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**The Relationship of the Conners Continuous Performance Test
and Neuropsychological Tests of Attention
in an Adult Population**

by

Jeannine B. Mielke

B.A. University of Central Florida, 1994

M.A. University of Montana, 1998

presented in partial fulfillment of the requirements

for the degree of Doctor of Philosophy

The University of Montana

2001

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Director: Stuart Hall

The diagnosis and assessment of Adult ADHD has risen dramatically in the last several years, due in part to the public's increased awareness through the popular media. The purpose of this study was to explore the relationship between scores derived from the Conners Continuous Performance Test (CPT) with other commonly used neuropsychological measures of attention in an adult population. Participants included two groups of 36 adults age 18 to 57. The first group was a mixed Clinical Group of patients referred for neuropsychological testing (diagnoses included, head injury, mood disorder, attention deficit disorder, neuropsychological disorder not otherwise specified, or a combination of these disorders). The second group, the Control Group, was comprised of adult volunteers from the community matched for age, education, and gender to the Clinical Group participants. The Control Group performed significantly better on all tests given than the Clinical Group. Several statistically significant correlations were found within the Clinical Group for tests sensitive to executive function, processing speed, and complex attention. No statistically significant correlations were found in the Control Group test results. The Control Group demonstrated higher false positive rates than expected on the CPT measures. False positive rates were higher than cited in the manual and may be a result of the limited normative database for adults. The rate of false positive determinations was especially high for females as compared to males in this study, in contrast to the prevalence rates reported in the general population which indicate a much higher rate of diagnosis of ADHD for males. Older participants in this study were less likely to be categorized false positively than younger participants. This may have been due to a higher level of education, although not statistically different level of education, among the older participants. These results should be interpreted with caution due to the limited sample size and mixed clinical diagnoses.

Dedication

This project is dedicated to:

Mark L. Mielke

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There are many people to whom I am indebted for helping me with this dissertation. First, and foremost, I need to thank Stuart Hall, Ph.D., for the education and training in neuropsychology that made it possible to pursue this project and for his perseverance and guidance in seeing this project through to the end.

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Chapter One

Review of the Literature

Attention deficit hyperactivity disorder (ADHD) has become an increasingly common diagnosis in children, particularly in the United States and Europe. It has a prevalence rate of 3% to 5% in school age children with a ratio ranging from 4:1 to 9:1 occurrence in males versus females (American Psychiatric Association, 1994). Due to the increase in diagnosis, despite the relatively low prevalence rate, the assessment, pattern of deficits, course, and diagnostic features, of ADHD in children have been the focus of considerable research over the past two decades. This has not been the case in adult ADHD. Despite a rapid increase in the assessment and diagnosis of Adult ADHD, similar to that seen previously in children, research on adult ADHD, its diagnostic features, course, assessment, and treatment, has been sparse.

The diagnosis of attention deficit hyperactivity disorder (ADHD) in adults, as it was with children, has been a source of controversy. Experts have differed widely in their perception of the disorder, ranging from questioning its existence to suggesting it is an urgent clinical problem (Faraone, 2000). The medical and psychology fields are now seeing an increase in the diagnosis of ADHD in adults paralleling the early years of ADHD diagnosis in children. This trend has been exacerbated by popular accounts of the disorder and broad media coverage (Epstein, Conners, Sitarenios & Erhardt, 1998) and the "acceptability" of the diagnosis which may result in the prescription of restricted drugs, and/or financial compensation. The rapid proliferation of self-referral (Johnson-

Greene & Emery, 1999) for neuropsychological assessment of ADHD in adults, and the lack of research on adult populations regarding the assessment of ADHD, led professionals in the field of neuropsychology to hold the following symposium.

The International Neuropsychological Society's annual scientific conference was held in Boston, Massachusetts, in February 1999. At this conference a symposium was conducted entitled, Diagnosis Du Jour? Research and Perspectives on Adult ADHD, (Mapou, 1999). Several issues were identified: the rapid increase in self-referral by adults for evaluation of ADHD, (Johnson-Greene & Emery, 1999) the need for adequate diagnostic criteria for the assessment and diagnosis of Adult ADHD, (Mapou, 1999; Quinlan & Brown, 1999; Epstein, Johnson, & Conners, 1999) the lack of research on neuropsychological tests of attention and concentration on an adult population, and the treatment of adults diagnosed with ADHD, (Mapou, 1999).

With regard to the increase in self-referrals of adults for diagnosis of ADHD, it was hypothesized that adults have become very familiar with the symptoms and diagnosis of childhood ADHD. The popular media has contributed to the public's awareness, portraying ADHD in a more positive light than other possible psychiatric diagnoses, such as depression. It was suggested that the increased familiarity and the de-stigmatization of the diagnosis of ADHD resulted in more adults presenting themselves with symptoms that they associated with ADHD. One study reported that only 4 out of 33 consecutive adult patients of an HMO in an urban area, presenting as self-referred for the assessment of ADHD, met the criteria for diagnosis of ADHD (Johnson-Greene & Emery, 1999). The risks of misdiagnosing adults with self-reported symptoms of ADHD could include

failure to address and treat comorbid or separate disorders with similar symptoms, such as learning disabilities, conduct disorders, mood disorders, and anxiety.

With regard to assessment of ADHD in adults, speakers put forth the issue of the lack of research on and development of instruments specifically designed for use in adult populations as opposed to the extrapolation of findings on instruments developed and normed for the assessment of ADHD in children to adults. Clarification of the deficits defining ADHD in adults was also addressed. It has been suggested that the defining deficit in children with ADHD is a deficiency in behavioral inhibition/response inhibition, a pattern expected to be paralleled in adult studies. Recent research on an adult population has suggested that inattention, rather than response inhibition may be the defining deficit in adults. The difference in defining symptomatology across the age span was hypothesized to be a result of maturational factors, specifically the development of the frontal lobes and executive function (Walker, Shores, Trollor, Lee, & Sachdev, 2000).

Treatment of adult ADHD was also addressed. Treatment of ADHD typically involves individual or group therapy, structured behavioral plans, and/or medication. Methylphenidate (Ritalin), a stimulant, has been shown to improve the function of children with ADHD and has been widely prescribed, but few studies have addressed the use of medication, or any other treatment on an adult population. The symposium highlighted the need for further research on the assessment, diagnosis, and treatment of adult ADHD. Since the time of the symposium, several studies regarding medication treatment have been conducted. A study by Riordan, Flashman, Saykin, Frutiger, Carroll, and Huey, 1999, that included a yoked group of normal controls, found that adult patients

with ADHD, with and without depression, benefited from a trial of methylphenidate. A group of studies (Spencer, Wilens, Biederman, Faraone, Ablon, & Lakey, 1995; Heiligenstein, Johnston, Neilsen, 1996; Levin, Evans, McDowell & Kleber, 1998; Spencer, Wilens, Biederman, Bostic, Prince, Gerard, et al., 1999) reviewed by Faraone, 2000, found three stimulants (methylphenidate, Adderall, and magnesium pemoline) and tricyclic antidepressants had significant positive effects on adults diagnosed with ADHD as compared to adults with ADHD given placebo treatment. These results suggest, that with accurate diagnosis, adults with ADHD have options including medication for relief of their symptoms.

The present study addressed the need for research on neuropsychological tests for the assessment and diagnosis of ADHD in adults. To date, most of what is known is based on research using neuropsychological instruments found to be sensitive to executive function, attention, and concentration deficits associated with ADHD in children, based on current diagnostic criteria.

DSM-IV ADHD CRITERIA

The essential features of ADHD as defined by the DSM-IV and DSM-IV-TR are a persistent pattern of inattention and/or hyperactivity-impulsivity that is more severe or frequent than typically observed in individuals at a comparable level of development. Some symptoms of inattentive or hyperactivity/impulsivity behavior must have been present before seven years of age and be present in at least two settings, e.g., academic, occupational, and/or home. There must be evidence of interference in function in social,

academic, or occupational pursuits. The deficits must not be better accounted for by another mental disorder. (American Psychiatric Association, 1994 & 2000).

ADULT ADHD

ADHD and its associated symptoms were originally thought to occur only in childhood. ADHD was conceptualized as a disorder that children outgrew in late adolescence or early adulthood. Research conducted in the 1990's began to dispute this theory (Barkley, Murphy & Kwasnik, 1996; Denckla, 1991; Epstein, Conners, Sitarenios & Erhardt, 1998).

Denckla, 1991, reviewed longitudinal studies of children with ADHD. Hyperactivity and poor concentration persisted into the adult lives of these children at rates of up to 50%, with hyperactivity manifesting itself as restlessness. This restlessness and lack of concentration resulted in the attainment of lower levels of education, more frequent job changes and more frequent changes of important intimate relationships in comparison to controls.

Barkley et al., 1996, used a continuous performance test (CPT) to assess inattention and impulsivity in young adults diagnosed with ADHD and compared the results to a control group of nondisordered young adults. Compared to the control group, the young adults with ADHD made significantly more errors indicative of attentional difficulties, (omission responses-failure to respond to a target stimulus and commission responses-responding to an incorrect stimulus similar to the target stimulus). Epstein, et al., 1998, also used a continuous performance test to assess inattention, sustained attention, and impulsivity with similar results. The participants were all adults. Those with ADHD had

a mean age of 35. The Control Group had a mean age of 25. Because of the discrepancy in ages, age was used as a covariate in all the between-participants comparisons.

The results indicated that the participants diagnosed with ADHD had significantly more errors of omission, commission, and signal detection-recognizing and discriminating a target stimulus from a group of similar stimuli.

More recently, a few studies have evaluated the pattern of deficits in cognitive function in adults with ADHD compared to those of children with ADHD. Although the findings have been variable, several deficits have been consistent for both children and adults with ADHD that look functionally similar to frontal lobe dysfunction (Walker, Shores, Trollor, Lee, & Sachdev, 2000). These include deficits in frontally-mediated executive functions, memory, learning, attention, concentration, verbal fluency, and psychomotor function, as measured by neuropsychological instruments.

Findings in both structural and functional neuroimaging studies, although limited by small sample size, have also demonstrated a pattern of frontosubcortical system dysfunction implicated in the pathophysiology of ADHD (Faraone & Biederman, 1998). The frontal lobes and the pathways that project into the frontal lobes appear to be involved in the deficits associated with ADHD in both adults and children. A disruption in function at any point along this pathway may result in difficulties with attention.

Not all deficits associated with ADHD have been found consistently in both adults and children. One inconsistent finding between children diagnosed with ADHD and adults diagnosed with ADHD is the role of impulsivity. It is a core feature of ADHD in children. Children with ADHD display impulsive response patterns on

neuropsychological testing as well as in observational studies. In some research, impulsivity in adults with ADHD appears to be within normal limits, possibly reflecting maturational development of the frontal lobes and executive function (Walker et al., 2000). Adults with ADHD may also be better able to inhibit behaviors within the structure of the testing situation compared to children. Differences may also be attributed to insufficient means of assessment and methodological problems.

Denkla's data suggested half the children diagnosed with ADHD would continue to manifest symptoms in adulthood. Long-term follow up studies indicated that 30% to 60% of cases of ADHD in children would persist into adulthood (Mannuzz, Klein, Bessler, Malloy, & LaPadula, 1993; Weiss & Hechtman, 1993). These findings supported the inclusion of ADHD as an adult disorder in the current American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders – IV - TR, edition (DSM-IV-TR). However, until further research is conducted, the prevalence rate of Adult ADHD is still listed as unknown in the DSM – IV - TR (American Psychiatric Association, 2000).

ASSESSMENT OF ADHD

The evaluation of ADHD involves a broad spectrum assessment that relies heavily on self-report regarding personal, academic and occupational history. Obtaining information from individuals familiar with the patient's history, i.e., parents, siblings, teachers, supervisors and documentation of academic achievement and work history are also important. Medical and neuropsychological testing may be conducted to rule out other disorders with similar symptoms.

The diagnosis in childhood is facilitated by the availability of historical and current behavioral information from the sources closest to the patient, (e.g., parents, teachers and other observers). For adults presenting with ADHD the diagnosis is more complicated. The patient's self report may be colored by a bias towards diagnosis for secondary gain or the natural limitations of recall (Epstein, et al., 1998). Additionally, finding observers close to the patient and familiar with their long-term history may be difficult due to the often chaotic and unstable life patterns of adults presenting with ADHD (Denckla, 1991). It is because of the difficulty obtaining other's reports and historical information that objective tests of core indicators of ADHD such as, inattention, sustained attention, and impulsivity, have been developed. These measures will aid in the diagnosis of ADHD, specifically in adults, but also in children, through a multidimensional assessment battery.

Continuous Performance Tests

One type of objective indicator developed for use in the diagnosis of inattention, sustained attention, and impulsivity is the continuous performance test (CPT). Continuous performance tests are characterized by the following principles: the patient is tested alone with only the examiner in a distraction-free environment, the patient is asked to push a lever or press a space bar on a key board in recognition of a target letter or number and not to press for any other letter/number displayed. The letters/numbers are presented one at a time on a screen in front of them. The letters come at various interstimulus intervals (ISI) dependent upon the specific CPT. The scores used may be the total correct responses, errors of commission, errors of omission, and in some CPTs, signal detection scores and reaction times. Errors of omission have been considered

indicative of inattention and errors of commission have been considered indicative of impulsivity.

Rosvold, Mirsky, Sarason, Bransome, and Beck, 1956 developed the first CPT for the purpose of studying brain-damaged individuals, not specifically attention deficit disorders. They theorized that brain-damaged individuals would perform normally on short attention tests such as the digit span or digit symbol tests of the Wechsler-Bellevue intelligence scale but perform more poorly on the CPT requiring sustained attention and alertness. They based their hypothesis on the fact that EEG's of brain damaged individuals indicated random bursts of high amplitude (hypersynchronous) activity that interferes with normal activity resulting in reduced vigilance and attention. Rosvold et al. hypothesized that the momentary lapses of attention would not be revealed by the short tests but would be revealed in the 10 minute CPT. Rosvold et al., results supported their hypothesis. Brain-damaged individuals scored more poorly than nonbrain-damaged individuals in both child and adult populations. It was suggested that the inferior performance of the brain-damaged group resulted from decreased alertness. However, other explanations for inferior performance, such as global cognitive deficits, could not be ruled out.

Research followed the development of the first CPT to corroborate its use as an instrument to detect inattention and impulsivity and to correlate these findings with behavioral indicators of ADHD, (e.g., teacher/parent ratings scales). Results have been mixed in the use of the CPT in its original form and in subsequent adaptations (Barkley, 1991; DuPaul, Anastopoulos, Shelton, Guevremont, & Metevia, 1992; Halperin, Sharma,

Greenblatt, & Schwartz, 1991; Klee & Garfinkel, 1993; Schachar, Logan, Wachsmuth, & Chajczyk, 1988; Trommer, Hoepfner, Lorber, & Armstrong, 1988).

Klee & Garfinkel, 1983, used Rosvold's continuous performance test concept, adapted for use on an Apple II computer, to evaluate the performance of children hospitalized with a variety of psychiatric diagnoses. Results of Klee and Garfinkel's study indicated that CPT scores were highly correlated with age, behavioral rating scales, and the Kagan (1964) Matching Familiar Figures Test (MFFT), a neuropsychological measure of reflectivity/impulsivity in children.

Schachar, Logan, Wachsmuth, and Chajczyk, 1988, conducted a study controlling for diagnosis, age, and IQ of children diagnosed with ADHD with or without learning disabilities or conduct disorder and 15 control participants, all male. The participants were administered an adaptation of the Rosvold et al., CPT, lasting 45 minutes. Schachar et al., results indicated that the ADHD groups, regardless of comorbid diagnosis, did not perform below controls on sustained attention tasks but did score below controls on tasks of impulsivity. Schacher et al., also found that IQ was not a factor in performance, but age was significantly correlated with CPT performance and reaction time.

The finding of IQ as not a significant factor in CPT performance is in direct opposition to the findings of Trommer, Hoepfner, Lorber, & Armstrong, 1988. Trommer et al., used a newer version CPT, the Gordon Diagnostic System Vigilance Task, 1986. Trommer et al., found that cognitive ability, specifically IQ scores, were positively correlated with performance on the Gordon CPT for children diagnosed with Attention Deficit Disorder and controls. Trommer also found contradictory evidence in the

correlation of CPT scores and behavioral rating scales. In this study of children with ADD, there was no relationship between behavioral rating scales and performance on the Gordon CPT. A larger percentage (83%) of participants rated behaviorally as normal received below normal scores on the CPT in comparison to 71% of participants rated ADD.

One important difference between the Rosvold et al., CPT and the Gordon CPT is the administration apparatus. The original Rosvold et al., CPT was administered via a mechanical device consisting of a drum with letters illuminated one by one on its surface. The Gordon CPT was administered via microprocessor with a display panel and a response button. The two tests also differed in type of stimulus, the Rosvold et al., CPT used letters as target stimuli, the Gordon CPT used numbers as the target stimuli. Both tests required the participant to press the response button every time they saw a recurrent two-digit sequence (Trommer et al., 1988).

Halperin, Sharma, Greenblatt & Schwartz, 1991, conducted a study of 138 nonreferred 7 - 11 year old boys comparing their performance on a computerized version of the Rosvold et al., CPT to their performance on a variety of neuropsychological measures and behavioral rating scales. Age was a significant factor in performance. No CPT measures significantly correlated with the conduct problems factor of the Conners Teacher Questionnaire (CTQ), a behavioral rating scale. The CPT measure of False alarms was significantly correlated to the Inattention/Passivity factor of the CTQ. CPT measures were significantly, but not robustly, correlated with reading and decoding ability as measured by the Wide Range Achievement Test-Revised (Jastak & Wilkinson,

1984). Measures of the CPT were also unrelated to two other verbal performance measures, the Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981) vocabulary score and the Peabody Individual Achievement Test-Revised, (Markwardt, 1989), reading comprehension score (Halperin, et al., 1991).

Barkley, 1991, analyzed the ecological validity of continuous performance tests, specifically the Gordon CPT, in the evaluation of ADHD. In other words, do errors of omission and commission reflect behaviors core to ADHD in natural settings? Barkley's study included 140 ADHD children (6 - 11) and 159 ADHD adolescents (12 - 20). Scores of both groups on the Kagan Matching Familiar Figures Test (MFFT) and direct observations of target behaviors were correlated with the omission and commission scores on the Gordon CPT. Omission scores and commission scores were significantly correlated with the total number of errors on the MFFT and total ADHD behavior ratings scores in children 6 - 11 years old. Omission scores were not significantly correlated to any scores for adolescents 12 - 20 years old. Commission scores were significantly correlated to individual behavior ratings scores and the Total ADHD behavior rating score for adolescents 12 - 20 years old. Although the correlations were not robust (.26 - .44), Barkley found evidence to support the ecological validity of the Gordon CPT test in the assessment of ADHD in children. The Gordon CPT discriminated ADHD participants from normal controls but not from other clinical populations. The Gordon CPT was also found, in this study, to be related to observer ratings and other clinical measures, e.g., the MFFT.

In 1992, DuPaul, Anastopoulos, Shelton, Guevremont, & Metevia conducted a study utilizing the Gordon CPT. Participants were 68 children referred for ADHD assessment. DuPaul et al., compared the Gordon CPT scores to scores on behavioral ratings scales, and the neuropsychological test, the MFFT. Results indicated that the two clinic tests, the Gordon CPT and the MFFT failed to classify as ADHD nearly 40% of the participants who were diagnosed as ADHD. Furthermore, all correlations between behavioral ratings scales and Gordon CPT scores were nonsignificant (DuPaul et al., 1992).

As evidenced by the literature, there has been considerable variability in the relationship between CPT test results, other diagnostic criteria, and the diagnosis of ADHD in child populations. One possibility is that the relationship between these variables is weak. Another explanation for the inconsistent findings may be the different versions of CPTs administered to different populations, and the small sample size of some studies (Halperin, et al., 1991). These variable findings have led to continued development and refinement of the continuous performance tests and more rigorous control of variables in individual studies.

CONNERS CPT

In 1992 a new version of the CPT became available to researchers and clinicians developed by C. Keith Conners. In many ways this CPT retains the characteristics of the previous models. It is a computerized test administered in a distraction-free environment with an examiner present. The participant views letters approximately one inch high that appear one at a time on the monitor. It is the participant's task to discriminate responses

for all letters other than X. The administration of the Conners CPT differs from other CPTs in that instead of responding for the X and not the other letters, the participant is asked to press the space bar for any letter except X. In other words, they are to inhibit their response to the target letter X. Conners research indicated that previous CPTs may have been too easy resulting in ceiling effects. By making the test more difficult, Conners hypothesized that the test would gain greater face validity (Conners, 1992). There has been some criticism of this hypothesis. Barkley, 1991, questioned whether increasing the difficulty of a CPT would make it more a test of higher cognition, executive function, rather than a test of attention and impulsivity. If in fact it did become a test of higher cognition and executive function, it may indicate deficits that do not involve basic attention and impulsivity.

The Conners CPT also differs in the rate at which letters are displayed. Previous CPTs tended to use a fixed interval stimulus, i.e., a consistent exposure rate from one letter to the next letter on the monitor. Conners uses a variable rate of exposure. The computer then tracks and scores not only correct responses, omissions, and commissions, but also reaction time. The variability of reaction time across ISIs along with scores of omission and commission may make evident problems of impulsivity and inattention not captured by other CPTs (Conners, 1992).

If a child responds at the same speed to stimuli at the end of the test as at the beginning, it indicates that he or she cannot modulate responses to conform to the task's demands, and is a good operational definition of impulsive or inattentive

behavior. Very fast reaction times in conjunction with a high commission error rate also indicate impulsive responding. (Conners, 1994, pp. 7).

Conners also states that it may be misleading to look at omission error rates only as an indicator of inattention. Participants who respond slowly to a target, incurring an omission error, may also cause a commission error after the omission error (Conners & Rothschild, 1968, in Conners 1994, pp. 5). The work of Conners and Halperin et al., 1991, suggests that looking at reaction time and omissions yields a more valid measure of inattention than just omissions alone.

The Conners CPT has become widely used by clinicians as an instrument to assess attention and concentration abilities. Research indicates that in summary, the CPT is a brief task that can be administered to various populations to measure inattention, sustained attention, reaction time, and impulsivity in global terms comparable to, but not exactly the same as, other neuropsychological measures. (Klee & Garfinkel, 1983). The Conners CPT has been found to correlate with some categories of behavioral rating scales indicative of ADHD and with the DSM-IV criteria for diagnosis of ADHD (Barkley, 1991). It has also proven to discriminate between individuals with ADHD and normals.

However, there are limitations to the use of the Conners CPT. As with other computerized continuous performance tests, the Conners CPT relies on timing mechanisms to record reaction time, variability of speed, and interstimulus intervals that determine omission errors versus commission errors. Research on computer timing (Segalowitz & Graves, 1990) has shown inaccuracies and inconsistencies in timing and recording responses. Specifically, on the Conners CPT, timing was inaccurate if the

program was not run through the correct operating system on the personal computer. This information was not clear in earlier versions of the CPT manual and may have affected the pattern of results used in the analysis and diagnosis of patient profiles.

Additional limitations include the inability to distinguish between various diagnostic groups with attentional problems (Schacher, et al., 1988). Also, the majority of research conducted on the Conners CPT, and CPTs in general, has been with young children. A few studies have been conducted with adolescents with findings that indicate differences in results of CPT scores dependent upon age (Barkley, 1991). Very few studies have been conducted on adults using the Conners CPT (Epstein, et al., 1998). With the increase in the diagnosis of Adult ADHD, additional research on this widely used instrument in the context of a full neuropsychological assessment is warranted.

NEUROPSYCHOLOGICAL ASSESSMENT OF ATTENTION DEFICITS

A typical neuropsychology assessment includes an indepth clinical history and a broad spectrum of tests. Tests are determined by the referral question. In the case of a referral for assessment of attention deficits, a number of tests may be appropriate (Lezak, 1995). Most neuropsychological tests are complex, measuring at least two functions (Lezak, 1995). Many of these tests have attention/concentration/impulsivity components as well as memory, executive function, motor, sensory, signal detection, and learning components.

Past research on the assessment of attention deficits has included a variety of neuropsychological tests to tap into the cognitive functions associated with ADHD. Among these tests are: Continuous Performance tests, the Digit Span and Visual Memory

Span subtests of the Wechsler Memory Scale-Revised (WMS-R) (Wechsler, 1987), the Digit Symbol subtest of the Wechsler Adult Intelligence Scale-R (WAIS-R) (Wechsler, 1981), the Halstead-Reitan Neuropsychological Test Battery (HRNB) tests; Speech-Sounds Perception, Seashore Rhythm, Trails A, and Trails B (Reitan & Wolfson, 1993), and the Verbal Fluency test (CWA) (Benton & Hamsher, 1978). In a factor analysis of the WMS-R the subtests Digit Span and Visual Memory Span have been found to contribute to the Attention/Concentration Index (Burton, Mittenberg, & Burton, 1993; Roth, Conroy, Reeder, & Boll, 1990; Woodard, 1993). Lezak, 1995, refers to these subtests as measures of storage capacity and attention and the WAIS-R Digit Symbol subtest as a test of complex attention. Lezak includes both the Digit Span and Digit Symbol tests in a recommended basic attention deficit battery (Lezak, 1995, pp. 122). The Visual Memory Span subtest is a visual analogue of the auditory Digit Span subtest of the WMS-R (Wechsler, 1987).

The HRNB Speech-Sound Perception test and the Seashore Rhythm test are recommended by Lezak (1995, pp. 366) for suspected tracking or concentration problems as well as more complex mental operations. Trails A and Trails B from the HRNB measure psychomotor speed and integration, recognition or signal detection, visual scanning and tracking skills (Reitan & Wolfson, 1993). Trails B also yields information regarding cognitive flexibility. Holdnack et al., 1995, found patients with attention deficits performed significantly poorer on Trails A than controls, but not on Trails B, indicating deficits in cognitive speed but not cognitive flexibility.

Barkley, (1992) and Barkley, Grodzinsky, & DuPaul, (1994) reviewed frontal lobe/executive function tests in the assessment of ADHD. Barkley et al., found that the WCST Failure to Maintain Set score best discriminated between children with ADHD and a control group by identifying problems of disinhibitory control, but did not discriminate children with ADHD from children with other attention deficit disorders (e.g., ADD). Other frontal lobe tests were inconsistent in their findings and dependent on age. Holdnack, et al., 1995, found no significant differences between adults with ADD and controls on four of the WCST scores, Number of Categories obtained, the Percent Correct Responses, Percent Perseverative Responses, and Percent Perseverative Errors. The WCST score for Failure to Maintain Set was not analyzed in this particular study.

Inconsistent findings across studies for these various tests may be attributed to differences in population demographics. Education, age, and gender have been found to significantly affect the scores of individuals on the CPT (Holdnack, et al., 1995), HRNB Speech-Sounds Perception Test, Seashore Rhythm Test, and the Trail Making Test Part A and Part B, (Lezak, 1995). Age and education have also been found to significantly affect scores on the Wechsler Adult Intelligence Scale-Revised, the Wechsler Memory Scale-Revised and the Wisconsin Card Sorting Test, (Lezak, 1995).

Chapter Two

Purpose

This study addressed the lack of research on neuropsychological tests used in the assessment of ADHD in an adult population. It explored the relationship of participants' performance on the Conners CPT (typically used in the assessment of children and

lacking in normative data for adults) and other neuropsychological measures used in the diagnosis of Adult ADHD. This study evaluated two groups of adults, a Clinical Group and a Control group. The Clinical Group was composed of patients referred for neuropsychological assessment (a mixed clinical sample with a variety of neuropsychological diagnoses, e.g., head injury, mood disorder, attention deficit disorder, neuropsychological disorder not otherwise specified, or a combination of these disorders). The Control Group was a matched sample of adult volunteers from the community.

This study examined the differences in test performance between the two groups, it also examined the relationship between the Conners Continuous Performance Test results and the results of neuropsychological tests frequently used in the evaluation of attention deficits. Each measure of the Conners CPT was analyzed for correlation with the results of each of the other neuropsychological tests for both the Clinical Group and the Control Group.

Hypotheses

1. It is hypothesized that, for the Control Group, there will be a higher false positive rate than the 14.2% false positive rate reported in the CPT manual based on normative data for children age 6 to 17.
2. It is hypothesized that the performance of the Control Group will be significantly better than the performance of the Clinical Group on all tests administered.

3. It is hypothesized that both the Control Group and the Clinical Group will demonstrate significant correlations between the five Conners CPT scores and the other neuropsychological measures of attention administered as evidence of convergent data.
4. It is hypothesized that reaction time will be significantly faster in the Control Group than the Clinical Group as measured by the CPT hit rate.
5. It is hypothesized that within the Clinical Group, those on medication will perform better than those not on medication.

Chapter Three

Methodology

Participants

Data from 72 participants, age 18 years through 57, were included in this experiment. They were divided into two groups of 36 participants each and matched for gender, age, and education. A mixed Clinical Group was drawn from an archival data set of patients referred to the Western Montana Clinic Neurosciences department for neuropsychological evaluation. Patients were diagnosed with disorders that included cognitive deficits with an attentional component, (e.g., head injury, mood disorder, attention deficit disorder, neuropsychological disorder not otherwise specified, or a combination of these disorders). These patients had a complete neuropsychological evaluation including the attentional measures that the present study examined. (See Materials). Thirteen participants in the mixed Clinical Group were on medication. The number of participants and the type of medications prescribed are listed in Appendix H.

A Control Group was drawn from individuals in the community who volunteered for this experiment. They were matched for gender, age, and education to the Clinical Group participants. A ten dollar financial incentive was given for participation. The Control Group participants were free of the following exclusionary criteria: neurological disorder, head injury with loss of consciousness greater than five minutes, diagnosis of psychosis or Major Affective Disorder, diagnosis of attentional deficits or learning disabilities, frequent alcohol or substance use, currently, or in the past. (See Appendix D).

Materials

Archival data for the Clinical Group was obtained from patient records of the Western Montana Neurosciences Department. The Control Group was recruited through the use of posters (Appendix G) in the community. The Control Group was administered an Informed Consent Form (Appendix A), a cover letter (Appendix B), a demographic questionnaire (Appendix C) the Health Screening Questionnaire (Appendix D) and a verbal script (Appendix E) prior to the following tests: Conners Continuous Performance Test (Conners, 1994), Verbal Fluency test (Controlled Oral Word test, CWA, Benton & Hamsher, 1976), WMS-R Digit Span and Visual Memory Span subtests (Wechsler, 1987), WAIS-R Digit Symbol subtest (Wechsler, 1981), the Halstead-Reitan Neuropsychological Test Battery subtests; Speech Sounds Perception test and Seashore Rhythm test, Trails A, and Trails B (Reitan & Wolfson, 1993). The tests were given in randomized order to avoid administration effects.

Conners Continuous Performance Test (CPT)

The Conners Continuous Performance Test (Conners, 1994) is a computerized test of attention deficits and impulsivity. It was administered on a Personal Computer (PC) (AMD-K6 processor, 380 MHz, 64 Megabytes of Ram) by the examiner using the standard test instructions. Three hundred and sixty letters, approximately one inch high, appeared on the computer screen, one at a time, for approximately 250ms. The 360 letters are presented in 18 consecutive blocks of 20 trials.

The 18 ISI blocks consisted of a separate ISI (1, 2, or 4 s). The ISIs are block-randomized across the 18 ISIs so that all three ISI conditions occurred every 3 blocks. Therefore, the entire CPT could be divided into 6 consecutive time blocks with each time block containing all three ISI conditions (Epstein et al., 1998).

The order of ISI conditions for the entire CPT task was: (1-2-4)-(2-4-1)-(4-2-1)-(1-4-2)-(2-1-4)-(4-1-2). The participant depresses the space bar on the keyboard for all letters of the alphabet shown except for the target letter, "X". When the target letter appears, the participant inhibits the reaction to respond. The event rate was the percentage of trials when letters other than the target letter appeared. The event rate was 90% and remained constant across ISI and time blocks. The test took approximately fourteen minutes to complete (Epstein, et al., 1998).

The CPT yields several dependent measures. The following are the specific types of measures obtained by the Conners CPT (Conners, 1994, pp. 30 - 31):

1. Hits: The number of targets the person responded to correctly.
2. Omissions: The number of targets the person did not respond to.

3. Commissions: The number times the person responded to a nontarget "X".
4. Hit Rate: The mean response time for all target responses over all six blocks.
5. Hit Rate Standard Error: The consistency of response times, expressed in terms of standard error for responses to targets.
6. Variability of Standard Errors: A different method for calculating response time consistency; the standard deviation of the 18 standard error values calculated for each sub-block.
7. Attentiveness (d'): A measure of how well the individual discriminates between targets and non-targets.
8. Risk Taking (B): An individual's response tendency. Some individuals are cautious and choose not to respond very often relative to others in the general population. These individuals will obtain high B scores, indicating poor performance in comparison to norms. Others are more risk-taking or impulsive and respond more frequently than others in the general population. These individuals will obtain low B scores, also indicating a less than typical response pattern in comparison to norms.
9. Hit Rate Block Change: The slope of change in reaction times over the six time blocks. A positive slope indicates a slowing reaction time, while a negative slope indicates quicker reaction times as the test progressed.
10. Hit Standard Error Block Change: The slope of change in reaction time standard errors over the six time blocks. A positive slope indicates that reaction times became less consistent as the test progressed. Negative slopes imply reaction times became more consistent as the test progressed.

11. Hit Rate ISI Change: The slope of change in reaction times over the three ISIs (1, 2, and 4 seconds). A positive slope indicates a slowing of reaction time as the time between targets increased, while a negative slope indicates faster reaction times as the time between targets increased.

12. Hit Standard Error ISI Change: The slope of change in reaction time standard errors over the three ISIs (1, 2, 4 seconds). A positive slope means the person's reaction times became more erratic as the time between targets increased. A negative slope indicates increased consistency as the time between targets increased.

In this study, scores frequently explored in the research of children with attention deficits were analyzed in an adult population. Those CPT scores were hits, commissions, omissions, hit rate standard error and d' . Hit rate (reaction time) was also analyzed. False positive rates in the Control Group were based on the CPT narrative statement, as recommended in the CPT manual for the accurate analysis of results (Conners, 1995). Individuals in the control group that received a narrative statement explicitly stating that they had attention deficits or that they displayed significant symptoms that strongly suggested attention deficits warranting further observation and testing, were considered a false positive response.

Studies of the reliability and validity of the Conners CPT have been conducted primarily with children and have produced variable results. Conners (1995) conducted split-half reliabilities on the original data set that indicated reliability scores for the measures used in the present study ranging from .83 to .95. A validity study of

adults produced a sensitivity coefficient of 55%, and a specificity coefficient of 76% (Epstein, Conners, Sitarenios, & Erhardt, 1998).

Wechsler Memory Scale-Revised subtests

The Wechsler Memory Scale-Revised yields an Attention-Concentration Index score comprised of the Digit Span, Visual Memory Span, and Mental Control subtests. For this study the Digit Span Forward and Backward and the Visual Memory Span Forward and Backward subtests were administered. Split-half reliability coefficient estimates were computed for the Digit Span and Visual Memory Span subtests, for the age range relevant to the present study, with the following findings: Digit Span Forward, .84 - .87, Digit Span Backwards, .76 - .82. Validity scores, based on a factor analysis of principle components indicated correlations with the Attention/Concentration factor of .75 for Digit Span and .65 for Visual Memory Span (Wechsler, 1987)

The Digit Span subtest was administered by the examiner according to standardized test instructions. The participant was required to repeat a list of numbers read by the examiner in the same order. The subtest is divided into two parts. In the first part of the subtest the participant was asked to repeat the numbers in the same order as read by the examiner. In the second part of the subtest the participant was asked to repeat the numbers in the reverse order as read by the examiner (Wechsler, 1987). The length of digits to be recalled for Digit Span forward ranged from three digits to eight digits. The length of digits to be recalled for Digit Span backward ranged from two digits to seven digits. The raw score for Digit Span Forward and the raw score for Digit Span Backward were analyzed.

Visual Memory Span is a visual analog of the Digit Span subtest (Wechsler, 1987). Visual Memory Span requires the participant to touch a series of colored squares in a predetermined order demonstrated by the examiner. The number of squares touched increases with each item. This subtest is divided into two parts. In the first part of the subtest the participant was required to touch the squares in the same consecutive order as the examiner. In the second part of the subtest the participant was required to touch the squares in the reverse order of the examiner. The length of digits to be recalled for Visual Memory Span forward ranged from three digits to eight digits. The length of digits to be recalled for Visual Memory Span backward ranged from two digits to seven digits. The raw score for Visual Memory Span Forward and the raw score for Visual Memory Span Backward were analyzed.

Wechsler Adult Intelligence Scale-Revised subtests

The Wechsler Adult Intelligence Scale-Revised consists of eleven subtests that yield Intelligence Quotient (IQ) scores for Verbal IQ, Performance IQ, and Full Scale IQ. Information and Picture Completion subtests may be given as a means of estimating IQ (Kaufman, 1990). For this study, the Digit Symbol subtest was administered. Reliability coefficient estimates for test-retest of the Digit Symbol subtest indicate scores, relevant to the age range evaluated in the present study of .82 - .86. In terms of validity the overall correlation of performance on the WAIS-R with performance in school is .50 (Wechsler, 1981). The Digit Symbol subtest has been shown to involve signal detection, attention, and distractibility.

The Digit Symbol subtest requires the participant to fill in blank squares with a symbol that matches the number as indicated at the top of the protocol. The first three squares were filled in by the examiner as a demonstration of the task. Then the participant was given four squares to fill in for practice. The participant then filled in as many of the remaining squares as possible, without skipping or erasing until the 90 second time limit expired. The Digit Symbol subtest yielded a raw score of the total correct responses and a standard score. In this study only the raw score was used for analysis.

Halstead-Reitan Neuropsychological Test Battery (HRNB) subtests

The Halstead-Reitan Neuropsychological Test Battery (Reitan & Wolfson, 1995) consists of several subtests for the neuropsychological evaluation of adults. This study used the Speech-Sounds Perception Test and the Seashore Rhythm Test. These tests require the use of a variety of cognitive functions, but have been shown to be primarily sensitive to attention and concentration deficits. (Lezak, 1995). In test-retest reliability studies the Speech Sounds Perception test has demonstrated a coefficient estimate of .60 and the Seashore Rhythm test has demonstrated a coefficient estimate of .50 - .77 (Lezak, 1995). In terms of validity, the Speech Sounds Perception tests has been shown to correlate with left brain lesions greater than with bilateral or right brain lesions. It has also been shown to load heavily on general ability levels (Lezak, 1995). The Seashore Rhythm test loads on attention and concentration and is more strongly associated with bilateral lesions than unilateral lesions (Lezak, 1995).

The Speech-Sounds Perception Test was administered by audiotape. There were a total of 60 items on this test. The participant was required to listen for a specific nonsense syllable for each of the sixty items. There were four similar choices for each item. When the participant identified one of the four nonsense syllables for a particular item they underlined their choice and waited for the next consecutive item to be read. The participant was given a practice set consisting of the first three items. The participant was required to keep pace with the cassette. There was no stopping once the test started. The test took approximately 14 minutes to complete. This study analyzed the raw score consisting of the total number of errors.

The Seashore Rhythm Test was also administered by audiotape. The participant was required to listen to pairs of rhythmic patterns. They were asked to determine if the patterns were the same or different. The participant entered their response on the protocol. The participant was given a practice trial consisting of the first three pairs of rhythmic patterns. Then the actual test started. There were 30 pairs of rhythmic patterns. Because there was no stopping or pausing during the subtest, the participant was required to stay on task. The test took approximately 12 minutes to complete. This study analyzed the raw score for total correct responses.

Trails A & B

Trails A & B of the Halstead-Reitan Neuropsychological test battery measure psychomotor speed and integration as well as involving attention, concentration, signal detection, cognitive flexibility, and executive function (Holdnack et al., 1995; Lezak, 1995; Reitan & Wolfson, 1993). In test-retest reliability studies Trails A demonstrated a

coefficient of concordance of .98 and Trails B a coefficient concordance of .67. Validity studies have suggested that the Trails tests load heavily on rapid visual search and visual/spatial sequencing factors and with cognitive set shift (Spreeen and Strauss, 1998).

Trails A required the participant to draw a line from one to two, two to three and three to four, until reaching the last number, twenty-five, as fast as possible without making errors. The numbers must be in consecutive order. If the participant makes an error the examiner directs the participant back to the last correct response and the participant continues the test from that point. The participant was given a short practice test first. Trails A yields a raw score, a standard score and a T-score for the time to complete the test and a raw score for the number of errors. This study analyzed the time in seconds to complete the test.

Trails B differed from Trails A in that the participant was required to connect both numbers and letters in a predetermined order as fast as possible without making errors. The order was as follows: the first number (1) and then the first letter (A), second number (2), second letter (B) until the participant reached the end at number thirteen. Trails B yields a raw score, a standard score and a T-score for the time to complete the test and a raw score for the number of errors. This study analyzed the raw score for time in seconds to complete the test.

Controlled Oral Word Association Test

The Benton Controlled Oral Word Association Test (Benton & Hamsher, 1976), is a test of verbal fluency, cognitive flexibility, and executive function. The participant was

given a specific letter and asked to say as many words as possible in one minute beginning with that letter. There were a total of three letters administered. The total raw score was analyzed for this study. The majority of reliability studies have been conducted on the previous form of this test using different letters (FAS rather than CFL). Those studies indicate reliability coefficients estimates for the age ranges evaluated in the current study of .65 - .88. In terms of validity, the CWA demonstrated a correlation of .15 with the WAIS-R Vocabulary test (Tombaugh and Rees, 1996, in Spreen and Strauss, 1998).

Procedures

Testing was conducted on an individual basis by an experienced psychometrician in a relatively distraction free environment. The Clinical Group participants were tested at the Western Montana Clinic Neurosciences Department. The Control Group participants were tested at community sites convenient to the individual. These sites included University of Montana research laboratories, and church community rooms in Missoula, Montana and Orlando, Florida.

The Control Group participants were given an Informed Consent Form and Demographic Survey to document gender, age, and education. They were asked to complete the Tindal Modified Health Screening Questionnaire before beginning the neuropsychological test battery. Visual or auditory deficits that would interfere with testing were also noted. At the beginning of each test the participant was read the standardized instructions for the test. The test battery was given in a randomized order, consisting of the CPT, WMS-R Digit Span subtest and Visual Memory Span subtest,

WAIS-R Digit Symbol subtest, Information and Picture Completion subtests, Halstead-Reitan Speech-Sounds Perception test, Seashore Rhythm test, Trails A and B, and the CWA. The total testing time was approximately ninety minutes.

Analysis

Analyses were conducted to determine whether there were significant differences in performance on the tests administered between the Clinical Group and the Control Group. An independent samples t -test was computed for all tests comparing scores for the Clinical Group and the Control Group.

Analyses were conducted to determine whether there were correlations between the Conners CPT scores and the scores from the other neuropsychological tests within each of the two groups, Clinical and Control. A Pearson product-moment correlation was computed for raw scores of the five Conners CPT scores and the scores of the other neuropsychological tests of attention.

Analyses were conducted to determine whether there was a significant difference in reaction time between the Clinical Group and the Control Group. An independent samples t -test was computed between groups on the results of the Conners CPT Hit Rate (reaction time) scores.

Analyses were conducted to determine whether there was a significant difference in test results within the Clinical Group between those on medication and those not on medication. An independent samples t -test was computed between those on medication and those not on medication within the Clinical Group for each test administered.

Analyses were conducted to determine the percentage of individuals presenting with a false positive designation for the Control Group overall, for individuals by gender, and for individuals by age group.

Chapter Four

Results

Analysis of False Positive Rates on the Conners CPT in the Control Group

Results indicated that 47% of the Control Group participants were identified as having attention deficits, or symptoms of attention deficits, requiring ongoing observation as measured by the Conners CPT and defined by the overall narrative statement (Conners, 1994). Results on the CPT indicated that 11/16 females and 6/20 males, in the Control Group, demonstrated atypical performance suggestive of attention deficits. The group was then further subdivided into three age categories as follows: 18-31 (N=12), 32-44 (N=13), 45-57 (N=11). Results indicating symptoms of attention deficit for the three groups respectively were: 50%, 54%, 30% (see Table 1). Because education has been shown to effect performance on continuous performance tests, a oneway analysis of variance was conducted to determine whether there were significant differences in education between the three age levels of the Control Group evaluated for false positives. There were no statistical differences in education between the three age levels in the Control Group $F(2, 34) = 1.67, p = .204$ (see Table 2). However, the oldest group had the highest level of education (15.82). For a complete breakdown of the distribution of false positive designations in the Control Group, see Table 3.

Table 1. Analysis of False Positive Rates in the Control Group.**Overall Performance of the Control Group Based on CPT Scores**

Attention Deficits	No Attention Deficits
47%	53%

Attention Deficits Indicated by Gender

Males	Females
30%	69%

Attention Deficits Indicated by Age

18-31 (N=12)	32-44 (N=13)	45-57 (N=11)
50%	54%	36%

Table 2. Differences in Education based on Age within the Control Group. Means and (+/-) standard deviations

Age (Years)	N	Education (Years)
18 – 31	12	14.75 (2.14)
32 – 44	13	14.15 (1.95)
45 – 57	11	15.82 (2.64)

Note *Differences are significant at $p < .05$.

Table 3. Distribution of False Positive Designations in the Control Group.

Age:	18 – 31 N=12	32 – 44 N=13	45 – 57 N=11
Male:	8 (3FP's)	6 (1FP's)	6 (2FP's)
Female:	4 (3FP's)	7 (6FP's)	5 (2FP's)

Note: FP denotes False Positive Designation.

Participant Characteristics

The sample for this study included 16 females and 20 males in each of the two groups for a total of 72 participants. The age range for all participants was 18 to 57. The mean age for the Control Group and Clinical Group participants was 37.33 and 37.28 years respectively. The mean level of education for the Control Group and Clinical Group participants was 14.86 and 13.86 years respectively. There were no significant differences between the two groups for age ($t = -.022$, $p > .05$) or education ($t = -.1.85$, $p > .05$). However, the effect of education approached statistical significance (see Table 4).

Table 4. Demographic Comparisons for the Clinical and Control Groups.

Test	Clinical (N = 36)	Control (N = 36)	t	p	Significance
Mean Age (years)	37.28 (10.33)	37.33 (10.69)	-.022	.982	NS
Mean Education (years)	13.86 (2.31)	14.86 (2.28)	-1.85	.069	NS
Male/Female (ratio)	20/16	20/16	-----	-----	

Note: NS denotes a nonsignificant difference.

Comparison of Clinical and Control Groups

Independent samples *t*-tests were conducted comparing the Clinical Group and the Control Group for all tests given (see Table 5). Results indicated that the Control Group performed better than the Clinical Group for all tests. Additionally, the Control Group performed statistically better than the Clinical Group on all but three tests. Moreover, of the three tests that did not meet criteria for statistical significance, one approached significance. While the Control Group performed better than the Clinical Group, it is important to note that the Clinical Group mean scores did not indicate notable deficits as compared to normative data with scores falling into the low average to average range.

Table 5. Comparison of Clinical and Control Groups. Means and (+/-) standard deviations.

Test	N	Clinical	N	Control	t	p
Digit Symbol ^a	36	45.53 (14.80)	36	65.08 (11.96)	-6.17	0.00***
Trails A ^c	33	33.79 (13.77)	36	22.19 (6.49)	4.53	0.00***
Trails B ^c	33	83.18 (41.43)	36	54.86 (14.64)	3.85	0.00***
Speech Sounds ^b	32	5.53 (4.95)	36	3.89 (1.62)	1.88	0.06
Seashore Rhythm ^d	33	26.21 (3.95)	36	26.69 (2.39)	-0.70	0.48
Controlled Oral Word ^a	28	37.29 (11.11)	36	42.19 (8.73)	-1.98	0.05*
Digit Span Forward ^a	36	7.80 (2.15)	36	9.28 (1.91)	-3.08	0.00**
Digit Span Backward ^a	36	6.22 (1.97)	36	7.64 (2.18)	-2.89	0.00**
Visual Memory Span Fd. ^a	36	8.08 (2.13)	36	9.47 (1.32)	-3.33	0.00***
Visual Memory Span Bd. ^a	36	7.83 (2.20)	36	8.25 (1.59)	-0.92	0.36
CPT Hits ^a	30	318.73 (8.53)	36	321.97 (2.41)	-2.18	0.03*
CPT Omissions ^b	30	5.27 (8.53)	36	2.03 (2.41)	2.18	0.03*
CPT Commissions ^b	30	13.70 (7.03)	36	8.67 (5.48)	3.27	0.00**
CPT Hit Rate Stand. Error ^d	30	7.48 (3.62)	36	5.77 (1.49)	2.58	0.01*
CPT d' ^a	30	2.73 (0.97)	36	3.44 (0.71)	-3.42	0.00***

Note. *Differences are significant at $p < .05$.

**Differences are significant at $p < .01$.

***Differences are significant at $p < .001$.

a = number correct, b = number of errors, c = time in seconds, d = standard error for responses

Within groups, there were no significant differences based on gender for the Clinical Group, but there was a significant difference for gender for the Control Group (see Tables 6 & 7). Within the Control Group, overall, females performed significantly better on two of the fifteen tests (Digit Symbol and Trails B). A much greater variability in scores (see standard deviations) was noted for the Clinical Group (see Table 3) than for the Control Group (see Table 7) in this analysis. This suggests that interpretation and comparison of the data in Tables 6 and 7 is limited by a lack of statistical power.

Table 6. Comparison of Performance Based on Gender within the Clinical Group. Means and (+/-) standard deviations.

Test	N	Females	N	Males	t	p
Digit Symbol ^a	16	46.69 (12.29)	20	44.60 (16.80)	0.41	0.68
Trails A ^c	14	35.57 (11.95)	19	32.47 (15.16)	0.63	0.53
Trails B ^c	14	72.36 (37.17)	19	91.16 (43.53)	-1.30	0.20
Speech Sounds ^b	15	6.07 (5.93)	17	5.06 (4.02)	0.57	0.57
Seashore Rhythm ^a	15	25.87 (3.98)	18	26.50 (2.68)	-0.54	0.59
Controlled Oral Word ^a	14	40.07 (10.68)	14	34.50 (11.02)	-1.35	0.19
Digit Span Forward ^a	16	7.81 (2.25)	20	7.80 (2.12)	0.02	0.97
Digit Span Backward ^a	15	6.31 (1.99)	20	6.15 (2.01)	0.24	0.81
Visual Memory Span Frd ^a	16	7.88 (2.39)	20	8.25 (1.94)	-0.52	0.61
Visual Memory Span Brd ^a	16	7.69 (2.47)	20	7.95 (2.01)	-0.35	0.73
CPT Hits ^a	13	320.38 (4.48)	17	317.47 (10.62)	0.93	0.36
CPT Omissions ^b	13	3.62 (4.48)	17	6.53 (10.62)	-0.93	0.36
CPT Commissions ^b	13	12.92 (6.61)	17	14.29 (7.46)	-0.52	0.61
CPT Hit Rate Stand. Error ^d	13	6.94 (2.90)	17	7.89 (4.13)	-0.70	0.49
CPT d' ^a	13	2.90 (0.87)	17	2.60 (1.04)	0.84	0.41

Note. *Differences are significant at $p < .05$.

**Differences are significant at $p < .01$.

***Differences are significant at $p < .001$.

a = number correct, b = number of errors, c = time in seconds, d = standard error for responses

Table 7. Comparison of Performance Based on Gender within the Control Group. Means and (+/-) standard deviations.

Test	N	Females	N	Males	t	p
Digit Symbol ^a	16	71.13 (9.85)	20	60.25 (11.46)	3.01	0.00**
Trails A ^c	16	20.31 (4.38)	20	23.70 (7.55)	-1.59	0.12
Trails B ^c	16	48.69 (9.55)	20	59.80 (16.28)	-2.41	0.02*
Speech Sounds ^b	16	3.94 (1.77)	20	3.85 (1.53)	0.16	0.86
Seashore Rhythm ^a	16	27.19 (1.64)	20	26.30 (2.83)	1.11	0.27
Controlled Oral Word ^a	16	44.06 (9.24)	20	40.70 (8.23)	1.15	0.25
Digit Span Forward ^d	16	9.18 (1.87)	20	9.35 (1.98)	-0.25	0.80
Digit Span Backward ^d	16	7.75 (2.08)	20	7.55 (2.31)	-0.27	0.79
Visual Memory Span Frd ^a	16	9.50 (0.97)	20	9.45 (1.57)	0.11	0.91
Visual Memory Span Brd ^a	16	7.94 (1.44)	20	8.50 (1.70)	-1.06	0.30
CPT Hits ^d	16	321.69 (3.26)	20	322.20 (1.47)	-0.63	0.53
CPT Omissions ^b	16	2.31 (3.26)	20	1.80 (1.47)	0.63	0.53
CPT Commissions ^b	16	9.13 (5.43)	20	8.30 (5.64)	0.44	0.66
CPT Hit Rate Stand Error ^d	16	5.82 (1.70)	20	5.73 (1.35)	0.18	0.86
CPT d' ^a	16	3.32 (0.68)	20	3.53 (0.74)	-0.84	0.41

Note *Differences are significant at $p < .05$.

**Differences are significant at $p < .01$.

***Differences are significant at $p < .001$.

a = number correct, b = number of errors, c = time in seconds, d = standard error for responses.

Clinical Group Correlations

Pearson's product-moment correlations were conducted for the Clinical Group to determine the correlation between the five Conners Continuous Performance Test scores for Hits, Omissions, Commissions, Hit Rate Standard Error, and d' scores and all the neuropsychological tests administered (see Table 8). Visual inspection of Table 8 reveals a general tendency for significant correlations between tests administered visually (CPT, Digit Symbol, Trails A & B, and WMS-R Visual Memory Span Forward and Backward) compared to those administered auditorally (Speech Sounds Perception, Seashore Rhythm, Controlled Oral Word, and Digit Span Forward & Backward).

Table 8: Correlations of CPT measures with other tests of Attention in the Clinical Group.

Clinical Group:	N	Hits	Omissions	Commissions	Hit Rate SE	d'
Digit Symbol	36	.633**	-.633**	-.277	-.488**	.497**
Trails A	33	-.175	.175	-.202	.121	-.015
Trails B	33	-.413*	.413*	.135	.432*	-.368
Speech Sounds	32	.018	-.018	-.201	.170	.101
Seashore Rhythm	33	-.005	.005	.235	.096	-.134
Controlled Oral Word	28	.388	-.388	-.094	-.233	.250
Digit Span Forward	36	.536**	-.536**	-.265	-.213	.464**
Digit Span Backward	36	.225	-.225	-.074	.045	.170
Visual Memory Span Ford.	36	.472**	-.472**	-.513**	-.160	.466**
Visual Memory Span Back.	36	.557*	-.557*	-.467*	-.181	.594*

Note. *Correlations are significant at $p < 0.05$.

**Correlations are significant at $p < 0.01$

Control Group Correlations

Pearson's product-moment correlations were also conducted for the Control Group to determine the correlation between the five Conners Continuous Performance Test scores for Hits, Omissions, Commissions, Hit Rate Standard Error, and d Prime scores and the other neuropsychological tests of attention (see Table 9). In the Control Group, there were no significant correlations for the CPT test scores with any of the other neuropsychological test scores. This finding was consistent with the expected profile of normal controls.

Table 9: Correlations of CPT measures with other tests of Attention in the Control Group.

Control Group:						
	N=36	Hits	Omissions	Commissions	Hit Rate SE	d'
Digit Symbol		.045	-.045	-.251	.095	.219
Trails A		.103	-.103	-.224	-.053	.271
Trails B		.062	-.062	-.077	-.005	.207
Speech Sounds		-.140	.140	.025	.070	.050
Seashore Rhythm		-.156	.156	.119	.192	-.215
Controlled Oral Word		-.060	.060	.018	.118	-.226
Digit Span Forward		-.067	.067	-.130	.126	-.141
Digit Span Backward		-.127	.127	-.209	.050	-.060
Visual Memory Span Forward		-.005	.005	-.041	.167	-.042
Visual Memory Span Backward		-.214	.214	.180	-.014	-.222

Note. *Correlations are significant at $p < .05$.

Analysis of Reaction Times

An independent samples t -test was conducted between groups to determine whether there were significant differences between the Control Group and Clinical Group for reaction time using the CPT Hit Rate scores. The means and standard deviations are shown in Table 10. The Control Group demonstrated faster reaction times compared to the Clinical Group, but the difference of 8 msec. was not statistically significant. The findings are also limited by the computer keyboard response delay of approximately 10 msec. (Segalowitz & Gaves, 1990).

Table 10: Analysis of Reaction Time Differences between the Clinical Group and the Control Group. For Response Time Data, Means and (+/-) standard deviations are expressed in milliseconds.

Test	Clinical (N=36)	Control (N=30)	t	p
CPT Reaction Time	401.50 (69.43)	393.09 (54.63)	0.55	0.58

Note. *Differences are significant at $p < .05$.

Analysis of Medication Effects

An independent samples t -test was conducted within the Clinical Group to determine whether there were significant differences based on medication use (see Table 11). The CPT d' score, a measure of sensitivity, was poorer for the medication group compared to the nonmedication group. No other differences in test performance were found within the mixed Clinical Group participants based on medication use.

Table 11. Analysis of Medication Effects within the Clinical Group. Means and (+/-) standard deviations.

Test	No Medication (N = 23)	Medication (N = 13)	t	p
Digit Symbol ^a	48.11 (1.89)	42.30 (15.16)	1.11	0.27
Trails A ^c	35.25 (16.29)	32.67 (11.04)	0.47	0.64
Trails B ^c	80.19 (48.28)	89.00 (34.67)	-0.54	0.59
Speech Sounds ^b	5.81 (5.34)	5.16 (5.36)	0.32	0.75
Seashore Rhythm ^a	26.59 (3.59)	25.25 (3.19)	1.03	0.31
Controlled Oral Word ^a	36.21 (9.31)	35.70 (13.82)	0.11	0.91
Digit Span Forward ^a	8.50 (1.65)	7.31 (2.56)	1.58	0.12
Digit Span Backward ^a	6.39 (1.95)	5.92 (2.17)	0.63	0.53
Visual Memory Span Frd ^a	8.61 (2.03)	7.62 (2.26)	1.29	0.20
Visual Memory Span Brd ^a	8.22 (2.24)	7.38 (2.25)	1.03	0.31
CPT Hits ^a	320.76 (4.27)	316.07 (11.74)	1.53	0.13
CPT Omissions ^b	3.24 (4.28)	7.92 (11.74)	-1.53	0.13
CPT Commissions ^b	11.88 (5.87)	16.08 (7.90)	-1.67	0.10
CPT Reaction Time ^c	401.24 (75.47)	401.84 (63.68)	-0.02	0.98
CPT Hit Rate Stand Error ^d	6.86 (3.83)	8.29 (3.31)	-1.07	0.29
CPT d' ^a	3.08 (0.75)	2.28 (1.07)	2.42	0.02*

Note. *Differences are significant at $p < .05$.

**Differences are significant at $p < .01$.

***Differences are significant at $p < .001$.

a = number correct, b = number of errors, c = time in seconds, d = standard error for responses.

e = time in milliseconds

8

Chapter Five

Discussion

The purpose of this study was to evaluate the relationship between scores derived from the Conners CPT and scores from other frequently used measures in the neuropsychological assessment of cognitive deficits associated with ADHD in an adult population. In general, the results are consistent with the profiles associated with a clinical population referred for neuropsychological assessment and normal controls. The exception to the pattern of results was the high frequency of false positives reported in the Control Group.

An examination of the Control Group on measures from the CPT revealed significantly better performance than the Clinical Group, as anticipated. However, it also revealed that a large percentage of the Control Group scores fell into the atypical range and warranted, by the computer generated report, either a diagnosis of attention deficits, or ongoing observation and testing due to significant symptoms of attention deficits (Conners, 1995; APA, 1986). This finding was surprising, given the stringent screening of Control Group participants and the average performance of the Control Group on all other measures evaluated in this study, suggesting a possible false positive bias in the results of the Control Group data (see Table 1). Given the limited sample size in this study, any results should be cautiously interpreted. However, it is notable that the Conners CPT Manual indicates false positive rates in the general population sample of between 9.9% and 14.2% (calculated for 6 to 17 year olds only), and the results of this study indicated false positive rates of 47% overall (adults only).

Further examination of the false positive results in the Control Group raised additional questions regarding the role of gender, age, and education on the findings. The small sample size limits the ability to interpret the results statistically, but several trends were noted in the data. One of the most notable findings in the present study was the high prevalence rate of females to males in the false positive category. This finding was in direct opposition to the prevalence rates reported in the general population where males are more likely to be diagnosed with attention deficits at a ratio ranging from 4:1 to 9:1.

A second result that was contrary to expectations was the finding of a lower percentage of the oldest participants in the false positive category than younger adult participants (see Table 1). Given the limited adult normative data for the CPT, that is most limited with increased age, it would have been expected that the false positive rate would be highest for the older group. Because the false positive rate for the Control Group overall was skewed towards females, it could be suggested that gender within the oldest Control Group sample affected the rate of false positive designation. This was not the case. As seen in Table 3, equal numbers (2) of males and females were designated as false positive in this group, suggesting that gender was probably not related to the relatively better performance of the oldest group of participants in the Control Group.

Next, the effect of education was evaluated for the 45-57 year old group. It was found that this group had a relatively higher level of education than the mean education of the total group, although not statistically different (see Table 2). Education has been found to be significantly correlated with CPT results, but given the slight difference in education levels seen between these groups, it is also unlikely that education was related

to the better performance of the oldest participants of the Control Group. (Holdnack, et al., 1995).

The majority of participants designated as false positives were females in the 32 – 44 age range (see Table 3). This may be due to a variety of factors including characteristics of this particular sample, i.e., fatigue, motivation, or rapport. The high number of false positives for the Control Group overall may also be attributed to the lack of CPT normative data for adults as a whole. With only 74 adults in the normative data sample, and only 13 of them over the age of thirty, making inferences regarding adult performance from the data is difficult at best.

In addition to evaluating the rate of false positives, differences in test performance between the two groups was also evaluated. The two groups were matched for age, gender, and education to minimize differences based on these factors. There was a trend towards significant differences between groups on level of education, but these differences were minimal and unlikely to have affected the results.

The Clinical Group's results suggested relatively poorer performance across all of the tests administered compared to the Control Group's performance. Specifically, the Clinical Group demonstrated decreased abilities across a number of neuropsychological measures shown to be sensitive to executive function and attention deficits. The findings were consistent with the expectation that individuals referred for neuropsychological evaluation would have a profile marked by poorer performance across a broad range of neuropsychological measures.

The findings were also consistent with the observation of Mapou (1999) that attention and processing speed/capacity are the two most frequently observed and robust cognitive deficits in psychiatric, neurological, or systemic medical disorders. Processing speed and capacity, the ability to encode and manipulate information, would be demonstrated in several of the test results evaluated in this study (Digit Symbol, Trails B, Digit Span Backwards, and Visual Memory Span Backwards). For the participants in the mixed clinical sample presenting with similar diagnoses, it was likely that their performance on the neuropsychological measures chosen for this study would reflect these deficits. It should be noted that although the Clinical Group performed more poorly than the Control Group, the Clinical Group's scores were in the low average to average range indicating only mild deficits in comparison to the Control Group, whose scores were in the average to high average range.

Reaction time differences were evaluated to determine if there were differences in test performance between the two groups. It was hypothesized that the Control Group would have faster reaction times than the Clinical Group. Using the CPT Hit Reaction Time raw score, results indicated that there were no differences between the two groups for reaction time. However, this finding needs to be interpreted cautiously. As reported by Segalowitz and Graves (1990), reaction time accuracy on computerized tests has been variable, but the keyboard response delay is relatively consistent at 10msec. This is greater than the difference (8msec.) in reaction time between the two groups (see Table 10). The CPT has also demonstrated problems in timing accuracy. For the purpose of this study, the CPT was run on a PC computer (AMD-K6 processor, 380 MHz, 64 Meg

of Ram) through the DOS/Windows 98 operating system, as recommended by the manufacturer to minimize timing problems (Conners, 1995).

It has been suggested that individuals with ADHD have slower reaction times and or more variable reaction times that impact their performance on reaction based tests, such as continuous performance tests (Barkley & Grodzinsky, 1994). That has been disputed more recently by research that suggests adult individuals with ADHD have normal reaction times, but slower processing speed than controls (Walker, et al., 2000). The reaction time results of the present study are questionable due to the small differences between groups, but the Clinical Group did not demonstrate reaction times that were vastly different from the Control Group. This finding suggests that the differences in performance between the two groups on the Conners CPT and other neuropsychological tests with a time component (Digit Symbol, Trails A & B) may not be due to slower reaction time, but more likely involved higher level processing abilities (Mapou, 1999), such as working memory, processing speed/capacity, impulse control, the ability to shift attention, planning, and organization of information.

Medication use was another factor analyzed to determine its impact on performance between groups. It was hypothesized that medicated participants in the Clinical Group would perform significantly better than nonmedicated participants in the Clinical Group. This was not supported by the data. Only one test score indicated significant differences within the Clinical Group based on prescribed medication use. The score was the CPT d' score, a measure of sensitivity in signal detection theory. Those not on medication performed significantly better on this signal detection measure than those on medication.

Since this was the only measure that indicated significantly different performance, out of five scores from the CPT and ten other test scores, it should be interpreted cautiously. It may be that the diversity of diagnoses within the Clinical Group required a variety of medication treatment that differentially affected their ability on the tests given in this study (see Appendix H). One explanation for the lack of differences in performance may be that any improvement gained by those on medication was relative. Those most likely to be prescribed medication would be those individuals with the worst symptoms. Medicated individuals in the study likely experienced improvement in their symptoms that may have negated the differences in performance between them and their nonmedicated counterparts.

In determining differences in test performance between the groups, four of the tests administered in this study were found to have insufficient power to make statistical inferences due to the limited sample size. The tests were the Controlled Oral Word Association test, Speech Sounds Perception test, the Seashore Rhythm test, and the WMS-R Visual Memory Span Backwards test.

In addition to evaluating false positives and differences between the two groups on test performance, the relationship of the test scores within each group was also explored. It was hypothesized that both groups would demonstrate significant correlations between the CPT scores and the other neuropsychological test scores and that the two groups would demonstrate different patterns of correlations.

The Clinical Group data revealed several significant correlations between the five CPT scores and the scores of the other neuropsychological measures evaluated in this

study indicating a mild underlying and cohesive pattern of decreased executive and attention abilities. The pattern of significant correlations in the Clinical Group was also notable for the inclusion of tests administered visually. Only one auditory test demonstrated significant correlations with the CPT scores. This pattern may be due to the fact that the CPT itself is a visually administered test. The pattern of correlations may have been different if an auditory test of attention had been the focus of this study. Auditory and visual processing systems require changes in neural networks located in different areas of sensory association cortex (Carlson, 1994). Therefore, the mode of administration may differentially affect the results. In a previous study evaluating a test of attention and processing speed and capacity, results indicated significant differences in the level of performance based on the mode of administration, visual versus auditory (Mielke & Hall, 1998).

More of the neuropsychological tests correlated with the CPT Omissions score, indicative of inattention, than with the CPT Commission score, indicative of impulsivity. This finding is consistent with the theory that adults with ADHD may be more likely to display deficits in sustained attention rather than impulsivity, as compared to children with ADHD who are more likely to display deficits in impulsivity as well as attention (Walker, et al., 2000). It is also consistent with the profiles anticipated for the Clinical Group. It would be expected that individuals who are neuropsychologically compromised would demonstrate a range of deficits that would be tapped by several of the tests administered in this study (Lezak, 1995; Mapou, 1999). The results did not find consistent relationships between the CPT scores and several measures of basic attention.

This may be due to the fact that the decreased abilities in the Clinical Group were very mild.

The variable findings of this study do not fit neatly into many of the existing models of attention (Mirsky, 1987; Sohlberg & Mateer, 1989; Mirsky et al., 1991; Mirsky et al., 1995; Mateer & Mapou, 1996). However, the Clinical Group results are somewhat consistent with the theoretical model of attention put forth by Barkley (1997) and with Barkley's suggestion that the CPT may load more heavily on executive function than basic attention. Barkley constructed a model of attention deficits to predict ADHD. His model links deficits in inhibition to deficits in four executive neuropsychological functions. The impaired functions that were most evident in individuals with ADHD included behavioral inhibition, working memory, regulation of motivation, and motor control. Consistent with this model, the present study found strong relationships within the Clinical Group on scores from measures of working memory, sustained attention, and inhibition control, but not with the majority of basic attention measures. The Clinical Group's reaction time scores, as a function of motor control, were not consistent with this model in that they were not significantly different from the Control Group reaction times.

The pattern of results suggests that basic attention was not strongly associated with the mild decreased abilities in executive and complex attention found in this sample. This is consistent with Barkley's assertion that the CPT may be a more sensitive measure of executive function than of basic attention. At some variance with the findings of this study was the work of Mateer and Mapou (1996). They conducted a study that compared

overall CPT scores to other measures in a brain injured sample and found that it demonstrated significant relationships with Trails A and Digit Span Forward, both measures sensitive to basic attention function. The differences in findings between the present study and the study by Mateer and Mapou may have been due to differences in severity of cognitive impairment between the two samples. The sample in the present study appeared to exhibit very mild decreased cognitive ability compared to the cognitive impairment observed in the brain injured sample of the Mateer and Mapou study. The greater impairment in cognitive ability would likely increase the deficits at all levels demonstrated on the CPT (Conners, 1995).

The variable findings in the Clinical Group in this study may have been a result of several mitigating factors. The small sample size limited statistical power as demonstrated by several of the tests. The lack of statistical power prevented inferences based on those tests that may have been important in the interpretation of the results of this study. Also, the variety of neuropsychological diagnoses that the Clinical Group participants presented with and the medications and side effects to treat the disorders, may have confounded the results. For example, patients on stimulants may have had different response patterns than patients on antidepressant medications. Many of them may have had deficits that did not involve an attentional component, or any deficits. Therefore, the tests selected for this study may have tapped into other cognitive aspects such as intellectual ability, or mood disorders, requiring caution in interpreting the results of this mixed clinical sample.

The Control Group data, counter to the hypothesis, revealed no significant correlations. Although counter to the hypothesis, the findings are consistent with the expected profile of a group of normal individuals from the community. It would be a common finding, due to a variety of factors (i.e., the variable sensitivity of the tests administered, the aspects of cognition measured by the various tests, the motivation of the participant, the effects of fatigue, the effects of anxiety, and rapport), to have participants in the Control Group with a scattering of test scores across a broad range of function, including the cognitively impaired range (Heaton, Grant, & Matthews, 1991). The broad distribution of scores and the lack of a cohesive pattern of underlying deficits could result in nonsignificant correlations, as the data from this study suggest.

The Conners CPT has many benefits including: ease of administration, a variety of measures associated with attention deficits, convenience of a printed narrative, a graphic analysis of performance, a representative normative database for children, and sensitivity to medication therapy in children with attention deficits. However, the findings of this study corroborate the findings in the literature (Spren & Strauss, 1998), that the CPT needs a more representative normative database for use in the neuropsychological assessment of attention deficits in an adult population. The results of this study indicated that the CPT is sensitive to cognitive processes associated with attention deficits in a Clinical Population and that it demonstrated several significant relationships with other measures used in the assessment of ADHD, particularly tests administered visually. However, in a group of well-screened controls, it demonstrated a high false positive rate, indicating a possible tendency to overstate deficits.

This study addressed several issues regarding the assessment of attention in an adult population. The results of this study corroborated the findings in the literature that attention is a complex concept that is difficult to assess with any one instrument (Mirsky, 1987; Halperin et al., 1991; Barkley, 1995; Mirsky et al., 1997; Mapou, 1999; Faraone, 2000). The assessment of attention is mitigated by a variety of cognitive processes as demonstrated by the model of attention proposed by Barkley (1997) that included motor control, and aspects of executive function, processing speed, and complex and basic attention. In this study, while the findings were variable, the strongest relationships between measures were those of executive function, processing speed, and complex attention. Basic attention measures and psychomotor speed were less likely to be associated with the CPT scores in the sample evaluated. This is consistent with Barkley's (1991) research on the assessment of attention in children, suggesting that continuous performance tests are more likely tests of executive function than attention. It is also consistent with (Barkley, 1991, Halperin et al., 1991) findings of great variability in research results comparing CPT scores with other measures of neuropsychological assessment in children. The findings were often affected by participant characteristics, sample size, and inconsistent methodology between studies (Walker et al., 2000).

The variability in research findings emphasizes the need for convergence of evidence based on a variety of measures including neuropsychological instruments, clinical history, behavioral observation, and self-report in the diagnosis of adult ADHD. The neuropsychological measures themselves are problematic in that no one instrument taps into only one cognitive domain because of the considerable overlap in cognitive

processes (Halperin et al., 1991). Finding converging evidence of attention deficits in an adult population with existing instruments is also affected, as demonstrated in this study, by the sensitivity/specificity of the various instruments to the severity of impairment. Additionally, the assessment of attention deficits may be impacted by the participant's level of motivation, fatigue, mood, anxiety, and rapport with the examiner.

Future Directions

A revision of the CPT, the CPT-II, has been developed since this study was conducted. The revisions address two of the issues presented here, sparse adult normative data from the general population, and the tendency for high false positive rates in a normal population. The CPT-II has a new, expanded normative database across the age span, including adults, 18 - 55+. In addition to the new normative data, the new version includes software options to reduce false positives or to reduce false negatives dependent upon local base rates. Future research to evaluate the effect of these changes on response patterns in clinical as well as non-clinical populations is warranted. It may also be informative to compare the test results of normal controls on the original Conners CPT to their performance on the new CPT-II.

Future research would benefit from further exploration of false positive rates in a normative sample. Research evaluating the effects of varying the false positive/false negative settings on the CPT-II in a normative sample may help refine the interpretation and consistency of results in an adult population.

Future research would also benefit from the identification of an adequate sample of pure ADHD adults to be evaluated in the Clinical sample and normal controls. Many of

the findings of the present study may have been compromised by the small sample size of both groups. The variety of diagnoses within the Clinical Group may also have impacted the results. For example, participants in the mixed clinical sample with mood disorders or memory deficits are likely to exhibit different response patterns on neuropsychological tests than participants with other disorders, such as pure ADHD. Depressed patients may demonstrate slower processing speed but produce accurate results, whereas patients with ADHD may also display slower processing speed, and respond impulsively and less accurately on timed measures (Lezak, 1995; Walker et al., 2000).

The results of this study indicated a sensitivity to mode of administration of the assessment measures with those presented visually demonstrating stronger correlations. Future research may benefit from the evaluation of both visual and auditory continuous performance tests with other neuropsychological measures of attention to increase our understanding of the role of mode of administration on the pattern of performance.

The choice of measures used and compared in this study may also warrant further investigation. Different measures may have demonstrated stronger relationships with the Conners CPT scores, such as a measure of processing speed and capacity and divided attention. The increase in interest in adult ADHD has led to the development of new neuropsychological assessment instruments. Inclusion of these new measures in future studies may improve our understanding of the construct of attention. Part of the development of new instruments to assess ADHD will include expanding the adult normative database. The increase in normative data will be particularly important given the atmosphere of increased public demand for assessment of this disorder.

References

- American Psychiatric Association (1994). Diagnostic and statistical manual of mental disorders (4th ed.) Washington, DC: Author.
- American Psychiatric Association (2000). Diagnostic and statistical manual of mental disorders (4th ed.) (TR) Washington, DC: Author.
- American Psychological Association (1986). Guidelines for computer-based tests and interpretations. Washington, DC: Author.
- Barkley, R. A. (1991). The ecological validity of laboratory and analogue assessment methods of ADHD symptoms. Journal of Abnormal Child Psychology, 19(2), 149-178.
- Barkley, R. A. (1990). Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment. NY: Guilford Press.
- Barkley, R. A. & Grodzinsky, G. (1994). Are test of frontal lobe functions useful in the diagnosis of attention deficit disorders? The Clinical Neuropsychologist, 8, 121-139.
- Barkley, R. A., Grodzinsky, G., & DuPaul, G. J. (1992). Frontal lobe functions in attention deficit disorder with and without hyperactivity: A review and research report. Journal of Abnormal Child Psychology, 20(2), 163-188.
- Barkley, R. A., Murphy, K., & Kwasnik, D. (1996). Psychological adjustment and adaptive impairments in young adults with ADHD. Journal of Attention Disorders, 1, 41-54.
- Berg, E. A. (1948). A simple objective technique for measuring flexibility in thinking. The Journal of General Psychology, 39, 15-22.

- Campbell, J. W., D'Amato, R. C., Raggio, D. J., & Stephens, K. D. (1991). Construct validity of the Computerized Continuous Performance Test with measures of intelligence, achievement, and behavior. Journal of School Psychology, 29, 143-150.
- Carlson, N. R. (1994). Physiology of Behavior (5th ed.) Needham Heights, MA: Allyn & Bacon
- Conners, C. K. (1994). The Conners Continuous Performance Test. Toronto, Canada: Multi-health Systems.
- Denkla, M. B. (1991). Attention Deficit Hyperactivity Disorder – Residual Type. Journal of Child Neurology, 6, Supplement, S44-50.
- Epstein, J. N., Conners, C. K., Sitarenios, G., and Erhardt, D. (1998). Continuous performance test results of adults with attention deficit hyperactivity disorder. The Clinical Neuropsychologist, 12(2), 155-168.
- Epstein, J., Johnson, D. & Conners, C. K. (1999). Neuropsychological assessment of response inhibition in adults with attention deficit hyperactivity disorder. Journal of the International Neuropsychological Society, 5(2), 112. (Published Abstract).
- Faraone, S. V. (2000). Attention Deficit Hyperactivity Disorder in adults: Implications for theories of diagnosis. Psychological Science, 9, 33-36.
- Faraone, S. V. & Biederman, J. (2000). Neurobiology of Attention-Deficit Hyperactivity Disorder. Biological Psychiatry, 44, 951-958.
- Halperin, J. M., Sharma, V., Greenblatt, E., & Schwartz, S. T. (1991). Assessment of the Continuous Performance Test: Reliability and validity in a nonreferred sample. Psychological Assessment, 3(4), 603-608.

Heaton, R. K., Grant, I., & Matthews, C. G. (1991). Comprehensive norms for an expanded Halstead-Reitan Battery. Odessa, FL, Psychological Assessment Resources, Inc.

Heiligenstein, E., Johnston, H. F., Neilsen, J. K. (1996). Pemoline therapy in college students with attention deficit hyperactivity disorder: A retrospective study. Journal of American College Health, 45, 35-39.

Johnson-Greene, D. & Emery, E. (1999). Characteristics of adult patients seeking evaluation for ADHD. Journal of the International Neuropsychological Society, 5(2), 112. (Published Abstract).

Kaufman, A. S. (1990). Assessing adolescent and adult intelligence. Boston: Allyn & Bacon.

Klee, S. H., & B. D., Garfinkle (1983). The computerized Continuous Performance Task: A new measure of inattention. Journal of Abnormal Child Psychology, 11, 487-496.

Klee, S. H., & B. D., Garfinkle, & Beauchesne, H. (1986). Attention deficits in adults. Psychiatric Annals, 16, 52-56.

Levin, F. R., Evans, S. M., McDowell, D. M., & Kleber, H. D. (1998). Methylphenidate treatment for cocaine abusers with adult attention-deficit/hyperactivity disorder: A pilot study. Journal of Clinical Psychiatry, 59, 300-305.

Lezak, M. D. (1995). Neuropsychological Assessment. New York: Oxford University Press.

Mannuzza, S., Klein, R.G., Bessler, A., Malloy, P., & LaPadula, M. (1993). Adult outcome of hyperactive boys. Educational achievement, occupational rank, and psychiatric status. Archives of General Psychiatry, 50(7), 565-576.

Mapou, R. L. (1999). Diagnosis du jour? Research perspectives on adult attention deficit hyperactivity disorder. (ADHD). Journal of the International Neuropsychological Society, 5(2), 112. (Published Abstract).

Mapou, R. L. (1999). Assessment, diagnosis, and documentation of adult attention deficit hyperactivity disorder (ADHD). Journal of the International Neuropsychological Society, 5(2), 112. (Published Abstract).

Mielke, J. & Hall, S. (1998). Anxiety level and performance on the PASAT, ASPAT, and VSPAT. Archives on Clinical Neuropsychology, 13(1), 90. (Published Abstract)

Quinlan, D. M. & Brown, T. E. (1999). Memory functioning in adults with attention deficit hyperactivity disorder (ADHD). Journal of the International Neuropsychological Society, 5(2), 112. (Published Abstract).

Reitan, R. M., & Wolfson, D. (1995). The Halstead-Reitan Neuropsychological Test Battery. Tucson, AZ: Neuropsychology Press.

Reitan, R. M., & Wolfson, D. (1993). The Halstead-Reitan Neuropsychological Test Battery. (2nd ed.). Tucson, AZ: Neuropsychology Press.

Riordan, H. J., Flashman, L. A., Saykin, A. J., Frutiger, S. A., Carroll, K. E., and Huey, L. (1999). Neuropsychological correlates of methylphenidate treatment in adult ADHD with and without depression. Archives of Clinical Neuropsychology, 14(2), 217-233.

Rosvold, H. E., Mirsky, A. F., Sarason, I., Bransome, E. D., & Beck, L. H. (1956). A continuous performance test of brain damage. Journal of Consulting Psychology, 20(5), 343-350.

Schachar, R., Logan, G., Wachsmuth, R., & Chajczyk, D. (1988). Attaining and maintaining preparation: A comparison of attention in hyperactive, normal and disturbed control children. Journal of Abnormal Child Psychology, 16(4), 361-378.

Segalowitz, S. J., and Graves, R. E. (1990). Suitability of the IBM XT, AT, and PS.2 keyboard, mouse, and game port as response devices in reaction time paradigms. Behavior Research Methods, Instruments, & Computers, 22(3), 283-289.

Spencer, T., Wilens, T., Biederman, J., Faraone, S. V., Ablon, J. S., & Lakey, K. (1995). A double-blind crossover comparison of methylphenidate and placebo in adults with childhood-onset attention deficit hyperactivity disorder. Archives of General Psychiatry, 52, 434-443.

Spencer, T., Wilens, T., Biederman, J., Bostic, J., Prince, J., Gerard, K., et al., (1999). Efficacy and tolerability of a mixed amphetamine salts compound in adults with attention deficit hyperactivity disorder. Paper presented at the 46th Annual meeting of the American Academy of Child and Adolescent Psychiatry, Chicago.

Spreen, O. and Strauss, E. (1998). A Compendium of Neuropsychological Tests. (2nd Ed.) NY: Oxford University Press.

Trommer, B. L., Hoepfner, J. B., Lorber, R., & Armstrong, K. (1988). Pitfalls in the use of a Continuous Performance Test as a diagnostic tool in attention deficit disorder. Developmental and Behavioral Pediatrics, 9,(6), 339-345.

Walker, A. J., Shores, E. A., Trollor, J. N., Lee, T., & Sachdev, P. S. (2000). Neuropsychological functioning of adults with Attention Deficit Hyperactivity Disorder. Journal of Clinical and Experimental Neuropsychology, 22(1), 115-124.

Wechsler, D. (1987). WMS-R manual: Wechsler memory Scale-Revised. New York: Psychological Corporation.

Wechsler, D. (1981). WAIS-R manual: Wechsler Adult Intelligence Scale-Revised. New York: Psychological Corporation.

Weiss, G. & Hechtman, L.T. (1993). Hyperactive children grown up. (2nd ed.). New York: Guilford Press.

Appendix A

Correlational Study of the CPT

Informed Consent Form

I understand that I am being asked to take a series of tests that measure various mental abilities. The purpose of this study is to evaluate the relationship of performance on several tests of attention, concentration, and cognitive function. These tests will take approximately 85 minutes to complete. Information regarding medication use, illegal drug use, psychological and medical history will also be requested. I further understand that the physical, psychological, emotional, and social risks involved in this experiment are minimal. I understand that the "Correlational Study of the CPT" research is presented truthfully and studies only the stated purpose. All information is confidential. I understand that my name will not be included on any data collected. The data will be kept in a locked file at the Western Montana Clinic Neurosciences Department.

I understand that my participation in this research is voluntary and that I may withdraw at any time. As an alternative to participation I may choose at any time to return the testing materials to the examiner. There are no immediate benefits to myself of participation. Potential benefits to society include a better understanding of the relationship of performance on several tests of cognitive function.

I understand that if I have any questions or concerns regarding this experiment that I can contact the project supervisor, Stuart Hall, Ph.D. or the project director, Jeannine Mielke, M.A., through the Department of Psychology, University of Montana, at phone number 406-243-4521 for further information. If I have any questions regarding my rights as a research participant, I may contact the Joint Investigational Review Board, 500 W. Broadway, Missoula, Mt 59802, 406-329-5669.

It is required by the legal counsel of the University of Montana that we include the following statement. In the event that you are injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by the negligence of the University or any of its employees, you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M.C.A., Title 2, Chapter 9. In the event of a claim for such injury, further information may be obtained from the University's Claims Representative or Legal Counsel.

I, _____, agree to participate in the research,
(print name) "Correlational Study of the CPT"

(participant signature) (date)

(406) - _____
(participant phone number to schedule testing)

(researcher) (date)

Appendix B

Dear participant,

We are asking your cooperation in participating in a joint research project with the University of Montana and Western Montana Clinic. You will be asked to take a series of tests that measure a variety of mental abilities, such as attention and concentration. Your participation may help us to better understand the relationship of performance on a variety of tests that measure attention deficits.

The decision to participate is entirely voluntary. If you prefer not to participate, simply inform the researcher. If you are interested in participating, read the next page which is an Informed Consent Form. This sheet must be read and signed before any information provided by you may be used for research purposes.

Your identifying information will be filed separately from your responses to the tests and all information will remain confidential.

Your time and consideration are appreciated.

Sincerely,

Jeannine Mielke, M.A.
Graduate Student, University of Montana

Appendix C

Demographics

Please fill in the following information.

Age: _____

Date of Birth: ____/____/____

Gender: (circle) M F

Years of Education: _____ (Add 12 years for highschool to your number of completed years of college, or add years of highschool completed before GED to your number of completed years of college)

Hearing problems: Yes _____ No _____

Vision problems: Yes _____ No _____

**Appendix D
Health Screening Questionnaire**

Please fill out this medical history form.

ALL INFORMATION YOU PROVIDE WILL BE HELD STRICTLY CONFIDENTIAL

Neurological History

Yes No

- | | | |
|---|-------|-------|
| 1. Have you ever been diagnosed with a neurological disorder? | _____ | _____ |
| 2. Have you experienced more than three minor head injuries with at least one resulting in concussion or loss of consciousness? | _____ | _____ |
| 3. Have you ever lost consciousness for more than five minutes? | _____ | _____ |

Psychiatric History

- | | | |
|---|-------|-------|
| 4. Have you ever been diagnosed with a psychiatric condition or Major Affective Disorder? | _____ | _____ |
| 5. Have you been diagnosed with an Attention Deficit Disorder? | _____ | _____ |
| 6. Have you been diagnosed with a Learning Disability? | _____ | _____ |

Drug History

- | | | |
|---|-------|-------|
| 7. Have you used the following 10 times or more in the last month? | | |
| A. alcohol | _____ | _____ |
| B. marijuana | _____ | _____ |
| C. hallucinogens | _____ | _____ |
| D. stimulants | _____ | _____ |
| E. tranquilizers | _____ | _____ |
| F. antidepressants | _____ | _____ |
| G. anticonvulsants | _____ | _____ |
| H. inhalants | _____ | _____ |
| 8. Have you or someone close to you expressed concern about your alcohol or drug use? | _____ | _____ |

Appendix E

SCRIPT

Thank you for participating in this study. You will be asked to do a variety of things today. The tests look at several cognitive abilities, including memory, attention, concentration and mental flexibility. Some will be easy and others will be more difficult. Just do your best on each one. Feel free to ask questions. On some tests I can repeat the directions or give you more information, but on other tests I can't give you any more details or repeat the instructions. So listen carefully for the instructions to each test.

Any questions?

Let's begin.

Appendix F

DEBRIEFING

Thank you for your time today.

Your participation helps us to look at how the general population performs on these tests in comparison to a group of people who were referred to a neuropsychologist for the same testing. Because these tests are in professional use we are not allowed give you much information about them or to interpret how you did today. Only a doctoral level neuropsychologist is allowed to make those interpretations, it's considered unethical for me to make inferences from this limited test data. Be sure to sign off on the credit sheet so you will receive your three credits.

Appendix G

**Interested
in Participating in a Research Study ?**

It requires approximately an hour and a half of your time.

**Receive
\$10.00**

To participate please call Jeannine Mielke at _____ in Missoula, MT. Or call

Jeannine Mielke at 208-676-0476 in Coeur d'Alene, ID.

Appendix H

Distribution of Medications in the Clinical Group by Classification.

<u>Medication Type</u>	<u>Number of Participants Prescribed the Medication</u>
Serotonin reuptake inhibitors	5
Benzodiazepines	2
Anticonvulsants	3
Tricyclics	4
Stimulants	1

Thirteen individuals in the Clinical Group were on prescribed medication, some individuals were prescribed more than one medication.