhibited by the child, during the past month, by indicating whether the behavior was not at all true of their child, just a little true, pretty much true, or very much true. Raw scores in each of the subscales were converted into T-scores and used to place the participant in a percentile rank, by the sex and age of the child.

Cogmed Working Memory Training

Cogmed is an interactive computer program, comprised of mainly visuospatial working memory exercises and phonological working memory exercises, which work to improve working memory abilities (Cogmed America Inc.). For example, one visuospatial exercise required participants to remember and repeat the position of objects in a 4 x 4 grid. Phonological tasks required the participants to remember and repeat phonemes, letters, or digits which were given auditorily. During each training session 15 trials, which rotated between 8 of 12 available exercises, were completed. An optional reward game, RoboRacing, is also included at the end of each session. Cogmed consists of 25 training sessions, which typically occurred 5 times a week and lasted 30-45 minutes. Weekly "coach calls" were made by a certified Cogmed personal coach. Each call consisted of short interviews with the participants and one of the participant's parents. During the coach calls participants were given simple instructions and positive feedback on how to improve their performance during each session. For example, personal coaches suggested that the participant should take a break during the training or complete a specific activity first. During the coach calls parents were given an opportunity to report on any difficulties the child was having with the training, any improvements that had been observed, or report any other thoughts relative to the training. Additionally, each child and parent arranged a system to reward the completion of training sessions. Since the reward system was arranged individually each participant's system varied.

The level of difficulty within each training session is automatically adjusted using a specific algorithm, which forces the participants to perform at one's "peak". For example, if a participant is successful on a trial the difficulty level increases. In conjunction, the difficulty level decreases when the participant misses or is unsuccessful at a trial. Progress in the program is measured by an index score which is based on the average of the child's three best trials in a particular day in two exercises; "visual data link" and "input module with an open lid". These two exercises are used to construct the index score because one, the "visual data link", represents a visuospatial exercise and the other, "input module with an open lid", represents a phonological exercise. Index progress is the difference between the child's start index score and their max index score.

Procedure

Officials at the private academy notified parents about the study and interested families attended an initial meeting regarding the program. During this meeting potential participants were given information on Cogmed Working Memory Training and general information on what participating in the study would entail, such as time and expenses. Interested parents signed a consent form and a parent permission form. Parents also filled out the initial screening measures, the working memory scale from the BRIEF and a scale based on the inattention scale from the DSM-IV-TR. Participants that had a T-score of 65 or higher on either of the screening measures were included in the study. Participants signed a child assent form. All participants were assigned to the experimental or the waiting list control group.

In a subsequent meeting, parents of participants in the experimental group were trained by certified Cogmed coaches to show their children how to use the Cogmed program, how to supervise and encourage their children during the training, and how to implement a reward system that coincides with the training. At the meeting parents completed the outcome measures; the CPRS-S:R and the BRIEF, and the Inattention scale from the DSM-IV-TR. Teachers also completed measures at this time. Control group participants also filled out these measures at the same time. Before training began each participant completed a structured clinical interview, the parent version of the ChIPS (P-ChIPS). Experimental group participants began the Cogmed training program and continued the program over a period of 5 to 6 weeks, completing the training after 25 sessions. Each of the participants completed the Cogmed program in the child's own home. Training was constantly monitored by certified Cogmed coaches through a Cogmed database which allowed coaches to see details of each participants training. Participants in the experimental group received weekly calls from a certified Cogmed coach. During these calls the coach talked with at least one of the parents and the child. Participants were given feedback and further instruction on how to complete the program.

Four weeks after the completion of the program parents from both the experimental and control group, completed outcome measures. Participants in the waitlist control group then attended an informational meeting and began the training. A replication study was conducted with the waitlist control group. Once both groups had completed the working memory training they were combined for analysis. The groups were then split between participants who were diagnosed with ADHD and no other externalizing disorder (n=22) and participants who were diagnosed with ADHD and one other externalizing disorder (n=19). The difference between pre and post scores on the P-BRIEF, T-BRIEF, CPRS-R:S, CTRS-R:S, and Inattention scale from the DSM-IV-TR were used to evaluate performance in both treatment groups.

Statistical Approach

The study's main hypothesis, that there would be no difference in training outcomes between ADHD only and ADHD comorbid groups, was evaluated using one way analyses of variance (ANOVA) and simple linear regressions. An alpha level of .05 was used for all statistical tests. The .05 level was used instead of a lower p-value because analyses are exploratory. All calculations were completed using SPSS 17.0. In a one-way ANOVA change scores on dependent measures from the ADHD only group, the group diagnosed with ADHD and no other externalizing disorders, were compared across change scores on dependent measures from the ADHD comorbid group, the group diagnosed with ADHD and one other externalizing disorders. To calculate change scores for participants post treatment scores were subtracted from pre treatment scores for both groups. Change scores, calculated for each scale from each dependent measure, delineated the increment of change seen between pre and post treatment. In an ANOVA, groups were also compared on the average amount of time each participant spent completing the training. An average active time, based on the time each participant spent completing working memory exercises during each training sessions, for each participant was used in the analysis. Active time did not include any breaks or time between exercises. Effect sizes were calculated using the formula for Cohen's d ($d = M_1 - M_2 / \sqrt{[(s_1^2 + s_2^2) / 2]}$), with S1 and S2 being the standard deviations from pre treatment. The formula includes a pooled baseline standard deviation of both groups, which is a conservative measure of effect size. A simple linear regression was used to measure the relationship between the total number of diagnoses and change scores for each dependent measure.

Results

Measures of Executive Functioning: BRIEF

There was a significant difference when groups were compared on the Monitor scale from the parent-rated BRIEF (P-BRIEF) $F(1,45) = 7.16$, $p = .01$. The participants in the ADHD only group (M = 5.69, SD = 6.28) demonstrated greater improvement on the monitor scale than did the ADHD comorbid group (M = -0.47, SD = 9.19). However, there were no significant differences between groups when compared over the remaining scales form the P-BRIEF, p>.05. No significant differences in improvement were observed between groups on the Working Memory scale from the P-BRIEF $F(1,45) = 0.89$, p>.05. The ADHD only group (M = 8.42, SD = 8.36) experienced similar improvement as the ADHD comorbid group (M = 5.42, SD = 12.97). Effect sizes were found to be small for each scale from the P-BRIEF: less than 0.56. The results of these tests are reported in table 1 along with means and standard deviations for each scale.

There were no significant differences between groups when compared over all the scales from the teacher-rated BRIEF (T-BRIEF). Most importantly there was no significant difference between groups on the level of improvement for the Working Memory scale from the T-BRIEF $F(1,45) = 0.89$, p>.05. The ADHD only group (M = 3.31, SD = 11.92) experienced a similar increment of improvement as the ADHD comorbid group (M = 0.35, SD = 8.34). The results of these tests are reported in table 1 along with means and standard deviations. Effect sizes for each scale from the T-BRIEF were calculated, however all effect sizes were small: less than .25. Effect sizes are reported in table 1.

Measure of ADHD: Conners Rating Scales

Both groups experienced improvement on the ADHD Index from the CPRS-R:S. The results of these tests are reported in table 2 along with means and standard deviations. When groups were compared on the Inattention scale from the Conners Rating Scale for teachers (CTRS-R:S) a significant difference was found $F(1,43) = 3.86$, $p = .05$. The participants in the ADHD comorbid group demonstrated a significantly greater increment of improvement on the Inattention scale from the CTRS-R:S ($M = 3.40$, $SD = 6.33$) than did the ADHD only group ($M = -0.88$, $SD = 8.01$). However, there were no significant results when groups were compared over the remaining scales from the CTRS-R:S. The results of these tests are reported in table 2 along with means and standard deviations. Effect sizes for each scale from both CPRS-R:S and the CTRS-R:S were calculated, however all effect sizes were small: less than 0.05. Effect sizes are reported in table 2.

Measure of Inattention: The Inattention Scale from the DSM-IV-TR

On the Inattention scale from the DSM-IV-TR, no significant difference between groups was found $F(1,45) = .001$, p>05. The ADHD only group ($M = 2.13$, $SD = 3.01$) showed similar improvement as the ADHD comorbid group ($M = 2.10$, $SD = 2.98$). An effect size was calculated for the Inattention Scales, but was small, d = 0.12.

Other Analysis

A simple linear regression model was used to determine the relationship between change scores and an individual's number of total diagnoses. Change scores from each of the dependent measures were calculated and the total number of diagnosis for each participant. Change scores did not significantly increase or decrease as the number of diagnoses increased. Near zero correlations were recorded for each scale on the dependent measures. Results are listed in table 3 and 4

In a one way ANOVA participants were also compared on the average active times taken to complete Cogmed working memory training. There were no significant differences between the average completion times of the ADHD only group when compared to the ADHD comorbid group

Discussion

The present study assessed the effectiveness of working memory training among children and adolescents with a comorbid diagnosis of ADHD and one other externalizing disorder in comparison with children and adolescents diagnosed with ADHD with no other externalizing disorders. As predicted, participants in both groups showed similar improvement after treatment on most scales from the dependent measures. Effect sizes for comparisons were all found to be small. Small effect sizes suggest that clinically significant differences between the groups were not significant.

However participants did vary significantly on measures of the Monitor scale from the parent rated BRIEF and the Inattention scale from the CTRS-R:S. Contrary to the hypothesis, children and adolescents diagnosed with ADHD only experienced significantly greater improvement than did children and adolescents comorbidly diagnosed with ADHD and one other externalizing disorder on the Monitor scale from parent-rated BRIEF. Additionally, children and adolescents from the ADHD only group experienced significantly less improvement on the Inattention scale from the CTRS-R:S than children and adolescents comorbidly diagnosed with ADHD and one other externalizing disorder. Both groups showed similar improvement on the Working Memory scale from both the P-BRIEF and the T-BRIEF. It is important to note that both groups experienced a decrease in the severity of ADHD symptoms based on group means from the ADHD Index from the Conners Rating Scale for teachers and parents. No linear relationship was found to exist between mean change scores and the total number of diagnoses for each participant. Additionally, no significant difference between groups was found for the average length of time each participant took to complete the training sessions.

The ADHD comorbid group demonstrated significantly less improvement on the monitor scale from the P-BRIEF when compared to the ADHD only group. The monitor scale specifically measures an individual's ability to check one's work and assess their performance on a task. Children and adolescents diagnosed with ODD often blame others for their mistakes (American Psychiatric Association, 1994). Therefore, children and adolescents comorbid with ADHD and ODD may display a lesser ability to assess performance on a certain task because they may attribute failures to external sources instead of to themselves. This is one possible explanation of why the ADHD comorbid group would be less likely to show improvements on the monitor scale than the ADHD only group.

The ADHD comorbid group demonstrated significantly more improvement on the Inattention scale from the Conners Rating Scale for teachers when compared to the ADHD only group. This result is puzzling and unexpected. Groups were compared across 24 total scales at the .05 level. Due to the fact that groups were compared on a large number of measures and at the .05 level, it was expected that by chance at least one scale would show a significant difference. Additionally, effect size was very small for the Inattention scale. Individuals with ODD and CD tend to exhibit behavior patterns that can be disrupting in a class setting. It has been speculated that perhaps the more disorderly patterns of behavior that are symptomatic of individuals with ODD and CD were attuned to by the teacher more than the behaviors of individual without ODD or CD. Children and adolescents from the ADHD only group may not have displayed disruptive behaviors which demanded the attention of the teacher and were therefore less memorable. For example, arguing with the teacher, a behavior characteristic of individuals with ODD would be more disruptive and demand more attention from the teacher than a child who daydreams during class, a behavior characteristic of decreased inattention. Due to varying levels of attention, it is possible that when teachers completed the Conners Rating Scales inventory they may have had stronger memories of behaviors exhibited by individuals from the ADHD comorbid group.

As expected, different results were reported on the parent-rated measures when compared to teacher-rated measures. The correlation between parent and teacher ratings on the Conners Rating Scales is about .50 for the ADHD scale. (Conners, 1998) However, correlations between parent and teacher ratings are lower among the remaining scales (.12-.55) (Conners, 1998). The correlations demonstrate that overall parents and teachers are in general agreement on the severity of the core symptoms of ADHD. In an analysis of the validity of the Conners Rating Scales it was discovered that teacher ratings yielded a significantly greater false positive rates (17%-18%) than did parent ratings (2%-8%) (Conners, 1998). In the present study, the ADHD comorbid group, when compared with the ADHD only group, showed a significantly greater level of improvement on the Cognitive Problems/Inattention scales from the CTRS-R:S only.

Additionally, the ADHD comorbid group, when compared with the ADHD only group, showed a significantly lower level of improvement on the Monitor scale from the P-BRIEF only. In addition to small correlations between parent and teacher ratings, these finding may also be explained by the different sets of behaviors observed in parent and teacher settings. For example, specific behaviors such as fidgeting may be more noticeable in a classroom setting.

Implications

First of all, based on the study's findings it may be concluded that children and adolescents with ADHD and working memory deficits experience similar benefits from Cogmed working memory training regardless of the number of additional Axis I disorder diagnoses, specifically ODD or CD. As previously stated, the presence of multiple diagnoses often results in a more severe form of the disorders (Jensen, 1997; Kuhne, 1997). Based on the similar increment of improvement experienced in both groups it may be inferred that having multiple diagnoses, and possibly more severe behavior patterns, does not interfere with an individual's ability to successfully complete the Cogmed working memory training. According to the results of this study, more oppositional behaviors seen among individuals with ODD or CD do not interfere with training results. Therefore, children and adolescents seeking working memory improvement should not be discouraged from completing a working memory training program on the basis of number of DSM-IV diagnoses.

By strengthening the applicability of Cogmed working memory training to comorbid populations the efficacy of the treatment is also strengthened. The results of this study, in addition to the results of Beck et al.'s unpublished manuscript (2009), further support the use of working memory training as one treatment option for ADHD. Beck et al. found that treatment improved working memory and lowered ADHD symptoms. The decrease in severity of working memory impairments specifically demonstrates the successfulness of the treatment at treating working memory deficits. Using the same sample, Beck et al. found significant improvements among participants using both the parent and teacher rated BRIEF and the Conners Rating Scales.

Past research has suggested a correlation between working memory deficits and the occurrence of ADHD (Barkley, 1997; Castellanos and Tannock, 2002; Rapport et al., 2000, Westerberg H., 2004). It has been suggested that the decreased ability to use cognitive functions associated with working memory, such as holding and manipulating information short term, may relate to behaviors which are symptomatic of individuals with ADHD. Additionally, Klingberg et al. (2005) and Beck et al. (2009) have suggested that by increasing working memory functioning through working memory training ADHD symptoms will be simultaneously decreased. The results of this study, the decrease in working memory impairment combined with the decrease in severity of ADHD symptoms seen by both groups, supports the association between working memory and symptoms of ADHD.

Past research has stated that deficits in working memory should primarily be considered a correlate of ADHD and not ODD or CD (Oosterlann et al., 2005; Clark, 2000; Klormann & Hazel-Fernandez, 1999; Pennington & Ozonoff, 1996). As in the previous research, this study suggests that deficits in working memory may correlate with ADHD but not with ODD or CD. Children and adolescents from the ADHD comorbid group did not display significantly different levels of working memory impairment at baseline, based on the working memory scale from both the parent and teacher rated BRIEF, than the ADHD only group. An additional diagnosis of ODD or CD did not lead to increased impairment of working memory functioning. This tentatively suggests that the working memory deficits were independent of the occurrence of ODD or CD.

Limitations and Future Directions

One short coming of the study is the lack of blindness on the parent reports. Parents were aware and observed their child's working memory training. The lack of blindness may have created an expectancy bias that led parents to rate their children as exhibiting rated behaviors less frequently (Caspi & Bootzin, 2002). However, teachers were blind to which students were in the experimental group and which were in the control group. In the present study follow up data was not analyzed to confirm the retention rates of working memory improvement for both groups. Past studies, Klingberg et al. (2005) and Beck et al. (2009) have found training effects to positively increase at follow-up. Children and adolescents in the present study had other diagnosis in addition to ADHD, ODD, and CD. However, it is worth noting that no linear relationship was found to exist between total number of disorders and level of improvement based on working memory training. Future studies may want to limit their inclusion criteria to individuals diagnosed with only ADHD or a combination of ADHD and ODD or CD.

In future studies it may bolster results to use a double blind manipulation as well as explore several other areas related to Cogmed working memory training. Future studies might consider assessing the effects of working memory training on children and adolescents comorbid with ADHD and other disorders, such as anxiety disorders and depression. Like ODD and CD, anxiety disorders are also frequently comorbidly diagnosed with ADHD (Faraone, Biederman, Weber, & Russell, 1998). Anxiety disorders occurred in about 20-40% of ADHD cases (Wells, Chi, Hinshaw, Epstein, Pfiffner, & Nebel-Schwalm, et al., 2006). It would also be worthwhile to explore the effects of working memory training for other targeted high risk populations. For example, individuals with strokes often experience working memory impairment (Westerburg et al., 2007). It is known that an individual's working memory capacity begins to decrease between the ages of 25 and 30 (Klingberg, Forssberg, & Westerberg, 2002; Klingberg et al., 2005). On average, individuals lose between 5% and 10% of their working memory capacity every decade (Klingberg et al., 2002; Klingberg et al., 2005). It would be interesting to explore the effects of regular working memory training on this gradual decay of working memory.

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Tables and Figures

Table 1: Parent and Teacher Ratings from the BRIEF for ADHD only group compared to ADHD comorbid group

	ADHD ONLY		ADHD COMORBID				
Measure and Scales	**M**	**SD**	**M**	**SD**	**F**	**p**	**ES**
Parent							
BRIEF Inhibit	7.15	11.35	2.84	9.55	1.81	0.19	0.27
BRIEF Shift	6.19	10.88	3.21	11.28	0.80	0.38	0.21
BRIEF Emotional Control	2.92	7.25	4.53	10.10	0.39	0.54	-0.14
BRIEF Initiate	7.15	11.35	2.84	9.55	1.81	0.19	0.40
BRIEF Working Memory	8.42	8.36	5.42	12.97	0.89	0.35	0.30
BRIEF Plan/Organize	7.12	6.69	5.63	11.49	0.30	0.59	0.17
BRIEF Organize Materials	4.62	5.73	1.05	10.17	2.23	0.14	0.42
BRIEF Monitor *	5.69	6.28	-0.47	9.19	7.16	0.01	0.56
	M	**SD**	**M**	**SD**	**F**	**p**	**ES**
Teacher							
BRIEF Inhibit	0.50	11.39	-1.95	7.88	.675	0.42	0.05
BRIEF Shift	-1.12	15.71	-3.10	8.91	0.26	0.62	0.25
BRIEF Emotional Control	-0.85	12.14	0.00	6.21	0.08	0.78	-0.01
BRIEF Initiate	1.50	11.31	2.00	9.85	0.02	0.88	-0.03
BRIEF Working Memory	3.31	11.92	0.35	8.34	0.89	0.35	0.16
BRIEF Plan/Organize	-0.77	9.23	-0.75	8.23	0.00	0.99	0.00
BRIEF Organize Materials	3.58	14.18	-1.90	8.64	2.32	0.14	0.24
BRIEF Monitor	1.08	10.87	0.60	7.32	0.03	0.87	0.03

*p<.05

Table 2: Parent and Teacher Ratings from the Conners Rating Scale for ADHD only group compared to ADHD comorbid group

	ADHD ONLY		ADHD COMORBID				
Measure and Scales	**M**	**SD**	**M**	**SD**	**F**	**p**	**ES**
Parent							
Conners Oppositional	4.42	7.97	3.74	6.86	1.81	0.76	0.05
Conners Hyperactive	4.77	11.70	6.89	11.73	0.80	0.55	-0.14
Conners Inattention	5.85	7.88	6.68	10.63	0.39	0.76	-0.08
Conners ADHD Index	5.65	8.54	7.47	9.59	1.81	0.51	-0.14
	M	**SD**	**M**	**SD**	**F**	**p**	**ES**
Teacher							
Conners Oppositional	0.60	12.94	1.40	6.19	0.06	0.80	-0.06
Conners Hyperactive	1.46	8.69	2.35	7.49	0.13	0.72	-0.06
Conners Inattention*	-0.88	8.01	3.40	6.33	3.86	0.05	-0.40
Conners ADHD Index	1.23	10.50	1.70	8.40	0.03	0.87	-0.03

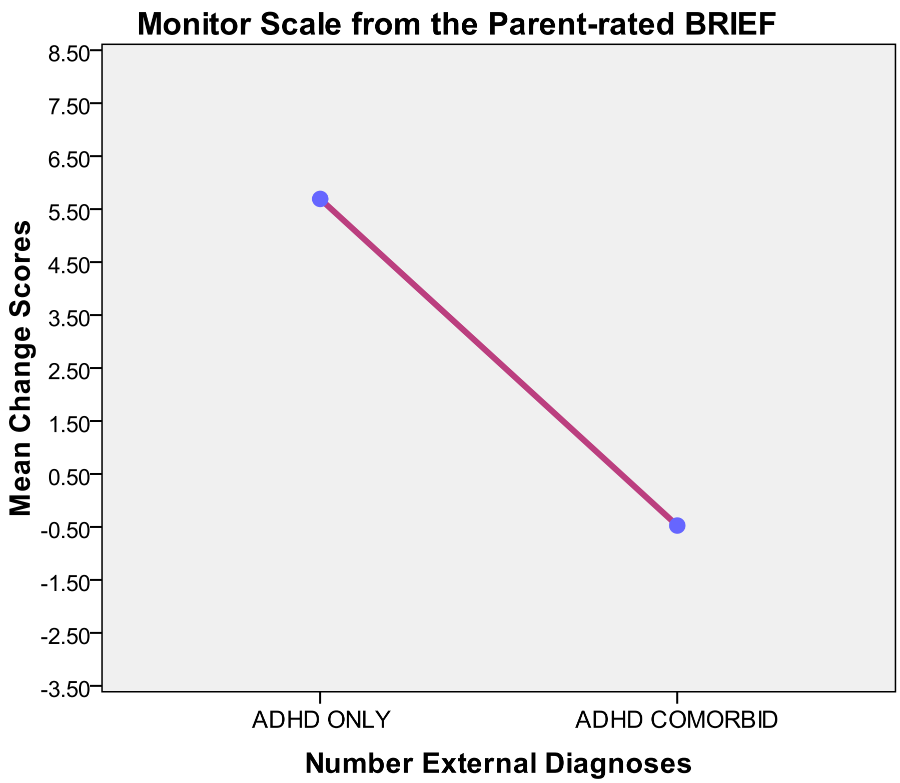
*p<.05

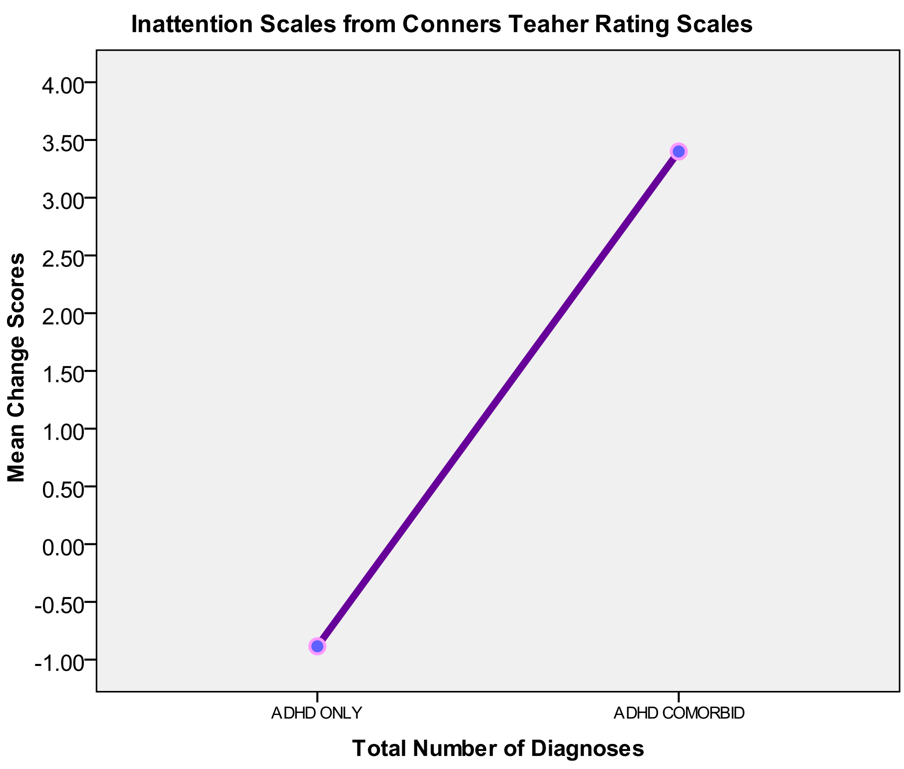
Table 3: Total Number of Disorders Compared to Change Scores for Parent and Teacher Rated BRIEF

Source	**R**	**R^2**	**p**
Parent			
BRIEF Inhibit	0.00	0.00	0.99
BRIEF Shift	0.14	0.02	0.36
BRIEF Emotional Control	0.41	0.17	0.00
BRIEF Initiate	0.00	0.00	0.99
BRIEF Working Memory	0.17	0.03	0.25
BRIEF Plan/Organize	0.05	0.00	0.76
BRIEF Organize Materials	0.11	0.01	0.46
BRIEF Monitor *	0.05	0.00	0.76
	R	**R^2**	**p**
Teacher			
BRIEF Inhibit	0.01	0.00	0.93
BRIEF Shift	0.01	0.00	0.96
BRIEF Emotional Control	0.03	0.00	0.86
BRIEF Initiate	0.01	0.00	0.96
BRIEF Working Memory	0.13	0.02	0.38
BRIEF Plan/Organize	0.03	0.00	0.86
BRIEF Organize Materials	0.01	0.00	0.93
BRIEF Monitor	0.07	0.00	0.64

Table 4: Total Number of Disorders Compared to Change Scores for Parent and Teacher Rated Conners

Source	**R**	**R^2**	**p**
Parent			
Conners Oppositional	0.07	0.00	0.66
Conners Hyperactive	0.21	0.04	0.15
Conners Inattention	0.04	0.00	0.78
Conners ADHD Index	0.08	0.01	0.60
	R	**R^2**	**p**
Teacher			
Conners Oppositional	0.06	0.00	0.70
Conners Hyperactive	0.02	0.00	0.84
Conners Inattention*	0.13	0.01	0.81
Conners ADHD Index	0.00	0.00	0.98


Monitor Scale from the Parent-rated BRIEF
8.50
7.50
6.50
5.50
4.50
3.50
2.50
1.50
0.50
-0.50
-1.50
-2.50
-3.50
Mean Change Scores
ADHD ONLY
ADHD COMORBID
Number External Diagnoses


Inattention Scales from Conners Teaher Rating Scales
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
Mean Change Scores
ADHD ONLY
ADHD COMORBID
Total Number of Diagnoses