Sustained attention and processing speed in children with traumatic brain injury (TBI) and children with attention-deficit hyperactivity disorder (ADHD)

Jody Lynn Hagen
The University of Montana

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SUSTAINED ATTENTION AND PROCESSING SPEED IN CHILDREN WITH
TRAUMATIC BRAIN INJURY (TBI) AND CHILDREN WITH ATTENTION-
DEFICIT HYPERACTIVITY DISORDER (ADHD)

by

JODY LYNN HAGEN, M.A.

B.S. Southwest Missouri State University, 1996
M.A. Appalachian State University, 1998

presented in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

The University of Montana

May 2003

Approved by:

[Signature]
Chairperson

[Signature]
Dean, Graduate School

5-19-03

Date
Sustained attention and processing speed was investigated in 9-14 year old children diagnosed with either Traumatic Brain Injury (TBI) or Attention Deficit Hyperactivity Disorder (ADHD). Both TBI and ADHD are disorders that result in similar behavioral and cognitive dysfunction. Additionally, the underlying neuropathology for both conditions involves similar brain structures. Therefore, archival medical records were examined and scores from various neurobehavioral tests of sustained attention and processing speed were recorded. Additionally, for the children diagnosed with TBI, the level of injury severity was determined, and only those who had sustained a mild or moderate TBI were included in this study. The present study was conducted to contribute to the literature base in a valuable way, by gaining understanding of neuropsychological functioning of children with milder forms of head injury. Secondarily, this study explored whether the current disparity between treatment approaches for children with TBI and those with ADHD are adequate.

There were significant differences found between the groups on some, but not all of the tests of sustained attention and processing speed. However, on the particular tests where there were significant differences, scores were within normal limits. Therefore, overall test performance between children with ADHD and mild-moderate TBI was more similar than dissimilar and thus, essentially undistinguishable from one another, at least on the measures used in this study. Importantly, this revealed that performance on neurobehavioral tasks of attention and processing speed does not add any unique contribution to aid in diagnosis.

Finally, based upon informal analysis only, there was initial evidence that the children with mild TBI did not evidence significant neuropsychological impairments after 6 months or more post-injury. However, future research needs to include pure mild head injured groups as well as an age/education matched control group in order to fully understand the meaning of these results.
PREFACE

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I have eternal gratitude to my parents and my brother for believing in my abilities and dreams, encouraging me to press on, and for always being there for me whenever I needed anything!!

To my beloved husband, Rich, you are such an amazing gift from God. You have edified me throughout this experience and selflessly followed me across the country to finish the race set before us. I am blessed to have you in my life and continue to be in awe of you. I love you with every fiber of my being. Thank you for your love.

Most importantly, I thank my Lord and Savior Jesus for placing this dream in my heart, ordering my footsteps along the way, and filling me with His strength to persever. All the glory and honor is to my God.
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INTRODUCTION

Many disorders seen by pediatric neuropsychologists have, as a cardinal or secondary symptom, problems in some aspect of attentional functioning or processing speed. Disorders such as schizophrenia, pervasive developmental disorder, conduct disorder, depression, attention-deficit hyperactivity disorder (ADHD), and learning disabilities are reported to have attention deficits as prominent symptoms (Light et al., 1996). Attention deficits have also been reported in children in many disorders associated with identifiable central nervous system (CNS) dysfunction. For example, attention deficits have been reported after head injury (Catroppa & Anderson, 1999; Fenwick & Anderson, 1999), treated leukemia (Brouwers, P., Riccardi, R., Poplack, D., & Fedio, P., 1984), seizure disorders (Holdsworth & Whitmore, 1974), encephalitis (Light et al., 1996), hypoxia/anoxia, toxic/lead poisoning, tumors, Tourettes/tic disorders (Light et al., 1996), and stroke (Aram, 1986). Likewise, slowed processing speed has been found to be a common sequela of CNS dysfunction. For instance, impaired processing speed has been associated with diabetes mellitus, ADHD, traumatic brain injury (TBI), some tumors, multiple sclerosis, and developmental disorders (Berg & Linton, 1989; Brassington & Marsh, 1998). ADHD and TBI are two disorders that commonly present with both attention deficits and slowed processing speed.

ADHD

ADHD is a disorder manifested by a conglomerate of behaviors such as impulsiveness, inattentiveness, restlessness, and over-activity. It is often accompanied by emotional immaturity, aggressiveness, and poor academic performance (Barkley, 1981). In order to meet diagnostic criteria, the child must display six or more symptoms of either
inattention or hyperactivity/impulsivity for at least six months. Some of the symptoms that cause impairment must have been present before age 7 years and must be manifested in at least two settings (DSM-IV-TR, 2000).

Prevalence and Incidence Data

Approximately 3-5% of United States children suffer with ADHD (DuPaul & Stoner, 1994). Higher global estimates for community samples have been reported as ranging from 7.5 - 21.6% for both parent and teacher generated samples (DuPaul et al., 1998; Gaub & Carlson, 1997). Additionally, the disorder tends to be more common in boys, at an estimated male:female ratio ranging from 4:1 to 9:1 depending on the setting (Campbell, 2000; DSM-IV-TR, 2000; Spreen, Risser, & Edgell, 1995). Although the incidence of ADHD has not likely increased, it does appear to be diagnosed more often, which may stem from heightened public and professional awareness as well as earlier preschool admission, which allows for earlier detection of the symptoms (Barkley, 1998).

Etiology

There have been a variety of etiologies proposed for the development of ADHD over time. Importantly, despite the appearance of mere behavioral disturbances, one must consider that all human behavior is mediated by the brain or central nervous system, including the ability to attend to tasks, to control impulsivity, and to regulate one’s activity (Lerner, Lowenthal, & Lerner, 1995). Therefore, researchers have focused on neurophysiological and neuroanatomical origins for ADHD. Originally, some tried to link ADHD to structural, minimal brain damage (MBD), a conceptualization that has since, found little empirical support (Spreen, Risser, & Edgell, 1995). However, recent studies applying structural and functional neuroimaging using magnetic resonance imaging.
(MRI) and positron emission topography (PET), electroencephalography (EEG), and neurochemical abnormalities have significantly increased the converging line of evidence to a common neurological pathway (Barkley, 1998). Taken together, this body of evidence indicates that the prefrontal cortex/frontostriatal networks are likely involved in the biology of ADHD, as discussed below (Tannock, 1998).

**MRI and PET.** Using MRI, researchers are able to identify areas of the brain that appear structurally different in children with ADHD versus children without the disorder. Giedd et al. (1994) found that the rostrum and the rostral body of the corpus callosum were significantly smaller in children with ADHD. Specifically, the rostral body corresponds to the pre-motor and supplementary motor areas of the cortex, which are located within the frontal cortex of the brain. This anatomical difference found by Giedd et al., (1994) also corresponded to behavioral measures and indicated that the smaller area was associated with a higher rating of impulsivity and hyperactivity. Other researchers found similar results; however, they also found differences in the genu and the selenium of the corpus callosum (Hynd, Semrud, Lorys, Nover, & Eliopoulos, 1991). Generally, the function of the corpus callosum can be conceptualized as the white matter structure that provides a pathway for the left and right hemispheres of the brain to transfer and integrate information. However, one of the primary components of this function is the allocation of attention and relative levels of arousal in the two hemispheres (Giedd et al., 1994). Therefore, in addition to reflecting abnormalities in the cortical sources of the fibers traversing through it, abnormalities of the corpus callosum in ADHD may reflect problems in interhemispheric connectivity itself (Giedd et al., 1994).

Furthermore, other researchers investigated the relationship between
neuroanatomical structural differences and neurobehavioral performance in children (age 8-17) with ADHD. Semrud-Clikeman, et al. (2000), selected participants who were positive responders to methylphenidate, with additional requirements for inclusion including uncomplicated pregnancy, benign medical history, intelligence scores of 85 or higher, and normal neurological examination. The researchers excluded children with a diagnosis of learning disability or comorbid psychiatric disorder (Semrud-Clikeman, et al., 2000). Each participant completed neuropsychological tests of sustained attention and response inhibition, and received a brain MRI. The researchers found that the children with ADHD performed worse than controls on sustained attention tasks and evidenced compromised right frontal volumes (Semrud-Clikeman, et al., 2000). Similarly, Katya et al. (1999), used functional magnetic resonance imaging to examine the prefrontal brain regions in adolescents (age 12-18) with ADHD, compared to controls, while engaged in a response inhibition task and a motor timing response task. The adolescents with ADHD were found to possess subnormal activation (hypofrontality) of the prefrontal systems necessary for higher-order motor control (Katya et al., 1999).

**EEG.** Studies using psychophysiological measures of nervous system electrical activity have been inconsistent in demonstrating group differences between ADHD and control children. However, the results of quantitative EEG (QEEG) and evoked response potential (ERP) measures taken in conjunction with performance of vigilance tests have been rather consistent (Frank, Lazar, & Seiden, 1992). The most constant pattern for QEEG research is increased slow wave, or theta activity, particularly in the frontal lobe, and excess beta activity (Chabot & Serfontein, 1996; Kuperman, Johnson, Arndt, Lindgren, & Wolraich, 1996). Other researchers evaluated the QEEG activity in a group
of children with ADHD (mean age 10.51), compared to a control group (mean age 10.03) at open eyes (with eyes open, but the children were not engaged in an attentional activity) and during performance on the Continuous Performance Test (El-Sayed, Larsson, Persson, & Rydelius, 2002). The children with ADHD showed an altered pattern of QEEG activity, especially during the attentional load task, with increased slow cortical activity primarily over the frontal areas, suggesting impaired frontal lobe functioning (El-Sayed et al., 2002). Additionally, ADHD children have been found to have smaller amplitudes in the late positive components of the ERPs, which are believed to be a function of the prefrontal regions of the brain. Moreover, poorer performances on vigilance tests (tests of sustained attention) were found to correlate with smaller amplitudes in the late positive components of the ERPs, again linking impaired attention with prefrontal region dysfunction. Performance on these tests of vigilance tends to improve with treatment by stimulant medication (Kuperman et al., 1996), which have been shown to exert their pharmacological effects in the prefrontal regions.

**Neurochemical Factors.** As mentioned previously, dysfunction of the prefrontal cortex (PFC) has been associated with the development of ADHD (Casey et al., 1997). The cognitive functioning of the PFC is modulated in a crucial manner by the neurotransmitters norepinephrine (NE) and dopamine (DA; Arnsten & Lombroso, 2000). An excess in the production of these critical neurotransmitters, NE or DA, results in over-stimulation of the brain, and a consequent dysfunction of the neural circuits underlying attention (Riccio, Hynd, Cohen, & Gonzalex, 1993). Additionally, levels of NE can be indirectly determined by measuring the metabolites it forms (normetanephrine and metanephrine; Pliszka et al., 1994). Researchers have shown that children with ADHD

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excrete significantly more metabolite than controls, which lends support for the possible role of NE levels in the etiology of ADHD (Pliszka et al., 1994).

Family, twin, and adoption studies have shown ADHD to have a substantial genetic component. In particular, the role of DA dysfunction in the development of ADHD has been evaluated primarily through pharmacological and genetic studies. Specifically, the gene for the dopamine D4 receptor (DRD4), with 7 copies of the 48-bp allele, has received considerable attention recently with regard to ADHD (Barr, 2001). Smalley et al. (1998) found an increased frequency of the DRD4 (7-repeat allele) in an ADHD sample compared with an ethnically matched control group. In a follow-up investigation of proband/parent trios, the same allele was found to occur at a higher frequency in probands than in the nontransmitted alleles of the parents (Faraone et al., 1999; Smalley et al., 1998).

Additionally, there is a considerable amount of interaction between the dopaminergic and serotonergic neurotransmitter systems (Kelland & Chiodo, 1996). Thus, researchers have suggested a hypothesis regarding the involvement of serotonin (5-HT) in the development of ADHD. They have suggested that 5-HT has regulatory control over DA neurotransmission, consequently, disruption of the 5-HT system would then disrupt the DA system and impact DA-mediated behaviors (Kelland & Chiodo, 1996). Quist et al., recently studied the 5-HT1B receptor gene for linkage disequilibrium between a particular polymorphism (mutation) and ADHD (2003). They found evidence for a trend towards excess transmission of this particular allele, especially through paternal transmission to the affected child (Quist et al., 2003). Although preliminary, the data suggests that 5-HT genes may be important risk factors for the development of
ADHD. Moreover, 5-HT neurons send projections to DA terminals present in the striatum, nucleus accumbens, and prefrontal cortex (Lombroso, Quist, & Kennedy, 2001).

Given the plethora of neurological studies that implicate the PFC/frontostriatal networks in the etiology and/or dysfunction of ADHD, it makes sense to compare this particular group of children to another group, whose neuroanatomical involvement is similar.

TBI

Traumatic head injury is the most common cause of brain damage (Kurtz, 1984). The neuropathology underlying TBI generally occurs in two stages. There is the primary injury, which is the damage that is incurred at the moment of impact, and there is the secondary injury, which results from the ensuing physiological processes (Bennett, Dittmar, & Ho, 1997). The secondary injury may be caused by epidural or subdural hematomas, raised intracranial pressure and swelling, leading to possible brain shift, hypoxia and/or anoxia, or hydrocephalus from blood filled ventricles (Bennett, Dittmar, & Ho, 1997). The primary injury can be either open or closed. Open head injuries are penetrating injuries in which the skull is compromised and the brain is essentially exposed. Oftentimes, these injuries are caused by missile fragments, puncture wounds (e.g., nail gun), or gunshot wounds and account for less than 10% of all TBIs (Lezak, 1995). Closed head injuries occur when the brain sustains the injury while the skull remains intact and account for approximately 90% of TBIs (Lezak, 1995). A focal brain injury, diffuse axonal injury (DAI), or both can result from a closed head injury. Focal brain injuries result from collision of the brain with the rough interior surface of the skull at the time of impact (Bennett et al., 1997). This type of injury often occurs in the orbito-
frontal area frequently causing impaired response inhibition, disrupted attention, impaired social behavior, and difficulties with planning and organization (Kolb & Whishaw, 1996; Kraus & Sorenson, 1994). The term 'diffuse axonal injury', as it is now known, was first comprehensively described by Strich (1956) and referred to primary damage to the white matter in the brain. DAI is generally caused by the acceleration and deceleration forces present at the instant of brain injury that produce rotational or twisting effects on brain tissue (Bennett et al., 1997). The shear injury (rotation or twisting) tears axons and shears synaptic connections as well as often disrupting brain myelin and causing reactive swelling (Bennett et al., 1997). Researchers have also shown that DAI can occur without any direct impact to the head (e.g., whiplash), and can occur with concussion (Bennett et al., 1997; Putnam, Millis, & Adams, 1996). Microscopic axonal injury is thought to be the primary mechanism in mild closed head injury (Povlishock & Coburn, 1989).

Research has shown that the deficits present in mild TBI tend to be more subtle and include slowed information processing, mild memory problems, and difficulty in sustaining attention (Bigler & Clement, 1997).

Prevalence and Incidence Data

Brain injury is the most common cause of pediatric traumatic death (Ward, 1995). In 1988, an estimated 2.9 million head injuries were treated in emergency rooms, and roughly 77% involved children (Waldman, 1996). Overall, approximately 60% of all concussions, skull fractures and closed head injuries are suffered by children over the age of five, and approximately, 200-300 per 100,000 children suffer a TBI each year (Ward, 1995).
Relative Risk

An actual percentage of relative risk is not available, however, researchers have been able to identify a number of factors that contribute to an increased likelihood of suffering a TBI. Biological sex is one factor, with males sustaining brain injuries twice as frequently, or more, as females (Henry, Hauber, & Rice, 1992; Jelalian et al., 1997; Naugle, 1990). Researchers have linked this risk factor to risk taking behavior, especially in adolescence (Jelalian et al., 1997). In addition, researchers have found a link between pre-existing mental disorder such as neurohypophysis or ADHD and sustaining head injury (Li et al., 1995). In their study, of those children with pre-existing mental conditions, 73% sustained a head injury as compared to 53% for other patients with no mental health history (Li et al., 1995).

Etiology

Transport Accidents. In children, as in adults, automobile accidents account for the majority of fatal injuries; however, the prevalence increases significantly as the child goes from infancy (23%) to adolescence (82%; Waldman, 1996). Additionally, motor vehicle accidents, together with bicycle accidents account for approximately 67% of all TBIs in children and adolescents (Levin et al., 1992). In 1991, an estimated 492,000 bicycle-related injuries treated in emergency rooms involved children, and over 61,000 of these injuries were head injuries (Waldman, 1996). These head injuries account for more than 60% of bicycle-related deaths (Li, Baker, Fowler, & DiScala, 1995).

Shopping carts. In the years 1990-1992, an estimated 75,200 shopping cart-related injuries occurred in children treated in US emergency departments (Smith, Dietrich, Garcia, & Shields, 1995). Children younger than 5 years of age were at highest risk, with
TBI and cervical injuries accounting for nearly 74% of the total injuries (Smith et al., 1995).

**Falls/Assault/Abuse.** In 1992, in the United States, approximately 22% of TBIs sustained by children were the result of falls (16%) or an assault/abuse (6%; Levin et al.).

**Other contributing factors.** TBI can also occur from all-terrain vehicle accidents, skateboarding, snowboarding, and lawn darts (Waldman, 1996).

In summary, the epidemiological and etiological data for ADHD and TBI, evidences that both disorders involve the fronto-striatal areas of the brain. In addition to their shared neuroanatomical/neurophysiological foundations, ADHD and TBI manifest similar behavioral sequelae, such as: difficulties with sustained attention, slowed processing speed, planning and organization, problem solving, fidgeting, and poor affective control (Barkley, 1998; Fletcher et al., 1996).

**Attention**

Attention is a multifaceted construct that can refer to alertness, arousal, selectivity, sustained attention, or distractibility (Mirsky, 1996). By definition, children with ADHD display difficulties with attention relative to normal children. Douglas (1983) investigated the varying types of attention in ADHD children compared to matched controls and found that ADHD children have the greatest difficulty with sustaining their attention to tasks over time, (vigilance) compared to the control group.

Children who have sustained TBI also evidence attention deficits post-injury. Kaufmann, Fletcher, Levin, Miner, & Ewing-Cobbs, (1993) investigated sustained attention in children with TBI at 6-months post-injury, using a continuous performance task. Their results indicated that children with severe TBI, and those injured at a younger
age, exhibited inferior performance in comparison to uninjured peers. In contrast, Bijur & Haslum (1995) did not find evidence to support the existence of adverse long-term sequelae of mildly head-injured children compared to non-injured controls. However, Bijur & Haslum studied mildly head injured children versus severe (as in the Kaufmann et al. study), and they also used four subtests from the British Ability Scale as their dependent measure, which does not purely assess attention, and taken together, might account for this discrepant finding. Anderson, Fenwick, Manly, & Robertson (1998) examined differential aspects of attention and found that children with moderate-to-severe TBI exhibited significant deficits in sustained and divided attention, and response inhibition, but had relatively intact focused attention. In a different study, again comparing children with moderate-to-severe TBI to controls, researchers found significant deficits in focused and sustained attention, as well as response inhibition (Fenwick, Anderson, 1999). Other researchers have found that children with TBI have a reduced ability to inhibit pre-potent response tendencies using the Delay Task of the Gordon Diagnostic System (Dennis, Wilkinson, Koski, & Humphreys, 1995). Moreover, the TBI children evidenced deficits in sustained attention with severe, moderate, and mild injuries.

**Processing Speed**

In addition to impaired attention, children with ADHD tend to have difficulty processing information efficiently. Although a considerable amount of the research on children with ADHD focuses on the nature of attention deficits or impulsivity, some researchers have examined processing speed more directly. Weiler, Bernstein, Bellinger, & Waber (2000) and Mariani & Barkley (1997) found that children with ADHD or
ADHD – Inattentive Type, manifest significantly less proficient speed of mental computation than matched controls. Additional research has shown that adolescents with ADHD also display a slowness of mental processing speed (Rucklidge & Tannock, 2002). For children with TBI, there is insufficient research addressing processing speed post-injury. Much of the existing literature focuses on attention, memory and learning deficits following TBI in children, but does not examine processing speed. Although children and adults are developmentally different, they share enough commonalities with regard to basic neurological functioning, that one can begin to address processing speed deficits in children with TBI by extrapolating the data from the adult literature.

As a broad consequence of moderate-to-severe TBI in adults, the neuropsychological sequelae include generalized slowing of mental processes (Bigler & Clement, 1997). Slow performance on a visual scanning task such as Digit Vigilance or the Stroop Test (Trennery, Crosson, DeBoe, & Leber, 1989), or increased difficulty in task performance as the response time between trials decreases on the Paced Auditory Serial Addition Task (PASAT; Gronwall, 1986), are considered evidences of slowed information processing. Moreover, Gronwall has shown that individuals who have sustained mild TBI and continue to manifest deficits, (i.e., post-concussion syndrome), tend to perform poorly on the PASAT, which is indicative of impaired processing speed (1989). Additionally, Bennett et al., indicate that decreased speed and efficiency of information processing is a universal complaint from individuals suffering from the aftereffects of TBI, regardless of whether their presenting symptoms are judged to be mild, moderate, or severe (1997). In another study, researchers compared adults with moderate-to-severe TBI with matched controls to assess speed of information processing.
by two serial addition tests. They found that speed of information processing was a major impairment in the TBI group when unconfounded by performance accuracy (Madigan, DeLuca, Diamond, Tramontano, & Averill, 2000). These studies have yet to be replicated with a pediatric population.

If children with ADHD and TBI suffer from deficits in sustained attention and processing speed, they likely interfere with their continued success in academic settings. Oftentimes, the ability of the child to respond quickly affects performance across cognitive domains (Jaffe et al., 1993). Intuitively, such deficits should create significant disruption in dealing effectively with the demands of everyday life, especially in the classroom. Attention deficits interfere with the child being able to follow directions, effectively input information from lectures, and stay on task (Barkley, 1998). Therefore, given the clinically significant impact that ADHD and TBI have in children's lives, it is important to understand how treatment is approached for each of these groups of children.

**Treatment**

**ADHD**

**Pharmacotherapy.** Because the symptoms of ADHD are manifested across environmental settings, a treatment approach that targets the home, the child, and the school would be ideal. However, oftentimes, the first and only line of treatment for children with ADHD is pharmacological (Anastopoulos, Klinger, & Temple, 2001). The rationale for this approach comes from the literature reviewed previously that suggests neurochemical imbalances being involved in the etiology of ADHD (Pliszka et al., 1994; Riccio, Hynd, Cohen, & Gonzalex, 1993). Numerous studies have consistently
demonstrated that stimulant medications are highly effective in the management of ADHD symptoms in a large percentage of children and adolescents (Birmaher, Greenhill, Cooper, Fried, & Maminski, 1989; Rapport, Denney, DuPaul, & Gardner, 1994). However, the positive effects from stimulant medications disappear when the treatment is discontinued. Generally, stimulant medications produce effects on behavior within 30 to 45 minutes after oral ingestion, peak in their therapeutic impact within 2 to 4 hours, and effectively manage behavior for 3 to 7 hours (Cantwell & Carlson, 1978). Moreover, the long-term efficacy of stimulant medications was investigated and researchers found that there was little advantage of medication over no medication (Pelham, 1985; Weiss & Hechtman, 1993). In effect, children with ADHD who had been on medication, but were off at the time of follow-up were not found to differ in any important respect from those who had never received pharmacotherapy (Weiss & Hechtman, 1993).

Cognitive-behavioral Interventions. Given the strong link between cognitive processes and the symptoms of ADHD, some have suggested cognitive behavioral therapy (CBT) as a treatment approach for ADHD. However, research evidence to date has not shown significant benefits. Kendall and Braswell found that CBT reduced impulsivity but had little effect on other features of ADHD (e.g., inattention, disorganization, processing speed; 1993).

Educational interventions. Other treatment approaches include systematic behavioral management techniques to benefit the child’s learning in the school environment (O’Leary, Pelham, Rosenbaum, & Price, 1996). In educational settings, researchers have shown that ADHD symptoms are reduced in formal, structured classrooms versus informal, when children are in small classes with front row seats, when
work is given in small quantities with breaks in between, when tasks are novel with multimodal presentation, and when noise levels are reduced (Bogas, 1993; Jacob, O’Leary, Rosenblad, 1978; Zentall & Shaw, 1980; Zentall & Dwyer, 1998). However, in order for any school based intervention to be successful, it is essential that teachers are actively and willingly engaged in the process of working with ADHD students, and administration is supportive of the identification and intervention for ADHD (Piffner & Barkley, 1998). Unfortunately, due to budget constraints, shortages of qualified teachers, or incomplete treatment approaches (e.g., stimulant medication only), children are often not afforded the opportunity to receive multimodal therapeutic intervention (Piffner & Barkley, 1998).

**Combined interventions.** Singular treatments, whether they are pharmacological, educational, or home based are not, by themselves, sufficient to meet all of the clinical management needs of children with ADHD. Therefore, more recently, health care professionals have begun to employ multiple ADHD treatments in combination; however, there is presently little empirical justification for utilizing such combinations (Anastopoulos, Klinger, & Temple, 2001). Unfortunately, although limited in number, studies generally have shown that, regardless of which combination is used, the therapeutic impact of the combined treatment package typically does not exceed that of either treatment alone (Anastopoulos, Klinger, & Temple, 2001). Consequently, much research needs to be done to find additional treatment options for children with ADHD.

**TBI**

**Acute rehabilitation.** Rehabilitation may be considered an intervention that returns a person to the fullest physical, psychological, social, vocational, avocational, and
educational potential consistent with his or her type of injury and environmental limitations (DeLisa, Martin, & Currie, 1988). Given the individualized aspect of rehabilitation and the lack of standardization, it is difficult to assess efficacy for any one group of individuals. However, despite the lack of uniformity in treatment plans, rehabilitation programs tend to consist of a multidisciplinary approach and include: physicians, nurses, physical and occupational therapists, speech and language pathologists, psychologists, social workers, and special educators (Burke, 1995). Much of the rehabilitation is focused on recovery of function, but when recovery is not completely possible and there are residual deficits, the treatment program transitions its focus on teaching compensatory strategies (Burke, 1995). Teaching compensatory strategies continues from the acute phase of rehabilitation to the outpatient phase, when there is additional emphasis on generalization across environmental settings (Burke, 1995).

**Outpatient rehabilitation.** Oftentimes, acute rehabilitation is followed by outpatient rehabilitation in a day-treatment setting, or more variable, deficit specific therapy (e.g., speech therapy only, 3 times/week; Burke, 1995). The comprehensiveness of outpatient programs varies by region, but many offer comprehensive, coordinated, interdisciplinary services that are subsequently continued in the educational setting when needed (Michaud, 1995). For individuals with mild TBI, rehabilitation is not an automatic treatment intervention. Frequently, children with mild TBI are either treated and released from emergency rooms or not treated by a physician at all (Asarnow et al., 1995), and many question whether children even suffer from residual cognitive sequelae following a mild TBI. Post-concussion syndrome (PCS) is often defined as symptoms that include “somatic complaints (headache, dizziness, fatigue, blurry or double vision, noise...
intolerance, and light sensitivity), cognitive difficulties (subjective complaints of poor concentration, memory, intellectual impairment), and emotional changes (anxiety, depression, irritability)” (Mittenberg, Wittner, & Miller, 1997 p. 447). Most studies of pediatric head injury emphasize observed behavioral and cognitive effects rather than the child’s subjective appraisal of emotional, somatic, or cognitive symptoms. Therefore, Mittenberg et al., investigated if PCS occurs in children and whether the symptoms might be manifested differently (1997). The researchers found that PCS does occur in children and the symptoms are consistent with those reported by adults; however, the extent to which these symptoms persist beyond 6-months post-injury remains a question (Mittenberg et al., 1997). Therefore, even children with a mild TBI might have a need to receive some form of cognitive remediation.

Given the general neuropathological and behavioral similarities between TBI and ADHD, it is useful to compare their performance on neurobehavioral measures of sustained attention and processing speed in order to further understand how treatment should continue to be approached or modified. Unfortunately, there is minimal research that compares neurobehavioral performance between these two groups in adults or children. In adults, researchers compared individuals with severe TBI to matched controls and found impairments for speed of processing, but no significant deficits for accuracy or sustained attention (Posford & Kinsella, 1992). Another study compared adults with ADHD to adults with mild TBI and found that both groups had significantly more difficulties with sustained attention than controls. Moreover, the mild TBI group was characterized by a generalized slowness in their responses, whereas the ADHD group mainly suffered from impulsivity or an inability to regulate their attention and responses
To the author’s knowledge, there is only one published study comparing children with ADHD to children with TBI using neurobehavioral performance tasks (Konrad, Gauggel, Manz, & Schöll, 2000). The researchers examined 27 children with moderate-to-severe TBI, 31 children with developmental ADHD, and 26 matched controls aged 8-12, on two inhibition tasks: the Stop-Signal Task and a Delayed-Response-Task. (Konrad et al., 2000). The authors showed that both children with TBI and children with ADHD showed a pervasive deficit in their inhibitory control processes. In addition, children with TBI were found to suffer from a general slowing of their information processing, which was not correlated with the inhibition deficit. The authors concluded that slowing of information processing speed seemed to be a general consequence of TBI in childhood, whereas slowing of the inhibitory deficits, specifically, are associated with post-injury hypo- or hyperactivity (Konrad et al., 2000). Although this study examined the various components of response inhibition (impulsivity) and processing speed (mean reaction time), it did not address possible differential deficits of attention.

Therefore, due to the dearth of research comparing the performance of children with ADHD to children with TBI, given the dramatic societal impact of these disorders, the present research project was initiated. Attention is a prerequisite for encoding information and is therefore of prime importance for children in the school setting. As mentioned previously, in order for children to be successful academically, their ability to pay attention must be intact. Furthermore, the speed with which children are able to process incoming information will also impact academic achievement, learning of new knowledge, and social interactions. The aim of this study is to explore the nature of the
attention impairments and speed of information processing in children with ADHD compared to children with milder forms of TBI in order to better understand the residual cognitive deficits after mild or moderate TBI, and to better inform treatment decisions for both clinical populations.

Much of the research that investigates neuropsychological deficits in children after TBI, including the study by Konrad et al., use children that have sustained a moderate to severe brain injury. This trend in the literature occurs, despite epidemiological data that indicates that 80-90% of all brain injuries sustained by children fall within the mild range of severity (Kraus, 1996; National Pediatric Trauma Registry - Lescohier & DiScala, 1993). Therefore, the present study will utilize children that have sustained mild to moderate brain injuries, and were referred for neuropsychological evaluation to assess their residual difficulties.

Despite the similarities between behavioral presentations of children with ADHD and children with TBI, it is expected that the groups will exhibit differential performances. First, it is hypothesized that both the ADHD and the TBI groups will exhibit deficits on tasks of attention and processing speed. Second, it is hypothesized that the mild-to-moderate TBI group will perform slower on the processing speed tasks than the ADHD group. Again, there is limited research on speed of information processing following TBI in children; however, a slowness of mental processing and efficiency has been shown to be a general consequence of TBI regardless of severity in adults (Bigler & Clement, 1997; Gronwall, 1986 & 1989; Posford & Kinsella, 1992). Although previous research has found that children and adolescents with ADHD are less proficient in speed of mental computation, there is a possibility that the results were confounded with
mathematical ability and/or learning disability (Barkley et al., 1990, MacLeod & Prior, 1996). Finally, it is hypothesized that the ADHD group will have more difficulty sustaining their attention than the mild-to-moderate TBI group. In a meta-analytic review of the literature on mild head trauma in adults, Binder, Rohling, & Larrabee found that although measures of attention had the largest effect, it had a non-significant impact on neuropsychological performance (1997). Therefore, it is likely that the more severe injuries, even in childhood, account for the variance in performance on attention tasks.
METHOD

Participants

Participants were drawn from files of children seen for neuropsychological evaluation at a private neuropsychology practice in the Northwest. They were referred for evaluation by their parents, schools, psychologists, and/or primary care physicians. The final sample was composed of 58 participants.

Various selection criteria were used and are described below. The files of children 9 to 14 years of age, who had completed the measures utilized in this study, and who were diagnosed with either ADHD or TBI were selected. Children in this age range are considered to have already acquired numerous brain-related abilities to a significant degree in the course of normal development, and are therefore at risk to suffer impairment of previously existing abilities (Reitan & Wolfson, 1992). Additionally, this group of children has not completed the course of normal physical growth and maturation so future neuropsychological growth could also be compromised (Reitan & Wolfson, 1992). Therefore, due to the developmental and neuropsychological dynamics of this age group, it is an important and common age range for neuropsychological study.

The children included in the ADHD group were selected according to DSM-IV criteria, as diagnosed by a licensed clinical psychologist. Children with TBI were included based on documentation of their head injury in their medical record. Additionally, only children with a severity determination of mild to moderate brain injury were included, which again was obtained from information contained in the medical record. Oftentimes, the duration of impaired consciousness is used to determine injury severity. However, other researchers have adopted an alternative method of severity...
determination. Russell and Smith (1961) defined posttraumatic amnesia (PTA) as the period of time during which a patient is unable to store and recall ongoing events. Establishing this time period objectively in children is often accomplished using the Children’s Orientation and Amnesia Test (COAT; Ewing-Cobbs, Levin, Fletcher, Miner, & Eisenberg, 1990). Researchers evaluated the relationship between recovery of function and length of PTA to establish injury severity. They found that children with PTA ≤ 7 days, had functional outcomes in verbal and nonverbal memory scores that returned to the average range by 6 months following the injury, and therefore defined a mild injury (Ewing-Cobbs et al., 1990). Children with PTA from 8 to 14 days exhibited a reduction in verbal memory functions, and nonverbal memory scores were significantly lower at follow-up, thus indicating moderate injury. Finally, Ewing-Cobbs et al., determined PTA > 14 days was considered a severe TBI, as the outcome in verbal and nonverbal memory scores was severely impaired. Other researchers examined linguistic deficits related to injury severity in children and adolescents following TBI, and found similar results (Ewing-Cobbs, Levin, Eisenberg, & Fletcher, 1987). They found that expressive functions were more sensitive to severity of injury than receptive skills, and were more impaired in moderate and severe injuries, than mild (Ewing-Cobbs, Levin, Eisenberg, & Fletcher, 1987).

Therefore, for the present study, although the use of the COAT was not possible given the nature of archival data, severity was determined similarly to Ewing-Cobbs and colleagues based on information contained in the participant’s medical file, including the clinical interview with the children and their families, as well as available hospital documentation or previous treatment provider records (1990). Ultimately, an injury was
considered mild if PTA ≤ 7 days and moderate if PTA was between 8 and 14 days.

In the TBI group, although trauma had occurred at various ages (M = 11 years, range 6-14), all of the children that were included in the present study were at least two months post-injury. Previous research has shown that children with behavioral changes after TBI, manifest hyperactivity and attention deficits by two - three months after the injury (Max, Arndt, & Carlos, 1998). Therefore, it was determined that a period of at least two months post-injury was an appropriate amount of time to allow for manifestation of deficits.

In the ADHD and TBI groups, children on medication, with seizure disorder, severe psychopathology or psychosis, autism, cognitive delay, learning disability, a TBI prior to the age of five, or a Full Scale IQ Score (FSIQ) of less than 85 on the Wechsler Intelligence Scale for Children, Third Edition (WISC-III) were excluded from the study. Some of the ADHD children were prescribed stimulant medication (i.e., Ritalin) prior to testing, but did not take the medication for the day of testing. It is important to note that the mean half-life of methylphenidate (Ritalin) in children is 2.4 hours, which means that if a child is taking 10 mg, then in 2.4 hours he/she will have 5 mg remaining in his/her blood plasma, and every 2.4 hours after that, the level continues to reduce by half. Therefore, after approximately 12 hours, there is no longer any traceable amount of the stimulant in the child’s plasma (Ritalin product monograph, 1999). Therefore, those children who were taken off of their stimulant medication prior to testing, took their last dose in the morning of the day prior to testing.

In the ADHD group, children with a premorbid history of TBI were excluded. In the TBI group, children with premorbid indications of an attention disorder were excluded. These
exclusion criteria were included to help minimize their potential to confound the
dependent measures.

**Procedures**

The files of children that met the inclusion criteria were assigned an identification
number to ensure confidentiality at the time of data collection; therefore, there was no
master list of patient names that was generated. The information collected from each
selected file included demographic information (i.e., age, gender, race/ethnicity, WISC-III
FSIQ score, education, medications, diagnoses, date of injury for TBI group), and test
scores on the measures used (i.e., CPT-OE, CPT-RT, SSPT, Cd, Arith, DS, and SS - see
below). Following completion of the study, the data was stored in a locked file, accessible
only to the primary investigator, and will be destroyed after the requisite number of years.

All measures were individually administered and scored by trained psychometric
technicians as part of a full neuropsychological assessment. A clinical neuropsychologist
reviewed the results of the children’s testing, provided interpretations and made
appropriate recommendations.

**Measures**

**Conners’ Continuous Performance Test.** The Conners’ Continuous Performance
Test (CPT) is an approximately 14 minute long computer driven software program that
assesses sustained attention. An IBM compatible computer with 14-inch monitor and 233
MHz operating system was used to administer the CPT. However, research has shown
that the internal timing mechanism in Windows is insufficient for reaction time tasks,
therefore the CPT was run from the DOS system (Segalowitz & Graves, 1990). During
the CPT, the child is instructed to watch the computer and press the spacebar for every
letter they see flash onto the center of the screen, except for the letter 'X' for which they are to refrain from pressing the spacebar. Following the instructions, approximately 1-inch tall, bold-faced capital letters of the alphabet are presented for 250 milliseconds in six blocks. Within each block are three 20 trial sub-blocks with different inter-stimulus-intervals (ISIs) of 1, 2, or 4 seconds.

The CPT produces three types of basic measures. The first, omission errors (CPT-OE), is the number of non-target stimuli (i.e., letters other than X) to which the child did not respond. Omission errors are usually the result of inattention to the task (Conners, 1995). Next, commission errors are responses made to the target stimulus, X, rather than inhibiting response until another letter is presented and may be due to impulsive responding (Conners, 1995). The third type of measure is the reaction time (CPT-RT), particularly reaction time variability. Specifically, it has been suggested that intra-individual response time variability over the time of the task, is a more informative indicator of inattention or vigilance decrement (Conners, 1995; Halperin, Wolf, Greenblatt, & Young, 1991).

Inattentive and impulsive responding can produce a variety of patterns of scores on the CPT. Impulsive responding can be characterized by a high number of commission errors and unusually fast reaction times. However, high scores on omission errors or changes in response rate over time often characterize attention problems. Therefore, in addition to comparing the ADHD and TBI groups on the overall number of omissions, the variability of response time across the test will also be studied (i.e., Hit RT Block change).

The results of the CPT are expressed in T-scores and percentiles relative to a
general population sample and to a clinical sample of individuals with ADHD. Conners (1995) suggests the use of the general population norms in interpreting CPT results due to the larger size of the sample. The general population sample is 51.2% male and ranges in age from 4 to 70 ($n = 520$, with 273 between 8 and 15 years of age). The majority of the adult general sample is under 30 years of age (82.4%). Both norms for the general population and the clinical sample are broken down by age into two year intervals (e.g., 4-5, 6-7, etc.). The breakdown for the age groups that are relevant to the present study are as follows: 8-9, $n=71$; 10-11, $n=62$; 12-13, $n=82$; 14-15, $n=58$. The T-scores produced by the CPT have an average of 50 and a standard deviation of 10. A possible attention problem should be considered if two or more of the scores are atypically high (i.e., percentile $\geq 85$ or a T-score $\geq 60$).

An instrument should be validated for each intended purpose of its use. One of the primary purposes of the CPT is to act as an aid in identifying attention problems (Conners, 1995). The overall index score, which is a weighted sum of the other CPT measures (i.e., hits, omissions, commissions, Hit RT Block Change, etc.) yields a 9.6% false negative rate, and a 5.9% false positive rate, for children 6 to 17 years old in the normative sample, with 12.0% falling in the borderline range (Conners, 1995). Additionally, the overall index score cutoffs were cross-validated against an independent clinical sample. Among 6 to 17 year olds in this second analysis, the results indicated a false positive rate of 13.5% and a false negative rate of 26.1% (Conners, 1995). Other research findings show that attention capabilities generally improve with age, and it is expected that performance on the CPT should reflect this maturation. As children get older, reaction times should get faster, standard errors should lower, commission and
omission errors should decrease, and the block effect should be fairly flat, indicating less of a reaction time increase and better attention. Research has found that in children diagnosed with ADHD, they tend to slow down more as the test progresses, thereby having more trouble maintaining attention over the duration of the CPT (Conners, 1995). Additionally, there does not appear to be a practice effect with the CPT. In fact, it has been suggested that there may even be a negative practice effect (Conners, March, Fiore, & Butcher, 1993; Kirby, VandenBerg, & Sullins, 1993). Therefore, for the present study, the Omission Errors (OE) and Hit Reaction Time (RT) for individuals in the ADHD and TBI groups will be compared.

Speech-Sounds Perception Test. The Speech-Sounds Perception Test (SSPT) is an approximately 20 minute task that measures the child’s ability to sustain auditory attention and match a spoken sound to the correct alternative among a group of similar printed sounds. The SSPT consists of sixty spoken nonsense words, which are variants of the “ee” sound. The stimuli, presented in multiple-choice format, are played from a tape recording with the volume adjusted to the child’s preference. The child responds by underlining one of the three alternatives printed for each item on the test form. This test requires the subject to 1) maintain attention throughout all sixty items, 2) perceive the spoken stimulus sound through hearing, and 3) be able to translate what is heard into a visual representation of letters on the test form. Although some researchers have suggested that the SSPT is best considered a general indicator of brain dysfunction (Sherer, Parsons, Nixon, & Adams, 1991), the body of evidence points to its use as a measure of attention and concentration. Reitan & Wolfson indicate that the principal function of the SSPT in the Halstead-Reitan Battery is to serve as a measure of alertness,
attention, and ability to maintain concentration over time (1992). Additionally, Lezak
specifically recommends using the SSPT with patients who have suspected concentration
problems (1995). Moreover, other researchers indicate that an ability to sustain attention
over time is required to complete the SSPT successfully (Nussbaum & Bigler, 1989;
Reitan & Wolfson, 1992). Finally, Reitan & Wolfson suggest that because attention and
concentration are a prerequisite for problem-solving or memory, it is important to include
measures that evaluate this first level of central processing; the SSPT requires the person
to pay close attention over time to specific stimulus material (1996). For the present
study, the SSPT will be scored by calculating the number of errors made by each child.

Coding and Symbol Search. Coding (Cd) and Symbol Search (SS) are subtests
from the WISC-III and were used to assess processing speed in the present study. For the
Cd subtest, the child is expected to quickly translate symbols that are matched to numbers
from a key at the top of the test page, to blank squares that are under numbers throughout
the remainder of the test page. The child is given 120 seconds to fill in as many of the
symbols as possible, without making mistakes. The score is obtained by counting the
number of correctly translated symbols in the 120-second time limit. In the SS subtest,
the child must look at two target symbols on the left side of a page and determine if either
one of the symbols can be found in the group of shapes to the right. If so, the child is to
mark a ‘YES’ box and if not, then they are to mark a ‘NO’ box. Each page has 15
target/group sets and the subtest is four pages long. Once again, the child is given 120-
seconds to complete as many of the test items as possible within the time allowed. The
score is obtained by subtracting the number of incorrect responses from the number of
correct responses (i.e., 32 correct, 4 incorrect = raw score of 28). For both subtests, the
total score is considered a raw score and is converted into an age-adjusted-scale score equivalent (SSE) using conversion tables provided in the WISC-III manual.

**Arithmetic and Digit Span.** Arithmetic (Arith) and Digit Span (DS) are subtests from the WISC-III and were used to assess freedom from distractibility in the present study, or ability to maintain attention and concentration. For the Arith subtest, the child is expected to mentally manipulate mathematical information from word problems and provide an oral answer. The child is allowed 30-75 seconds to complete each question depending on the difficulty. Starting points vary depending on age and for 9-12 year-olds, the starting point is question 12, and for 13-16 year-olds the starting point is question 14. The test is discontinued when the child obtains a zero on four consecutive items. The subtest consists of 24 questions, and for questions 1-18, the child is given one point for a correct answer and a score of zero for an incorrect response or if time runs out. For questions 19-24, the child is rewarded for an exceptionally quick response. If the child provides a correct answer in 1-10 seconds, then two points are given, a correct response within 11-75 seconds earns one point, and again, if the time limit expires or an incorrect response is given, the score is zero. The subtest score is obtained by adding the scores from each question correctly answered.

For the first portion of the DS subtest (Digits Forward), the child is asked to listen carefully as the examiner says a list of numbers and then to repeat the numbers said, in the same order. The subtest consists of two trials at each level (two numbers, three, four, etc.) and the child obtains one point for each string of numbers correctly repeated. This portion is discontinued when the child is unable to correctly repeat the string of numbers
for both trials at any level. The second portion of the DS subtest (Digits Backward) is
similar to the first, except the child is asked to repeat the string of numbers backward, in
the reverse order of presentation by the examiner. The same discontinue rule applies. The
total score for this subtest is obtained by adding the scores from both portions of the
subtest, Digits Forward and Digits Backward. Again, for both subtests, the total score is
considered a raw score and is converted into an age-adjusted-scale score using conversion
tables provided in the WISC-III manual.

The WISC-III norms presented in the manual were derived from a standardization
sample that was representative of the U.S. population of children based upon census data.
The standardization sample of 2200 cases included 200 children in each of 11 age groups
ranging from 6 through 16 years. The sample included 100 males and 100 females in each
age group. The results of numerous factor analytic methods applied to the WISC-III
standardization data strongly suggest a four-factor solution (Wechsler, 1991). The first
two factors are Verbal Comprehension and Perceptual Organization. In the WISC-III, the
third factor consists of the Arithmetic and Digit Span subtests and is referred to as the
Freedom from Distractibility factor. The Coding subtest loads on a fourth factor with the
new Symbol Search subtest and is referred to as the Processing Speed factor. Each of
these four factors is norm-referenced to an index score with a mean of 100 and a standard
deviation of 15. Exploratory analyses and confirmatory analyses confirm the presence of
the freedom from distractibility and processing speed factors. The maximum-likelihood
factor loadings (Varimax rotation) for factor 3, Freedom from Distractibility were as
follows: for Arithmetic, ages 9-14, from .54 - .85 and for Digit Span, ages 9-14, from .30
-.44. The maximum-likelihood factor loadings (Varimax rotation) for factor 4,
Processing Speed were as follows: for Coding, ages 9-14, from .81 - .84 and for Symbol Search, ages 9-14, from .52-.60. This label (Processing Speed) was assigned based partially on evidence from Stone (as cited in Wechsler, 1991) that the Coding subtest of the WISC-R loads onto a factor with the Speed of Information Processing subtest of the Differential Ability Scales (as cited in Wechsler, 1991). Therefore, the SSE for Cd, SS, Arith and DS were used in the present study as measures of processing speed and freedom from distractibility (attention).

Level of Impairment

For the neuropsychological tests of attention and processing speed, performance was considered impaired if it fell at or below one standard deviation below the mean for each respective measure, which is generally considered an appropriate method of interpreting test data (Lezak, 1995).

For all of the subtests from the WISC-III (Cd, SS, Arith, DS), the mean age-adjusted scale score equivalents (SSE) for the normal population is $10 \pm 3$ ($M \pm SD$), therefore, a SSE of 7 or lower was considered impaired performance on tasks of processing speed or attention (Cd, SS or Arith, DS, respectively). Likewise, a SSE of 13 or higher indicated above average to superior processing speed or attention. For the present study, a score was considered borderline if it rounded down to the cut-off (SSE = 7). The number of omission errors (CPT-OE) is converted to a percentile with higher scores indicating greater difficulty sustaining attention. If the percentile was 0 - 84%, the performance was considered normal, 85 - 89% was mildly atypical, and CPT-OE $\geq 90$ was considered markedly atypical. A score on the CPT-OE was considered borderline if it was within 5 percentage points of the minimum cut-off percentage (85%). The change in
reaction time (CPT-RT) over the length of the CPT is reported as a T-score, with higher scores indicating problems with sustained attention. A T-score of 0 - 54 indicated normal attention, T = 55 - 59 indicated mildly impaired attention, and T ≥ 60 meant markedly impaired attention. For this measure, scores were considered borderline if the T-score rounded up to the impaired range (T = 55). For the SSPT, the score is obtained by totaling the number of errors. Normal performance was indicated by 0-5 errors, mildly impaired performance was 6-10 errors, moderately impaired attention was 11-16 errors, and 17 or more errors indicated severe sustained attention deficits. If a score on the SSPT would have rounded up to meet the minimum cut-off error score for mild impairment, it was considered borderline (i.e., 5.55 or greater).
RESULTS

Descriptive Statistics

Data was collected on 58 children who met the criteria for inclusion in the present study (see Table 1). The majority of the sample was male (n = 41 [70.7%]), and primarily Caucasian (n = 54 [93.1%]). The other ethnic groups represented in the sample were Native American (n = 2 [3.4%]) and African American (n = 2 [3.4%]). The TBI group had a mean age of 11.50 years (SD = 1.817; range 9 to 14), and mean WISC-III FSIQ score was 98.00 (SD = 7.950; range 85-117). The ADHD group had a mean age of 11.47 (SD = 1.722; range 9 to 14), and mean WISC-III FSIQ score was 97.09 (SD = 9.264; range 85 to 114). There were no significant differences between the groups for age (t (56) = -.067, p > .05) or FSIQ (t (56) = -.394, p > .05). For the TBI group, the mean age when the injury occurred was 10.85 (SD = 2.073; range 6 to 14), and the mean number of months post-injury that testing was completed was 8.42 (SD = 9.127; range 2 to 36).

Table 1. Demographics of children with TBI and children with ADHD

<table>
<thead>
<tr>
<th></th>
<th>TBI (n=26)</th>
<th>ADHD (n=32)</th>
<th>t</th>
<th>d.f.</th>
<th>sig</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of males</td>
<td>17 (SD)</td>
<td>24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of females</td>
<td>9</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at testing (years)</td>
<td>11.50 (1.817)</td>
<td>11.47 (1.722)</td>
<td>-.067</td>
<td>56</td>
<td>.947</td>
</tr>
<tr>
<td>Age of Injury (TBI only)</td>
<td>10.85 (2.073)</td>
<td>11.47 (1.722)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Months Post-Injury Tested</td>
<td>8.42 (9.127)</td>
<td>n/a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>25</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native American</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>0</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WISC-III FSIQ</td>
<td>98.00 (7.950)</td>
<td>97.09 (9.264)</td>
<td>-.394</td>
<td>56</td>
<td>.695</td>
</tr>
</tbody>
</table>

TBI= Traumatic Brain Injury; ADHD=Attention-Deficit Hyperactivity Disorder, d.f. = Degrees of Freedom, sig. = Significance
Processing Speed Tests

Coding & Symbol Search. Statistical results for the Cd and SS subtests are presented in table 2. For Cd, the mean SSE in the ADHD group was 7.22 (SD = 2.768) and in the TBI group, the mean SSE was 7.15 (SD = 2.203), which met the established criteria for borderline performance (i.e., would round down to 7, which is 1 standard deviation below the mean). There was no significant difference in processing speed between the ADHD and TBI groups on this measure of processing speed (t (56) = .097, p > .05). For SS, the mean SSE in the ADHD group was 9.75 (SD = 2.995) and in the TBI group, the mean SSE was 8.31 (SD = 2.328), which indicate average performance on this particular measure of processing speed. However, there was a significant difference when comparing performance between the ADHD and TBI groups on SS (t (56) = 2.010, p < .05), with the TBI group performing worse than the ADHD group.

Table 2. t-test values- comparisons between the ADHD, TBI groups & Mean group scores on Processing Speed Tests.

<table>
<thead>
<tr>
<th></th>
<th>ADHD M (SD)</th>
<th>TBI M(SD)</th>
<th>t</th>
<th>d.f.</th>
<th>sig</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>7.22(2.77)</td>
<td>7.15(2.20)</td>
<td>.097</td>
<td>56</td>
<td>.923</td>
</tr>
<tr>
<td>Level of Impairment</td>
<td>Bdl</td>
<td>Bdl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>9.75(3.0)</td>
<td>8.31(2.33)</td>
<td>2.010</td>
<td>56</td>
<td>.049*</td>
</tr>
<tr>
<td>Level of Impairment</td>
<td>WNL</td>
<td>WNL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CD= Coding; SS= Symbol Search; Bdl = Borderline; WNL = Within Normal Limits; d.f. = Degrees of freedom; sig. = Significance; ADHD= Attention Deficit Hyperactivity Disorder; TBI= Traumatic Brain Injury

* = p < .05

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Attention Tests

**Arithmetic.** Statistical results for the Arithmetic subtest are presented in table 3. For the ADHD group, the mean SSE was 8.59 (SD = 2.838) and for the TBI group, the mean SSE was 9.65 (SD = 2.171), which indicated average attention on this measure. There was no significant difference of test performance between the ADHD and TBI groups on Arithmetic (t (56) = -1.567, p > .05).

**Digit Span.** Statistical results for the DS subtest are presented in table 3. For the ADHD group, the mean SSE was 8.47 (SD = 2.840) and for the TBI group, the mean SSE was 9.69 (SD = 2.223), which would again indicate average attention for this measure as well. There was no significant difference when comparing performance between the ADHD and TBI groups on DS (t (56) = -1.794, p > .05).

**Continuous Performance Test - Omission Errors.** Statistical results for the CPT-OE are presented in table 3. In the ADHD group, the mean CPT-OE = 82.08 (SD = 26.80) and for the TBI group, CPT-OE = 68.56 (SD = 17.25), which both indicate normal response behavior for attention. However, while performance for the ADHD group was technically within normal limits (82%), this score was within five percent of the mildly impaired range, and therefore met this study’s established criteria for borderline performance. There was a significant difference found between the groups on this measure of sustained attention (t (56) = 2.223, p < .05), with the ADHD group scoring lower than the TBI group.

**Continuous Performance Test - Hit Reaction Time.** Statistical results for the CPT-RT are presented in table 3. There was no significant difference between the groups on mean reaction time (t (56) = 1.203, p > .05). However, both the TBI group’s performance
(CPT-RT = 55.0750 [SD = 11.02715]) and performance for the ADHD group (CPT-RT = 59.3650 [SD = 15.21992]) were mildly impaired.

**Speech Sounds Perception Test.** Statistical results for the SSPT are presented in table 3. For this task of sustained attention, there was no significant difference between the ADHD and TBI groups (t (56) = 1.491, p > .05). However, the TBI group performed in the borderline range, $M_{\text{errors}} = 5.65$ (SD = 3.224), and the ADHD group’s performance indicated mildly impaired sustained attention, $M_{\text{errors}} = 6.78$ (SD = 2.537).

<table>
<thead>
<tr>
<th>Task</th>
<th>ADHD M (SD)</th>
<th>TBI M(SD)</th>
<th>t</th>
<th>d.f.</th>
<th>sig</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CPT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OE (%)</td>
<td>82.08(26.80)</td>
<td>68.56(17.25)</td>
<td>2.223</td>
<td>56</td>
<td>.030*</td>
</tr>
<tr>
<td>Level of Impairment</td>
<td>Bdl</td>
<td>WNL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit RT Block Change (T-score)</td>
<td>59.37(15.22)</td>
<td>55.07(11.03)</td>
<td>1.203</td>
<td>56</td>
<td>.234</td>
</tr>
<tr>
<td>Level of Impairment</td>
<td>Mild</td>
<td>Mild</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SSPT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td>6.78(2.54)</td>
<td>5.65(3.22)</td>
<td>1.491</td>
<td>56</td>
<td>.142</td>
</tr>
<tr>
<td>Level of Impairment</td>
<td>Mild</td>
<td>Bdl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ARITH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>8.59(2.84)</td>
<td>9.65(2.17)</td>
<td>-1.567</td>
<td>56</td>
<td>.123</td>
</tr>
<tr>
<td>Level of Impairment</td>
<td>WNL</td>
<td>WNL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>8.47(2.84)</td>
<td>9.69(2.22)</td>
<td>-1.794</td>
<td>56</td>
<td>.078</td>
</tr>
<tr>
<td>Level of Impairment</td>
<td>WNL</td>
<td>WNL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CPT= Conner’s continuous performance test; SSPT= Speech sounds perception test; OE= omission errors; RT= reaction time; ARITH= Arithmetic; DS= Digit Span; Bdl = Borderline; WNL = Within Normal Limits; d.f. = Degrees of freedom; sig. = Significance; ADHD= Attention Deficit Hyperactivity Disorder; TBI= Traumatic Brain Injury * = p < .05

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Informal Analysis

With TBI, the length of time required for physiological healing and recovery of cognitive functions varies depending upon the severity of the injury, lesion site, the patient's age, and other factors. However, in general, there tends to be marked improvement within the first 6-8 months, and improvement at a progressively slower rate for many years thereafter (Dikmen, S., Reitan, R.M., & Temkin, N.R., 1983; Newcombe, F. & Artiola i Fortuny, L., 1979). Therefore, for the TBI group, given that the mean number of months post-injury the participants were tested in the present study was 8.42, an informal analysis was conducted to examine the differential performance of participants at varying times post-injury. The analysis was conducted informally due to insufficient numbers of participants to conduct an ANOVA. The TBI group was divided into three subgroups, 2-5 months post-injury (n=15), 6-10 months post-injury (n=6), and >10 months post-injury (n=5). Interestingly, for the WISC-III subtests, the participants who were tested more than 10 months after their injury performed worse than either the 2-5 month group or the 6-10 month group (see Table 4). However, for the SSPT, the 2-5 month group had the most errors, with the other two subgroups essentially the same. There was no consistent pattern of performance for the CPT-OE or CPT-RT between these subgroups.
Table 4. Informal Analysis of performance on all measures, grouped by number of months post-injury, TBI group.

<table>
<thead>
<tr>
<th></th>
<th>2-5 mths Post (n=15)</th>
<th>6-10 mths Post (n=6)</th>
<th>&gt;10 mths Post (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>7.3</td>
<td>7.5</td>
<td>6.2</td>
</tr>
<tr>
<td><strong>SS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>8.3</td>
<td>9.8</td>
<td>6.4</td>
</tr>
<tr>
<td><strong>CPT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OE (%)</td>
<td>69.36</td>
<td>62.50</td>
<td>73.45</td>
</tr>
<tr>
<td>Hit RT Block Change (T-score)</td>
<td>52.73</td>
<td>60.62</td>
<td>55.45</td>
</tr>
<tr>
<td><strong>SSPT</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td>6.8</td>
<td>4.0</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>ARITH</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>9.9</td>
<td>10.33</td>
<td>8.0</td>
</tr>
<tr>
<td><strong>DS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>9.6</td>
<td>10.8</td>
<td>8.6</td>
</tr>
</tbody>
</table>

TBI = Traumatic Brain Injury; CD= Coding; SS= Symbol Search; CPT= Conner’s continuous performance test; SSPT= Speech sounds perception test; OE= omission errors; RT= reaction time; ARITH= Arithmetic; DS= Digit Span; mths = Months; Post = Post-Injury

Since the amount of time post-injury did not account for the differential levels of performance within the TBI group, a second informal analysis was completed comparing the severity of injury, mild or moderate, across measures of attention and processing speed. For all the subtests of the WISC-III (Coding, Symbol Search, Arithmetic, and Digit Span), the SSPT, and CPT-RT, the participants with moderate brain injury (n=13) scored lower than those with mild brain injury (n=13; See Table 5). However, for most of these tests, the difference in performance appears minimal, with the most dramatic differences evident on processing speed tasks. In sum, irrespective of the amount of time post-injury...
that a participant was tested, if he or she had sustained a moderate brain injury, then scores were lower across most measures, with performance on processing speed tasks demonstrating the most significant difference between mild and moderate injuries.

Table 5. Informal Analysis of performance on all measures, grouped by severity of injury, TBI group only.

<table>
<thead>
<tr>
<th></th>
<th>Mild (n=13)</th>
<th>Moderate (n=13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>7.7</td>
<td>6.6</td>
</tr>
<tr>
<td>SS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>9.2</td>
<td>7.3</td>
</tr>
<tr>
<td>CPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OE (%)</td>
<td>69.26</td>
<td>67.87</td>
</tr>
<tr>
<td>Hit RT Block Change (T-score)</td>
<td>54.66</td>
<td>55.49</td>
</tr>
<tr>
<td>SSPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Errors</td>
<td>4.85</td>
<td>6.46</td>
</tr>
<tr>
<td>ARITH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>9.8</td>
<td>9.5</td>
</tr>
<tr>
<td>DS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Adjusted Scaled Score</td>
<td>10.2</td>
<td>9.1</td>
</tr>
</tbody>
</table>

TBI = Traumatic Brain Injury; CD= Coding; SS= Symbol Search; CPT= Conner's continuous performance test; SSPT= Speech sounds perception test; OE= omission errors; RT= reaction time; ARITH= Arithmetic; DS= Digit Span; mths = Months; Post = Post-Injury

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Correlations

As explained in the methods section, the CD and SS subtests of the WISC-III are highly correlated and load on the same factor of ‘Processing Speed’ in the standardization sample of the normal population. For the current study, a correlation matrix was generated to determine if this correlation also existed between CD and SS scores in children with ADHD and TBI, as well as to determine if there were any other correlations between measures (see Table 6). As can be seen, the expected positive correlation between SS and CD was found in this population; in fact, the correlation was significant at the .01 level. There was an inverse relationship between SS and DS that was significant at the .05 level, suggesting that they are at least measuring different constructs. For the attention measures, there was a positive correlation between Arithmetic and DS (p < .01), a negative correlation between DS and CPT-OE (p < .01), a negative correlation between DS and SSPT (p < .05), and a positive correlation between CPT-OE and SSPT (p < .01). Moreover, there were no correlations between any of the measures and CPT-RT, which could suggest that the CPT-RT does not assess an aspect of attention that is similar to the other attention measures used in this study.
Table 6. Correlations between tests of attention and processing speed.

<table>
<thead>
<tr>
<th></th>
<th>CD</th>
<th>SS</th>
<th>ARITH</th>
<th>DS</th>
<th>CPT-OE</th>
<th>CPT-RT</th>
<th>SSPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td>1</td>
<td>.514*</td>
<td>-.007</td>
<td>.148</td>
<td>-.207</td>
<td>.054</td>
<td>.203</td>
</tr>
<tr>
<td>SS</td>
<td>1</td>
<td>.084</td>
<td>.289**</td>
<td>-.169</td>
<td>.148</td>
<td>-0.036</td>
<td>-0.36</td>
</tr>
<tr>
<td>ARITH</td>
<td>1</td>
<td>.537**</td>
<td>-.111</td>
<td>.003</td>
<td>-.255</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DS</td>
<td>1</td>
<td>-.423**</td>
<td>-.048</td>
<td>-.318*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPT-OE</td>
<td>1</td>
<td>.117</td>
<td>.217**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPT-RT</td>
<td></td>
<td>1</td>
<td>-.082</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSPT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

CD= Coding; SS= Symbol Search; ARITH= Arithmetic; DS= Digit Span; CPT= Conner’s continuous performance test; OE= omission errors; RT= reaction time; SSPT= Speech sounds perception test

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
DISCUSSION

The purpose of this study was to compare the performance of children with mild-to-moderate TBI to children with ADHD on various neurobehavioral tasks of sustained attention and processing speed. Specifically, it was hypothesized that both the ADHD and TBI groups would exhibit impaired performance on attention and processing speed tasks, which was supported for some, but not all the neurobehavioral tasks used. There were certainly limitations to generalizability of this study such as, the use of archival data thus eliminating manipulation of independent variables, small sample size, and low power. However, given the exploratory nature of the present study, there were still clinically important insights gleaned from the data.

As a group, the children with ADHD performed in the normal range of functioning on SS, CPT-OE, ARITH, & DS. They performed in the borderline range of impairment on CD, which, given the paucity of research on processing speed deficits in children with ADHD, this borderline impairment, even on only one measure of processing speed, warrants further exploration. The ADHD group was mildly impaired on CPT-RT and SSPT, which lends support for the disruption in attention occurring with both visual and auditory stimulation. For the present study, diagnoses were obtained from each medical record reported as “ADHD”. Given that licensed clinical psychologists with specialized training in child and adolescent psychopathology made the diagnoses, it was felt that the diagnoses were accurate. Still, it is possible that the ADHD group included children with and without manifestations of hyperactivity, as the clinical subtypes were not indicated in the medical records, which could have impacted the results. The children in the ADHD group were less impaired than the author expected, so given the mild nature
of these findings, future research should investigate the performance of children identified as ADHD versus ADHD-Inattentive Type to determine if there are differences in the severity of deficits based on these clinical subtypes, as well as control for method of diagnosis. Overall, for the TBI group, performance was also in the normal range for SS, CPT-OE, ARITH, and DS. However they performed in the borderline range on both SSPT and CD, which indicates that, as a group, sustained attention and processing speed is minimally affected. This was in contrast to Konrad et al., who found that children with TBI performed in the impaired range on processing speed tasks (2000). However, TBI participants in the Konrad et al. had suffered moderate-severe TBI, whereas the participants in the present study had sustained mild-moderate injuries. Therefore, because the present study included more mild injuries, the results were likely attenuated compared to Konrad et al., (2000). Moreover, the TBI group was mildly impaired on the CPT-RT, which also indicated some impairment in the ability to sustain attention. However, as mentioned previously, informal analyses were completed to further evaluate the differential impact of months post-injury that testing occurred and injury severity had on performance for the TBI group. Interestingly, the number of months post-injury was not related to performance on neurobehavioral tasks of attention or processing speed (see Table 4), but was potentially washed out by severity of injury. In fact, it was found that for all measures, except CPT-OE, the children with moderate TBI performed worse than those with mild TBI, even though some of the differences were subtle. Indeed, the TBI group generally tended to perform worse on processing speed tasks than the ADHD group, but this only represented a trend, and is a tentative observation, since both groups had problems in this domain. Likewise, the ADHD group tended to do worse on attention
tasks relative to the TBI group. Again, this does not clearly distinguish the groups, since TBI patients had difficulties in this domain as well. Particularly, on the tests where there were significant differences between the TBI and ADHD groups, the scores were essentially in the normal range, which further underscores the difficulty in discerning meaningful differences between the two conditions, although a control group would help clarify the present findings. Consequently, in addition to the neuroanatomical similarities discussed previously, there is a notable amount of overlap on neurobehavioral performance between ADHD and milder forms of TBI on these tests. While certain patterns of performance in the current data may suggest additional studies to further investigate the trends noted above, the crux of this research is that one cannot distinguish ADHD from TBI on the basis of these tests (i.e., cannot determine accurate diagnosis based on pattern of test performance). Therefore, the findings in the present study actually lend support to the research of Asarnow et al., who found that children with mild head injuries did not evidence significant neuropsychological impairments at 1, 6, or 12 months post injury. Clinically, this finding is of paramount importance as it adds to the level of confidence in predicting recovery from mild TBI, gaining understanding of the morbidity of mild-moderate TBI in children, and speaks to the reality that >80% of all TBIs are mild (Kraus, 1996; Lescohier & DiScala, 1993; National Pediatric Trauma Registry). With this said, as mentioned, the strength of the current findings is hindered by the absence of a control group. Therefore, future research needs to include distinct/pure mild and moderate severity TBI groups compared to ADHD to further explore the differences in test performance, at varying times post-injury, as well as ensure the availability of a control group.
Additionally, it was hypothesized that the ADHD group would exhibit more impairment on tests of sustained attention than the TBI group, which was supported for CPT-OE, and approached significance for DS. This finding cannot be compared to Konrad et al. because that study investigated impulsivity versus sustained attention (2000). However, the possible explanations for this finding are varied. Certainly, the finding could be interpreted as children with ADHD have more impaired attention than children with TBI. However, this finding was only present on one measure of attention, therefore, one has to question why the difference was evident on the CPT-OE and not on other measures? Alternatively, the specific measures used in this study to assess sustained attention could be less adequate at measuring this particular domain of cognitive functioning than other tests of attention (Digit Vigilance, Gordon Diagnostic System, etc.). Moreover, given that there are different types of attention (sustained, divided, focused, response inhibition, etc.; Anderson et al., 1998; Fenwick & Anderson, 1999), it is possible that the measures used in this study were actually tapping into differing types of attention, and were therefore not consistently measuring the same construct. This would be partially supported by the negative correlations that were found between some of the attention measures, which would suggest inverse relationships. Furthermore, at least for the DS and ARITH subtests, perhaps performance on these particular tests reflects a construct other than sustained attention, albeit similar given the positive correlation that was found. For example, many professionals interpret the Freedom From Distractibility Index (FFD; DS & ARITH) from the WISC-III in the context of attention. If the FFD Index is impaired, then the conclusion that is often drawn is an inability to pay attention. However, perhaps the ability to pay attention, at least on these measures, is
unrelated to distractibility (i.e., a very brief disruption in attention). Therefore, perhaps DS and Arith should not be interpreted with regard to inattention, but only in terms of vulnerability to distraction (i.e., a child is able to maintain attention, but is easily distracted, then is able to return to task). A similar distinction between attention and distractibility was discussed by Sandford (1995).

Finally, it was hypothesized that the TBI group would perform worse than the ADHD group on measures of processing speed, which was supported for the SS task, but not CD; however, both groups performed in the borderline range on CD, as discussed above. It is possible that the degree of difficulty varies between these particular subtests (i.e., visual scanning requirements, more information to process, etc.), so the differences were detected on SS, but not CD. Alternatively, although SS and CD were validated as processing speed factors (Wechsler, 1991), it is possible that their sensitivity to detect cognitive processing speed deficits is confounded by the motoric requirements of the tests. Future studies might be carried out using a measure of processing speed that does not require motor involvement (i.e., Symbol Digit Modalities Test, Oral Version), or tests of motor speed (i.e., Finger Oscillation Test, Reitan & Wolfson, 1992) should be administered to control for any confounds. Moreover, although there was a significant difference between the groups on SS (TBI < ADHD), the mean scores for both ADHD and TBI groups were actually within normal limits, however the exact nature of what these results mean without an age/education matched control group is unclear.

As explained previously, a diagnosis cannot be determined from the tests used in the present study; however, one can still address the disparity in treatment approaches for children with ADHD compared to children with milder forms of TBI, which was another
purpose of this study. Interestingly, the performance of the groups was more similar than
dissimilar across tasks, at least with respect to the attention and processing measures used
in this study.

One could argue that given the similarities between children with TBI and ADHD,
treatment should also be approached similarly. Mahalick et al., investigated the use of
methylphenidate in the treatment of acquired attention disorders in children with brain
injury (1998). They found that, at least in the short-term, the use of psychostimulant
medication post-injury improved performance on neurobehavioral tasks of attention and
concentration. This finding did not appear to be attributable to practice effects because
there was no significant improvement in scores for the ‘placebo group’ between baseline
and placebo (Mahalick et al., 1998). Therefore, for at least mild attention problems
secondary to head injury, the use of medication might be beneficial. As mentioned above
however, this was only evaluated with short-term therapy, and as discussed previously,
the long-term efficacy of stimulant medications was investigated in children with ADHD,
and researchers found that there was little advantage of medication over no medication
(Pelham, 1985; Weiss & Hechtman, 1993). One must question whether this finding
would be consistent for children with TBI as well. Therefore, if the use of stimulant
medication would not be the optimal method for treatment of ADHD or TBI, then
perhaps the more comprehensive, rehabilitation model should be used. This would be
especially beneficial for those children with ADHD who demonstrate additional
impairment in other cognitive domains not tested in the present study (i.e., executive
functions, organization, planning, etc.; Barkley, 1998; Fletcher, 1996). Certainly, the
more complex/severe the ADHD or TBI, the more rationale there would be for suggesting
comprehensive, rehabilitative services. However, given the subtle nature of the findings in the present study, including many scores that were within the average range, for the milder forms of either condition, unless academic performance is being significantly disrupted, perhaps the best treatment would be highly individualized and as conservative as possible.
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*Academy of Child and Adolescent Psychiatry, 39,* 477-484.


