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Subtype and Gender Differences in Attention-Deficit/Hyperactivity Disorder: An Investigation of Selected Neuropsychological Variables

by

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ABSTRACT

Neuropsychological differences between DSM – IV subtypes of Attention-Deficit/Hyperactivity Disorder (AD/HD) have been postulated to exclude the predominantly inattentive subtype (AD/HD – PI) from the disorder. The present study investigated subtype and gender differences in three domains of functioning: (a) response inhibition, regarded as the core of the disorder, (b) processing speed, and (c) visual spatial skills.

The sample was comprised of 132 children age 7 – 13 years of age. Experimental groups included 40 AD/HD – PI, 39 AD/HD combined inattentive and hyperactive (AD/HD – C) and 40 control children with equal gender representation across groups. The Behavioral Assessment System for Children (BASC) provided screening information and The Diagnostic Interview for Children and Adolescents-IV (DICA – IV) was used for diagnostic categorization.

Study findings did not support the hypothesis that AD/HD – PI children differ from AD/HD – C on the core deficit of response inhibition as measured by the Stop Signal Task. Mixed results were found for measures of processing speed taken from the Stop Signal Task and the Test of Everyday Attention for Children (TEACh). AD/HD – C children were found to be more impaired than either AD/HD – PI or control children on Benton's Line Orientation (BLO) a measure of visual spatial proficiency. BLO was also the only measure to reflect significant gender differences, with girls showing weaker visual spatial skills. Patterns of neuropsychological functioning suggest that AD/HD – PI

and AD/HD – C are similar subtypes of the same disorder and that gender differences are not prominent.

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DEDICATION

As I was nearing the completion of this dissertation, engrossed in trying to understand the nature of the deficit in children with AD/HD, one of the children in the study, a 13 year old girl, sent me this note:

> Here is a poem that I thought you might like by Gary Snyder, he shares many of my morals!
>
> FOR THE CHILDREN
>
> The rising hills, the slopes
> of statistics lie before us.
> the steep climb
> of everything going up,
> up, as we all
> go down.
>
> In the next century
> or the one beyond that,
> so they say,
> are valleys, pastures,
> we can meet there in peace
> if we make it.
>
> To climb these coming crests
> one word to
> you, to your children:
>
> Stay together
> Learn the flowers
> Go light

I was struck by the insight and poignancy of this young girl's thoughts. She bridged the gap between my world and hers with such clarity and depth of understanding. She reminded me that as we work with the children, we are called to see beyond deficit and listen for their wisdom. We are privileged to help them "climb the crests."

FOR THE CHILDREN.

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INTRODUCTION

Overview

Attention Deficit/Hyperactivity Disorder (AD/HD) is an important, heterogeneous type of childhood psychopathology (Barkley, 1998; Lahey et al., 1994; Tannock, 1998). Clinic referrals for AD/HD consume an estimated 30 - 40% of clinical resources in child psychopathology making it the most common childhood disorder (Anderson, Williams, & McGee, 1987; Lorys, Hynd, & Lahey, 1990; Offord et al., 1987) and creating a heavy load on children, families, schools and mental health services (Biederman, Newcorn, & Sprich, 1991). Given the clinical significance of AD/HD, it is not surprising that considerable research effort has centered on the etiology, diagnosis and clinical manifestations of the disorder. More recently, investigation of neuropsychological correlates has begun. One shortcoming of the extensive research literature on AD/HD is that almost all work has focused on the hyperactive subtype of the disorder, with an emphasis on males. Dysfunction associated with the other subtypes, as well as the female presentation of the disorder, remains relatively unexplored and controversial (Seidman et al., 1997).

Contributions from neuroimaging, epidemiological studies, and clinical literature suggest that the presentation of the disorder in the less commonly explored subtypes and in females may be different from the presentation of the disorder in the more commonly investigated, primarily male, subtype (Benton, Sivan, Hamsher, Varney, & Spreen, 1994; Berry, Shaywitz, & Shaywitz, 1985; Eiraldi, Power, & Nezu, 1997; Ernst et al., 1994; Faraone, Beiderman, Weber, & Russell, 1998; Garcia-Sanchez, Estevez-Gonzalez, Emulia-Romero, & Junque, 1997; Gaub & Carlson, 1997a; Lahey et al., 1994; Morgan, Hynd, Riccio, & Hall, 1996). Recent epidemiological work suggests that one of the less investigated subtypes (the inattentive subtype) may in fact be the most common form of the disorder (Baumgaertel, Wolraich, & Dietrich, 1995; Gaub & Carlson, 1997a; Wolraich, Hannah, Pinnock, Baumgaertel, & Brown, 1996). In addition, given the magnitude of the disorder, cited as affecting thousands of females, it is imperative that the comparative male/female expression of the disorder be elucidated and made available for clinical application (Arnold, 1996).

To date, sizable female and subtype sample groups have been extremely hard to gather. Small numbers of female or subtype subjects have often been regarded as a research confound. As a result of the potential confound, females and subtypes have characteristically been coalesced in inconsistent or non-identifiable ways or dropped from data analysis (Goodyear & Hynd, 1992).

This study was designed to help build a clearer understanding of how AD/HD is manifested across all three subtypes of the disorder in both females and males. Data on potential subtype and gender differences were collected through the measurement of response inhibition, widely regarded as the core feature of the disorder (Barkley, 1997). The measurements of processing speed and visual spatial abilities were included to provide additional data on tasks that have, in some cases, been shown to differentiate AD/HD subtypes. The study was designed to fill a gap in the extant literature regarding possible subtype and gender differences in specific areas of neuropsychological functioning.

Subtyping Issues in AD/HD

AD/HD is not, and never has been, regarded as a homogeneous disorder. For more than 25 years the Diagnostic and Statistical Manual of Mental Disorders (DSM) has consistently recognized the diversity of the disorder in the subtyping possibilities that have accompanied the diagnosis (American Psychiatric Association, 1968; American Psychiatric Association, 1980; American Psychiatric Association, 1987; American Psychiatric Association, 1994). The differences in attentional problems with and without hyperactivity (variably expressed as ADD/+H and ADD/-H, or ADDH and ADDnoH, or ADD-H and ADD, or ADD+H and ADD-H, or ADD-H and ADD-NH, or ADHD and UADD, or ADD/H and ADD/WO) have continued to challenge the research and clinical community. With DSM-IV, two separate groups of descriptors have been created[1]. One group of descriptors designates a subtype of AD/HD that consists primarily of problems with inattention leading to a diagnosis of AD/HD Predominantly Inattentive Type (AD/HD-PI). A second list of descriptors, incorporating symptoms of developmentally inappropriate overactivity and impulsivity, leads to a diagnosis of AD/HD Hyperactive - Impulsive Type (AD/HD-HI). A third subtype combines descriptors of both inattentiveness and hyperactivity/impulsivity resulting in the diagnosis of AD/HD Combined Type (AD/HD-C). All three subtypes have been found to be more behaviorally and neuropsychologically impaired than normal control subjects, exhibiting more social problems, more underachievement, more problems with unfinished work, and poorer scores on tests of neuropsychological functioning (Barkley, DuPaul, &

McMurray, 1990; Bauermeister et al., 1995;). Aspects of symptomatology that are shared by the subtypes create an argument for maintaining unity in nosological representation while allowing for unique phenotypic expressions. Aspects of symptomatology that are unique for each subtype create an argument for viewing the subtypes as separate disorders.

Clearly the arguments for considering the subtypes under one rubric have waxed and waned [2]. Fourteen years ago Lahey and his colleagues, mirroring DSM III (American Psychiatric Association, 1980), stated "It is not clear, however that ADD with hyperactivity (ADD/H) and ADD without hyperactivity (ADD/WO) are similar subtypes of the same disorder" (Lahey, Schaughency, Strauss, & Frame, 1984, p. 302). Lahey noted that only three studies on the topic had been published to date and that they had reached contradictory conclusions. When DSM - III-R was published in 1987 the inattentive subtype had been marginalized in the nomenclature and was relegated to undifferentiated attention-deficit disorder (UADD); in effect, a separate disorder. Eight years later Goodyear and Hynd reviewed the more recent literature and concluded that DSM - III nomenclature more realistically fit the data than DSM - III-R; that is, that both subtypes were best regarded as different representations of the same disorder (Goodyear & Hynd, 1992). Work for the DSM-IV field trials supported this contention (Lahey et al., 1994). In 1998, however, the idea that the inattentive subtype is actually a different disorder has arisen again in recent discourse (Barkley, 1998).

Behavioral differences and similarities between hyperactive and inattentive subtypes

Unique expressions of the disorder across subtypes are well documented. In a comparison of 90 AD/HD children (82 boys and 8 girls) with and without hyperactivity, using interviews, behavior rating scales and direct observations, subtypes were found to differ significantly (Barkley et al., 1990). Children with hyperactivity were more likely than inattentive children to have received a diagnosis of AD/HD and were more likely to be comorbid for oppositional defiant disorder (ODD) (40%) and conduct disorder (CD) (21%). AD/HD-C children were also more likely to have received a special placement in a classroom for disruptive behavior and they were more likely to have been involved in individual or family therapy. Compared to AD/HD children without hyperactivity, teachers reported that AD/HD-C children had poorer peer relations and less success in meeting school expectations. For instance, they were more likely to be rated as acting too young, making odd noises, fidgeting, disturbing others, producing messy work and acting in irresponsible ways. They were also more likely to report symptoms of separation anxiety and were reportedly more active and demanding in their early development. Parental reports of psychiatric disorders among maternal and paternal relatives and siblings of the subjects revealed more attention deficits, aggression, and substance abuse in maternal relatives of children with hyperactivity.

By contrast, less than 20% of the children without hyperactivity were found to exhibit oppositional defiant behavior; however, a higher prevalence of major depressive disorder was found for this group. Children in this group were more likely to have received a placement in a classroom for learning disorders. Although both inattentive and hyperactive children were observed to be similarly off task during the completion of a series of math problems, children without hyperactivity performed significantly worse in the number of math problems completed. They also appeared more impaired on the coding test of the Weschler Intelligence Scale for Children – Revised and had greater problems with the retrieval of verbal information. Teachers described these children as having serious problems with being confused or "lost in a fog," daydreaming, apathetic or unmotivated. These children were likely to have maternal relatives with a history of anxiety disorders and siblings with learning disorders.

While considerable variability between groups was reported, several things remained constant between the subtypes. Groups did not differ with regard to the overall rate of comorbidity. The prevalence of overanxious disorder and learning disorder was similar across both groups. Prenatal histories did not differ across groups. Both hyperactive and inattentive groups were reported to have fair to poor motor coordination, 40% and 54% respectively. Teacher reports revealed that children in both groups were more likely than controls to be retained in grade level and to experience problems with peer relations, peer provocation and meeting teacher expectations. Both groups showed signs of underachieving and were unable to finish work, complete tasks, concentrate, be attentive, or follow through on directions. Psychiatric histories of relatives showed no difference between the groups with regard to depression, psychoses, mental retardation, antisocial behavior, police arrests, failure to complete school and tic disorders.

Earlier descriptive studies of AD/HD-C (ADD/H) and AD/HD-PI (ADD/WO) subgroups suggested behavioral differences between the two groups. In reviewing 22 studies that separated the subtypes, Goodyear and Hynd (1992) noted a range of differences between the groups. Among the findings presented were the following:

(a) Boys with ADD/WO (n = 11) improved their search rates more than boys with ADD/H (n = 15) when administered methylphenidate (Dykman, Ackerman, & McCray, 1980);

(b) boys with ADD/H (n = 22) exhibited more conduct disorder than boys with ADD/WO (n=9) (King & Young, 1982);

(c) ADD/WO boys (n = 7) exhibited more social withdrawal and grade retention, while ADD/H (n = 18) boys showed more social and school problems as well as more aggression (Edelbrock, Costello, & Kessler, 1984);

(d) ADD/H (n = 94) children were described as more aggressive, more rejected by peers, having lower self esteem, and more impaired on measures of cognitive and motor performance. Children with ADD/WO (n = 40) were identified as more anxious, daydreamy, lethargic and sluggish (Berry et al., 1985);

(e) ADD/WO (n = 20) children were described as slower and more sluggish than children with ADD/H (Lahey, Schaughency, Frame, & Strauss, 1985),(ADD/H n = 41 and ADD/WO n = 22);

(f) ADD/WO boys (n = 21) were less productive than ADD/H boys (n = 24) on tasks requiring speed, such as writing one's name, drawing O's or solving basic math facts (Ackerman, Anhalt, Holcomb, & Dykman, 1986); and

(g) ADD/WO children (n = 8) were more impulsive on Matching Familiar Figures (MFFT) than ADD/H children (n = 8) (Conte, Kinsbourne, Swanson, Zirk, & Samuels, 1986).

Other studies comparing the subgroups found no differences between groups. For instance, no difference was found between children with and without hyperactivity on the MMFT, Children's Checking Task, Embedded Figures Test, Attention–Concentration factor of WISC-R, tests of academic and reading achievement, parent behavioral rating scales (Rubenstein & Brown, 1984), peer ratings of social acceptance (Carlson, Lahey, Frame, Walker, & Hynd, 1987), or on improved self control with varying doses of methylphenidate (Barkley, DuPaul, & McMurray, 1991).

Taken together these findings suggest that attentional problems in general may predispose children to a variety of internalizing and externalizing problems. Inattention without hyperactivity may create less risk of disruptive disorders but may similarly compromise social and academic performance at least in kind if not in degree.

Despite some conflictual findings, the general consensus regarding behavioral differences across AD/HD subtypes appeared to confirm the existence of group differences particularly with regard to behavior rating scales, sociometric ratings, math achievement and cognitive processing. The findings are summarized by Goodyear and Hynd (1992) who note:

> It is possible, if not likely, based on the present clinical profiles that qualitative differences in the two groups underpin similar levels of impaired school performance just as qualitative differences are documented in inattention (p.289).

More recent epidemiological work using DSM-IV criteria with a school based population has revealed interesting patterns of impairment (Gaub & Carlson, 1997a). On measures of adjustment (Hard Working, Appropriate Behavior, and Happy) all three

AD/HD groups appeared more impaired than the normal control group. Comparing the three AD/HD groups, the hyperactive/impulsive group received the highest ratings of overall adjustment, that is, the least amount of impairment. They received higher rating of Hard Working than the other two groups and higher ratings of Happy than the combined group. The predominantly inattentive group obtained the highest rating of Appropriate Behavior. On sociometric ratings all three AD/HD groups were found to have poorer social functioning than the control group. The combined group received the highest ratings of Peer Dislike but on the Peer Ignore variable there was no difference between the groups. On externalizing variables (Aggressive Behavior, Delinquency, and Externalizing Behavior) the combined group was the most impaired and the predominantly inattentive group was the least impaired, although all three groups were significantly more impaired than the control group. This same pattern was replicated on the Thought Problems scale and the Attention scale. Thus the combined group was most pervasively impaired, with the highest percentages of children rated as impaired (a) behaviorally (90%), (b) socially (82%), and (c) academically (82%). By comparison, the predominantly inattentive group showed their most significant impairment in academic difficulties (76%) followed by social difficulties (59%) and behavioral problems (58%). The hyperactive/impulsive group were most impaired behaviorally (80%), followed by social difficulties (53%) but with relatively low rates of academic impairment (23%). Given that children spend the majority of their days in school, difficulty with academic tasks (shared almost equally by inattentive and combined groups) reveals a common pattern of dysfunction between these two subtypes.

The legitimacy of the hyperactive/impulsive group has been questioned based on observations that this subtype may simply be a younger version of the combined group (Barkley, 1997). This subtype, created by the DSM-IV field trials, was found to have the youngest onset (5.65 years), and was found primarily among preschoolers. Gaub and Carlson (1997) note, however, that the unique patterns of impairment and the evidence that this subtype was found across all ages in their sample supports the validity of hyperactive/impulsive group as a distinct subtype of AD/HD rather than simply a precursor to AD/HD - C. It is noteworthy however that, across studies, this subtype was, on average, the youngest and the least likely to be identified.

Given that previous studies have shown the patterns of psychiatric disturbance in biological relatives of AD/HD - C and AD/HD - PI groups are quite distinct, and that the behavioral, emotional and social characteristics of the subtypes are unique, it is certainly conceivable that varying subtypes of the disorder could present with discrepant neurological patterns (Barkley et al., 1990). Alternatively, distinct phenotypic presentations of the disorder may belie a common underlying impairment (Sherman, Iacono, & Mcgue, 1997). Furthermore, it is possible that varying presentations of the disorder may be an expression of unique etiologies or developmental trajectories within AD/HD (Frank & Ben-Nun, 1988).

<u>Neuropsychological differences between inattentive and hyperactive children</u>

The neuropsychological presentation of AD/HD with and without hyperactivity has received limited attention. In reviewing the findings from 22 studies of neuropsychological functioning in ADD, Barkley, Grodzinsky and DuPaul (1992) included only three studies that compare ADD/+H and ADD/-H. While general conclusions indicate that tests of response inhibition most reliably distinguished AD/HD - C from normal controls, there were discrepancies in the findings of differences between the subtypes that may have been due to methodological or developmental issues. One of the most consistent findings was that AD/HD–PI subjects showed problems with perceptual-motor tasks and processing speed. In addition, AD/HD-PI children were found to commit more early omission errors on tests of response inhibition (Trommer, Hoeppner, Lorber, & Armstrong, 1988).

In another review, Goodyear and Hynd (1992) found 10 studies that had attempted to differentiate children with and without hyperactivity. Average sample size in these studies was 26 for the hyperactive group and 19 for the inattentive group. Some samples contained only boys and overall 87% of the children studied were male. Studies included in the review employed 10 different measures. The authors note that 60% of the neuropsychological studies yielded significant differences among the groups. Differences included:

(a) The amplitude of the P2 component (an early response to a stimulus) of an auditory event-related potential was different for hyperactive and inattentive children, with hyperactive children showing greater amplitude (Holcomb, Ackerman, & Dykman, 1986);

(b) inattentive children were found to be slower than hyperactive children in rapid naming of familiar colors, numbers, and letters (Hynd et al., 1991);

(c) on a task of word retrieval, inattentive children needed more word retrieval clues to achieve a score similar to hyperactive children (Goodyear 1990 as cited in Goodyear & Hynd, 1992); and

(d) inattentive children were found to be slower in the search phase of information processing (Sergeant & Sholten, 1985).

In line with possible neuropsychological subtype differences, response to methylphenidate appears to be somewhat less positive in AD/HD - PI than in AD/HD – C with 24% of predominantly inattentive children proving to be nonresponders while only 5% of combined children have been reported to be nonresponders (Barkley et al., 1991).

Some similarities between AD/HD groups were also noted. For example:

(a) Both hyperactive and inattentive groups were found to have smaller P3 (response to a stimulus at 300 ms) components in both auditory and visual modalities of an event-related potential when compared to controls (Holcomb et al., 1986);

(b) no differences were found between inattentive and hyperactive children on omission and commission errors of the Children's Checking Task (Stone 1986 as cited in Goodyear & Hynd, 1992);

(c) on measures of reaction time to visual stimuli there were no differences between ADD/H and ADD/WO groups (Hynd et al., 1989); and

(d) no significant subtype differences were found on the subtests of the Luria-Nebraska Neuropsychological Battery – Children's Revision (Schaughency, Lahey, Hynd, Stone, & Piacnetini, 1990).

While the behavioral and neuropsychological studies cited earlier provide indications for the validity of subtypes, methodological problems such as small sample size, changing operational definitions of subtypes and inconsistency in measurement tools made clear conclusions difficult.

More recent work using DSM-IV criteria has tracked psychiatric, neuropsychological and psychosocial features of the subtypes in clinically referred children revealing some interesting differences and similarities (Faraone et al., 1998; Morgan et al., 1996). Utilizing a substantial sample (n = 185 combined, 89 inattentive and 27 hyperactive/impulsive) of children and adolescents, Faraone et al. (1998) reported no difference in anxiety, substance abuse or elimination disorders across subtypes. The AD/HD-C group had the highest rates of conduct, oppositional, bipolar, language and tic disorders. Rates of Major Depression were high and similar in the AD/HD-PI and AD/HD-C groups, both of which were higher than in the AD/HD-HI group. Overall the combined group were seen to exhibit more comorbidity than the other two subtypes.

Measures of social functioning revealed that combined and inattentive types showed consistently worse social functioning than controls. All subtypes had higher rates of service utilization (e.g., counselling, multimodal treatments) than controls, with the combined type showing the highest service utilization of all.

On measures of intellectual functioning and academic achievement, combined and inattentive groups were not significantly different from each other but both varied significantly from control children. Despite similar academic dysfunction, the combined type were more likely to be placed in special classes. Thus despite more severe comorbidity, the combined group were not more impaired on measures of neuropsychological functioning. In summing up the impairments that were evident in the hyperactive subtype the authors concluded:

> It would however be a mistake for clinicians to assume that other AD/HD children have "mild" AD/HD. Although they have fewer AD/HD symptoms and less comorbid psychopathology, their level of neuropsychological and social dysfunction is similar to that seen in children with combined-type ADHD (p. 192).

Subtyping as a neglected issue in AD/HD

Despite nosological, descriptive, and neuropsychological recognition regarding the heterogeneous nature of the disorder, most research studies have not separated the subtypes in their experimental sample. Studies with small AD/HD sample groups (generally less than 30), where no effort has been made to identify AD/HD subtypes, have produced conflicting findings regarding group differences in comparison to normal control children. On the one hand AD/HD subjects have been found to be inferior to controls on neurocognitive measures such as the Stroop, Trails B, and the Wisconsin Card Sorting Test (WCST), M.F.F.T., and the Stop signal task (Boucugnani & Jones, 1989; Chelune, Ferguson, Koon, & Dickey, 1986; Gorenstein, Mammato, & Sandy, 1989; Grodzinsky & Diamond, 1992; Schachar, Tannock, Marriot, & Logan, 1995a; Shue & Douglas, 1992). By contrast, a study using the largest AD/HD sample group (n=100) found that neurological measures including the WCST, the MFFT and Letter fluency, did not differentiate AD/HD and control groups (Fisher, Barkley, Edelbrock, & Smallish, 1990.). Weyandt and Willis (1994) also reported no differences between AD/HD and control groups on the WCST, WISC-R Mazes and verbal fluency. It is possible that the failure to identify subtypes has created a research confound, whereby composite groups that contain varying combinations of subtypes contribute to unique results for each study. Given this kind of inconsistency in identifying subtypes, comparison between studies becomes extremely difficult.

Problems with defining sample groups are exacerbated by conflict regarding the place of the inattentive subtype in nosological categorization. Attention and hyperactivity-impulsivity have largely been regarded as two independent dimensions of the disorder (Lahey et al., 1988). The independence of attention and hyperactivity-impulsivity has led to a division in thinking, particularly regarding the place of the inattentive subtype. The predominantly inattentive type is regarded variably as 1) a less severe form of AD/HD than the other subtypes (Barkley, 1994b; Frank & Ben-Nun, 1988; Goodyear & Hynd, 1992; Lahey et al., 1994; Szatmari, Offord, Siegal, Finlayson, & Tuff, 1990), 2) a different but legitimate form of AD/HD (Garcia-Sanchez et al., 1997; Lahey & Carlson, 1991), or 3) a different disorder not to be retained within the diagnostic category of AD/HD (Barkley, 1990; Barkley, 1997; Barkley, 1998; Barkley et al., 1990; Grodzinsky & Diamond, 1992).

In a review of studies assessing subtype differences, Barkley et al. (1990) assert "unfortunately, none of these studies have directly addressed the issues of whether ADD-H and ADD+H are subtypes of the same type of attentional disorder or whether they represent qualitatively different disorders" (p.775). In Barkley's 1997 model, AD/HD is characterized by a primary deficit in response inhibition. Barkley proposes that the inattentive subtype is likely to present without the core impairment in response inhibition but with different impairments not found in the other subtypes. He contends that children who are predominantly inattentive will exhibit a unique profile consisting of deficits in speed of information processing and in focused or selective attention as well as deficiencies in visual spatial abilities. At present there is no published data to support or refute the contention that AD/HD – PI children lack the core deficit of impaired response inhibition.

In contrast, other researchers, including those involved in the DSM-IV field trials, contend that the predominantly inattentive type is indeed a legitimate, common, and generally overlooked subtype of the disorder (Bauermeister et al., 1995; Baumgaertel et al., 1995; Gaub & Carlson, 1997a; Lahey et al., 1994; Lahey & Carlson, 1991; Lahey et al., 1988; Wolraich et al., 1996). There is some indication for example that while all subtypes of AD/HD may generally have weaker visual spatial abilities than normal children, the PI subtype may present with even greater weakness in visual spatial tasks than the other subtypes (Garcia-Sanchez et al., 1997).

Recent epidemiological work has identified the inattentive type as the most common subtype of the disorder (Baumgaertel et al., 1995; Gaub & Carlson, 1997a; Wolraich et al., 1996). Surveying 2,744 school children Gaub and Carlson (1997a) found that 4.5% of the sample were from the predominantly inattentive group, compared to 1.9% from the C group and 1.7% from the hyperactive/impulsive group. Wolraich et al. (1996) and Baumgaertel et al (1995) identified a similar breakdown in subtype prevalence. Surveying groups of 8,258 and 1,077 children, prevalence rates of inattentive children were recorded as 11% and 9% respectively, in both cases exceeding the prevalence of the other two subtypes.

The inattentive subtype has been found to be the most likely presentation for females with the disorder (Lahey et al., 1994; Wolraich et al., 1996). Neglect of the inattentive subtype has by definition meant that girls with AD/HD have received less research focus than is warranted. Confusion regarding the place of the inattentive subtype is understandable based on the paucity of research information on subtypes as well as conflicting findings from the small amount of data that are available.

In summary, the findings on AD/HD impairment suggest behavioral and neuropsychological impairment across the subtypes, but are conflicting regarding the kind of impairment that characterizes particular manifestations of the disorder.

Gender Issues in AD/HD

The female presentation of AD/HD is a relatively unexplored domain. For reasons that remain unclear, clinical samples of AD/HD contain far more boys than girls (Arnold, 1996; McGee & Feehan, 1991). If in fact girls rarely presented with AD/HD, it would offer some justification for disregarding the female presentation. On the contrary, recent epidemiological studies reveal that girls may comprise nearly one third of some subtypes of the disorder (Gaub & Carlson, 1997a). Thus there is a concern that girls may be under-identified and consequently under-served in mental health services (Biederman, Farone, Wilens, Mick, & Lapey, 1994; Shaywitz & Shaywitz, 1987, Berry, 1985).

Information on the ratio of males to females affected by the disorder has varied considerably depending on the historical period, the setting, and the age group being considered (Safer & Krager, 1988). DSM-III states that "the disorder is ten times more common in boys than in girls" (American Psychiatric Association, 1980, p. 42). Clinic referrals continued to reflect this ratio for some time (Barkley, 1990). Epidemiological studies reflect a gender ratio that is strikingly different from clinic samples with male/female ratios ranging from 5:1 (Anderson et al., 1987) to 3:1 (Szatmari, Offord, & Boyle, 1989). More recent epidemiological studies show a male:female ratio as low as 2:1 for the inattentive subtype (Baumgaertel et al., 1995; Gaub & Carlson, 1997a; Wolraich et al., 1996). Pennington and Ozonoff (1996) assert that "because much of the research on AD/HD has relied on referred samples, we know much more about AD/HD in males than in females" (p.59).

Male based diagnostic criteria

DSM criteria for the diagnosis of AD/HD have historically been based on predominantly male sample groups. Female representation in the DSM-IV field trials was approximately 18% (n=43) of the total sample for the 6 to 13 year old age group. More girls (27%) were found in the predominantly inattentive type and in the older 16 - 17 year old group (33%). Even the relatively modest female representation in the field trials for DSM-IV represents a substantial improvement over past editions.

Greater female representation in the DSM-IV field trials does not alter the finding that girls have a lower base rate of inattention and hyperactivity, and therefore have to deviate further from same sex peers to appear as impaired as boys. Creating sex-specific thresholds would undoubtedly increase the number of girls diagnosed. However, given the paucity of research data focusing on girls, it is difficult to know whether girls identified with sex-specific thresholds would be as functionally impaired as girls and boys now meeting diagnostic criteria.

Referral bias

Referral bias has been repeatedly cited as the reason for the gender discrepancy between clinic referred and non-referred groups (Arnold, 1996; Berry et al., 1985; Biederman, Faraone, Wilens, Mick, & Lapey, 1994). With a disorder conceptualized as "a guy thing" (Gordon, 1996), and a historical emphasis on overactivity associated with aggression, it becomes clear that girls with fewer externalizing symptoms may be missed. In reviewing prevalence rates gained from epidemiological studies, McGee and Feehan (1991) noted that teachers are much more likely to attribute symptoms of AD/HD to boys than girls. Five years later Wolraich and colleagues (1996) noted similar findings.

Parent identified symptoms on the other hand show less gender variation. It is possible that the discrepancy in parent and teacher ratings may be partly due to cross-situational changes in children's behavior. Alternatively, teachers may under-recognize attentional problems in girls, particularly if these behaviors do not cause behavioral disruption. Thus teachers may give selective attention to particular issues that cause classroom discord, but fail to consider the significance of inattentive behaviors that primarily affect the student (Nezu & Nezu, 1993). Berry (1985) highlight the problem of referral bias, contending that:

In concert, the data suggest that the lower visibility of children with ADD without hyperactivity often results in the delayed referral for girls, and the risk of the attention disordered girl who is passive, does not disrupt other children, and is not a "problem" remaining undiscovered is probably high. Yet she is vulnerable to academic underachievement and social and emotional disturbances (p.808).

The validity of referral bias as an explanation for lowered recognition of female AD/HD is strengthened by the finding that as individuals reach adulthood, and are able to self refer, males and female tend to appear in almost equal numbers (Biederman et al., 1994). It appears that sizable numbers of girls suffering AD/HD have not been diagnosed and have thus remained vulnerable to the academic underachievement and social and emotional disturbances that are likely to lead to life-long impairment (Berry et al., 1985).

Paucity of research on AD/HD in girls

A sequel to male-based criteria is referral bias, and referral bias in turn has meant that sizable samples of girls with AD/HD have been characteristically difficult to obtain. Thus a "chicken and egg" dilemma is established. Girls are not studied because they are difficult to find, and they are difficult to find because the criteria for identifying AD/HD children have been based on the male presentation of the disorder.

Clearly, the research literature on AD/HD contains a bias towards the investigation of the male presentation of the disorder (Arnold, 1996; Berry et al., 1985). While research data on boys with AD/HD are plentiful, information regarding girls with AD/HD is comparatively rare. By far the most common approach to girls with AD/HD has been to simply turn a blind eye to their existence, choosing to specifically investigate only the male presentation of the disorder. The paucity of research data regarding girls with AD/HD is related to two interconnected phenomena: (a) the small number of girls clinically identified as having AD/HD and (b) the desire for homogeneous research groups.

When only a small number of girls have been identified within a given research project, they present an unwelcome anomaly. Three approaches have characterized the treatment of small numbers of girls in research studies. The first approach is to include girls but to ignore any unique features of the female presentation of the disorder. For example, Barkley (1990), using a sample consisting of 82 boys and 8 girls noted: "The number of girls in each group was insufficient to permit examining the results for effects of sex of child, so groups were collapsed across sex" (p.776). Collapsing small groups across gender makes statistical sense, but does not consider the possibility of unique gender patterns. Studies of brain morphology, drug treatment, clinical presentation and outcome studies have collapsed findings across gender (for example see Faraone et al., 1993a; Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990; Matochick et al., 1994b). In a review of 21 studies utilizing AD/HD subtypes, 91% of the subjects were male (Goodyear & Hynd, 1992). Girls become invisible when research proceeds in this fashion. As a result of the tendency to lump a small number of girls with a large number of boys, evidence regarding possible gender differences in the neuropsychological presentation of the disorder is particularly lacking.

A second strategy is to include girls in the study if they appear in the sample, but to eliminate them from the data analysis. In a recent review of 18 studies using neuropsychological measures to assess the presentation of AD/HD, only three studies included girls (n = 1, n = 9 and n = 29) (Pennington & Ozonoff, 1996). In the study with the largest group of girls (n = 29), girls were excluded from the analysis based on the argument that the number of girls relative to boys (29:53) did not reflect the expected gender ratio or patterns of comorbidity (Dykman & Ackerman, 1991). The elimination strategy means that girls are not only invisible; they boost sample size but then become non-existent.

The third and less common approach to gender and AD/HD is to include girls and to report similarities and differences in findings between the genders (see for example Faraone et al., 1993b; Hynd et al., 1990; Matochick et al., 1994a). Sometimes sizable samples of girls are obtained although very small sample groups are more common. For example, a study endeavoring to test etiological models explaining male predominance for the disorder employed 80 boys and 13 girls (Silverthorn, Frick, Kuper, & Ott, 1996). On the surface these studies appear to be more representative since they at least include girls. Studies containing such a small number of girls may, however, be equally misleading since they purport to comment on gender differences but may lack the statistical power to draw accurate gender based conclusions.

By far the rarest of all approaches in the literature on AD/HD is to focus on the male *and* female presentation of the disorder. Unfortunately, the issue of gender and AD/HD is not immediately clarified by such studies due to conflicting findings among them. A number of studies have indicated gender differences in AD/HD samples (Befera & Barkley, 1985; Berry et al., 1985; James & Taylor, 1990; Kashani, Chapel, Ellis, &

Shekim, 1979). Other research has found nonsignificant gender differences (Horn, Wagner, & Ialongo, 1989; Korkman & Pesonen, 1994; Seidman et al., 1997). Methodological problems such as small sample size (usually less than 20) and inattention to medication status weaken the validity of findings.

The paucity of information on neuropsychological functioning in females is particularly glaring in light of findings from a small study using positron emission tomography where AD/HD girls were shown to have a 17.6% decrease in brain glucose metabolism when compared with boys (Zametkin et al., 1993). Specific areas of depressed function, unique to girls, have been identified, suggesting that lower brain metabolism may be more prevalent in females than in males (Ernst et al., 1994). Investigation of the unique markers of AD/HD in girls requires further investigation. A pilot study, of neuropsychological functioning in girls (43 girls with AD/HD) has suggested a “less complicated neuropsychological course” of the disorder in girls (Seidman et al., 1997, p.371). Unfortunately the findings from this study (boasting the largest female sample ever used) must be regarded with caution, based on the fact that over 80% of the girls with AD/HD were tested while receiving stimulant medication, which has been shown to improve neuropsychological functioning (van der Meere, Shalev, Borger, & Gross-Tsur, 1995).

It is not surprising that a recent conference sponsored by the National Institute of Mental Health concluded that while girls deserve a research focus in their own right, more information is also needed about comparative male/female differences in AD/HD (Ernst et al., 1994). It is possible that female representation in clinic samples and research studies may change over time based on findings that, when compared to DSM-III-R criteria, DSM-IV criteria have increased the likelihood of female identification of the disorder. Using DSM-IV criteria, new cases identified as AD/HD, while still predominantly male, have doubled the small number of girls previously identified. Most of the newly identified girls are in the predominantly inattentive subtype (Lahey et al., 1994), which has gained a legitimate diagnostic place in DSM – IV. Understanding the female presentation of the disorder takes on increasing clinical significance as the number of referred girls continues to grow.

AD/HD - Neuropsychological Explanations

First identified as Minimal Brain Dysfunction (MBD), attention deficit disorder has always been linked to suspected neuropsychological impairment. At the turn of the century, Still (as cited in Pennington & Ozonoff, 1996) regarded AD/HD as a deficit in brain based volitional inhibition. Carrying on Still's conceptualization, Barkley (1990) described AD/HD as essentially a biologically based disorder of motivation. Barkley's explanation of AD/HD echoed Luria's (1959) explanation that the frontal lobes play a critical role in translating volition into action. Volition or motivation appears essential for the inhibition of unwanted behavior. Inhibition has long been attributed to executive function and, as will be explained later, is presently held to be the central mechanism compromised in AD/HD (Barkley, 1996).

The premotor cortex in particular has been implicated in the cardinal symptomatology of ADHD. For example, regarding the often-observed motor restlessness and disinhibited responses of AD/HD, Copeland (1991) observes:

> Acting without thinking, or, more accurately, acting without appropriate inhibition, is seen frequently in the impulsive action of ADHD children, adolescents and adults. Calling out in class, not waiting one's turn, interrupting, or hitting another person in a moment of frustration are examples of motor responses which should have been inhibited by the premotor cortex (p. 23).

The motor restlessness of AD/HD patients is not dissimilar to aspects of akathesia (continual changes in posture), one of the commonly observed syndromes in frontal lobe damage. In reviewing a half-century of data on neurological structures linked to ADHD, Zametkin and Rapoport (1987) implicate many of the anomalies traditionally associated with frontal patients.

The Frontal Lobe Hypothesis

More than a decade ago Chelune, Ferguson, Koon, and Dickey (1986) proposed the 'frontal lobe hypothesis,' stating that AD/HD was the result of disinhibited higher order cortical functioning. Based on the similarities between AD/HD patients and those with frontal lobe damage, Chelune et al. proposed that symptomatology observed in AD/HD was most likely caused by the disruption of frontal lobe operations. Other researchers (Denckla, 1996; Mattes, 1980) advanced similar thoughts.

In reviewing the evidence relevant to the relationship between frontal lobe dysfunction and AD/HD, Mattes (1980) admitted that the evidence is controversial and use of the term 'frontal lobe' is global. However, despite this disclaimer, Mattes proceeded to present data linking frontal lobe dysfunction and symptoms of AD/HD including hyperkinesis, inattention, and lowered response to environmental clues. He noted that early descriptions of MBD were remarkably similar to Luria's (1966) description of patients with frontal lobe dysfunction, including lack of organizational ability and strategy formation deficits. In addition, Mattes reviewed studies indicating that monkeys with dorsolateral frontal lesions were found to show distractibility, difficulty in delayed response, and hyperactivity similar to those observed in children with AD/HD. Other functions found in animals with lesions also appeared to mirror behaviors observed in children with AD/HD. For example, concentration and attention paid to extraneous stimuli were found to alter with frontal lobe disruption in animals. The ability to suppress irrelevant inputs and inhibit unwanted responses was also defective in animals with frontal lobe interference (Mattes, 1980).

The sequential organization required for monkeys to attain a reward was disrupted by frontal lesions, but behavior became normalized when external clues for organization were supplied. Linking these findings, Mattes (1980) observed that hyperactive children generally behave more appropriately when external environmental clues to behavior are made salient by increased environmental structure (e.g., small structured classrooms, written instructions, rewards etc.). He went on to note that, like patients with frontal lobe dysfunction, children with AD/HD (a) generally have normal IQ's, (b) display a paucity of hard neurological signs, (c) perform normally on many standard psychometric tests, and (d) tend to show abnormalities on perceptual-motor tasks and more specialized tasks, such as visual search tasks, designed to demonstrate abnormalities.

The frontal lobe hypothesis has been supported by more recent brain imaging work which has noted anomalous structure and functioning in children and adults with AD/HD (Castelllanos et al., 1994; Ernst et al., 1994; Zametkin et al., 1993). Significantly lowered glucose metabolism has been observed in particular frontal lobe structures of AD/HD patients (Lou, Henriksen, & Bruhn, 1984; Zametkin et al., 1990). The evidence, however, is not without contradiction. For instance, while Castellanos et al.(1994) found smaller right caudate volumes in AD/HD boys, Hynd and his colleagues found greater right caudate volumes in AD/HD boys. The cause of discrepancies found in brain imaging work remains unclear. Methodological and technological differences between studies appear to be important factors in accounting for discrepant findings. In addition, the subtlety of impairment, or lack of precise measuring tools, may also account for inconsistent findings of changes in brain glucose metabolism structure and function (Matochick et al., 1994a).

A Theoretical Model for AD/HD

Descriptive studies of AD/HD have documented three primary symptom clusters within the disorder: hyperactivity, inattention and impulsivity. Current DSM-IV conceptualization combines hyperactivity and impulsivity into a single dimension thus creating an overall profile of two rather than three symptom clusters. A perusal of the literature on AD/HD shows that, at various times, each of the three symptom clusters have been regarded as *the* cardinal symptoms of the disorder. Descriptive studies continue to highlight the neurocognitive and functional sequelae of each subtype of the disorder, but a unifying theory has been lacking.

Recently, Barkley (Barkley, 1997) proposed a large-scale theory of AD/HD attempting to 1) account for the broad range of dysfunction described thus far in the literature on AD/HD, and 2) provide a conceptual model that fits with existing data, enabling hypotheses regarding neuropsychological dysfunction to be tested. Barkley's (1997) theory posits that a defect in behavioral inhibition (impulsivity) is the central component of the disorder. Behavioral impulsivity means that the child is likely to respond quickly, failing to consider the negative or destructive consequences of his or her actions. Such behavior is observed as interrupting, failure to follow rules, risk-taking, inability to delay gratification, and impaired ability to meet the demands of a social situation. Evidence for the systemic nature of the deficit is found in patterns of inaccurate and slow responses to tasks that require the speedy inhibition of a prepotent (previously established) response in favor of a more accurate response required by the task demand (Barkley, 1990; Barkley, 1997). In other words, children who are deficient in inhibition lack the ability to stop an action once it has been mentally initiated.

In Barkley's model, inhibition is linked to five other neuropsychological domains that depend on inhibition for their efficient performance. Four of the neuropsychological domains (working memory, self -regulation, internalization of speech, and reconstitution) are private, internal workings that allow the child to access memory of appropriate, self-regulating or goal directed strategies. The private internal domains are termed "executive functions" and are considered to "set the occasion" for the performance of the fifth domain: motor response (for a visual representation of the model see Barkley, 1997). In a properly functioning system, the fifth domain, motor control, is moderated by the engagement of executive functions. In the absence of adequate executive functioning, uninhibited behavior is the direct response to a stimulus. The three tiers of the model, inhibition, executive function and motor response, work together efficiently in most children. For example, in a classroom situation, if the teacher asks a question of the class, a child with intact inhibitory processes would (a) pause (inhibit immediate response), (b) retrieve information about the answer and the class rule of putting up a hand to answer, and (c) raise a hand to gain the teacher's attention. A child with AD/HD would (a) not pause, (b) not retrieve information relative to task, and (c) shout out a response. If Barkley's model is correct, deficits related to disinhibition should be clearly and reliably found.

Theoretical models explaining AD/HD as a deficit in behavioral inhibition have excluded the inattentive subtype (Barkley, 1997; Quay, 1997). These writers propose that other mechanisms such as processing speed or visual spatial ability may be responsible for the behavior that characterizes the inattentive subtype. The problems of the inattentive type are hypothesized to be qualitatively different from those of the other subtypes and not related to problems of behavioral inhibition (Barkley, 1994a). To date, no research data exist to support or refute the contention that the predominantly inattentive subtype does not exhibit the core problem of inhibitory control.

Neuropsychological Findings Regarding AD/HD

Three disclaimers must precede any discussion of neuropsychological findings with regard to AD/HD. First, the area of the brain implicated (the frontal cortex) remains one of the least understood areas of the brain (Becker, Issac, & Hynd, 1987; Passler, Isaac, & Hynd, 1985). Second, a plethora of assessment tools have been used to measure neuropsychological aspects of AD/HD. In a review of studies measuring executive functioning in AD/HD, the use of 60 measures is reported (Pennington & Ozonoff, 1996). Third, the ever changing, and unoperationally defined DSM criteria for the disorder render findings across studies and between varying time periods difficult to compare (American Psychiatric Association, 1968; American Psychiatric Association, 1980; American Psychiatric Association, 1987; American Psychiatric Association, 1994).

Despite constraints, a common theme runs through the data. Compared to both normal children and children diagnosed with other disorders, AD/HD children perform more poorly on neuropsychological measures (Barkley, 1997; Boucugnani & Jones, 1989; Dykman & Ackerman, 1991; Goodyear & Hynd, 1992; Robins, 1992, Pennington, 1996; Schachar, 1991; Schachar & Logan, 1990b; Schachar et al., 1995a; Seidman et al., 1995; Shue & Douglas, 1992). Children with AD/HD have been found to show inferior performance on measures requiring impulse control and sustained attention. Across tasks they are generally slower and less accurate than control children and have difficulty attending to more than one thing at a time.

In a review of 22 studies of neuropsychological functioning in AD/HD, mixed evidence was reported for distinguishing AD/HD from normal children using measures such as the WCST, the Stroop test, tests of verbal fluency, the Rey-Osterrieth test, Trail Making Test, MFFT, and maze tests (Barkley, Grodzinsky, & DuPaul, 1992).

Unfortunately many neuropsychological tasks that attempt to account for differences between groups may be confounded by requiring a variety of skills for task success. For instance, the MFFT, which purports to measure impulsivity, also requires task engagement, search strategies, metacognitive awareness regarding the importance of perusing all alternatives before choosing one, visual acuity, etc. Children who are reported to perform in an impulsive manner on this task may in fact have scores that reflect a failure in any one of the embedded skills.

However, in line with Barkley's theory, performance on measures of response inhibition clearly separated normal children from those diagnosed as AD/HD (Barkley et al., 1992). For instance, a study utilizing the Go-No Go tasks of response inhibition, requiring children to display a simple motor response to a *go* stimulus while inhibiting the same response to a *no-go* stimulus, found that the test reliably distinguished AD/HD from normal children (Trommer et al., 1988). Responses of these children were similar to 25 patients with frontal lesions who took longer to learn the task and made more false *go* responses, exhibiting an inability to inhibit responses to stimuli (Drewe, 1975). In a later study the Go-No Go test was found to be sensitive to even modest doses of methylphenidate which improved test performance by decreasing impulsive commission error (Trommer, Hoeppner, & Zecker, 1991).

In a separate review of 18 studies utilizing neuropsychological measures to identify children with AD/HD, Pennington and Ozonoff (1996) drew several conclusions: 1) Of all the measures used, 67% revealed a significantly impaired performance in AD/HD groups and none of the studies showed a better performance by AD/HD subjects when compared to controls, 2) measures of executive function appear to have greater sensitivity in distinguishing AD/HD groups than other measures such as verbal IQ, receptive language, or phoneme awareness, 3) the pattern of executive function deficits in AD/HD is distinct from the pattern in other disorders such as autism, and is distinct from other disorders such as Tourette's Syndrome and conduct disorder where no clear pattern of neurocognitive deficits is found, and 4) of the studies that used discriminant function analysis (n=6) all six found that the neuropsychological measures were significant in being able to predict AD/HD. The average correct classification was 80.1%: for AD/HD it was 70.3% and for normals it was 84%. Thus, neuropsychological measures are better at excluding normals from being falsely diagnosed, but may not be sensitive enough to identify all children with AD/HD, or specific enough to differentiate AD/HD children from other psychopathologies.

Specificity of Neurocognitive Measures

The ability of neuropsychological measures to distinguish AD/HD from other disorders is also of significance. The disorders most likely to be comorbid with AD/HD are learning disorders (LD) and conduct disorders (CD) (Biederman et al., 1991; Korkman & Pesonen, 1994; Schachar & Tannock, 1995 , Hynd, 1991). Neuropsychological data have been found to distinguish AD/HD from both LD and CD.

Robins (1992) found that neurocognitive measures reliably separated children with AD/HD and (LD). The two groups were separated by tasks measuring self-regulation, and task accuracy/planning/speed. Children with AD/HD were found to be more impulsive, less accurate in timed tasks, and experience more difficulty working independently than did children with LD. However, the neurocognitive battery used by

Robins was only slightly better at identifying AD/HD children than were adult reports on the Child Behavior Checklist (83.3 % vs 79.5%).

Further support for the neuropsychological distinction between LD and AD/HD is offered by Korkman and Pesonen (1994). The study examined children with either "pure" AD/HD or LD and compared them with children comorbid for both disorders using a battery of neurocognitive measures taken mostly from the NEPSY, a standardized test of neuropsychological functioning. Of particular interest in this study were the double dissociations that emerged. That is, children with AD/HD were found to have particular deficits not shared by children with LD and vice versa. Specifically, the AD/HD groups were found to have particular impairments on measures of impulsivity whereas the LD group displayed greater impairment on tasks requiring phonological ability such as auditory analysis, digit span, and storytelling as well as verbal IQ. Both groups showed impairments with speeded naming (naming the size, shape and color of tokens) and motor coordination. The authors suggest that while the double dissociation between AD/HD and LD groups does not appear to be operative across all tasks, it is possible that on tasks such as speeded naming, mechanisms unique to each group are operative in creating similar impairments. For example, the suggestion is made that AD/HD children may produce impaired results due to poor application of rehearsal strategies while the LD group may be influenced by linguistic impairment. These findings suggest that while it may be difficult, in clinical settings, to find children who present with only one disorder, the comorbid conditions may result from *specific* underlying features that tend to aggregate together.

To clarify the links between AD/HD and CD, Schachar and Tannock (1995) tested whether similar or different patterns of neurocognitive, developmental risk, and psychosocial stressors characterize "pure" forms of the disorders. Findings from the study revealed that AD/HD, but not CD, was associated with deficient inhibitory control in a *stop* and *go* task. AD/HD groups were also found to exhibit more developmental delays and problems with reading than children with CD.

Schachar and Tannock attributed the inability to control *stopping* to an "underlying problem in self-regulation or higher order executive control processes" (p. 645). Developmental delay was determined by a clinical interview in which AD/HD children were more likely to present with a history of exposure to developmental risk factors such as low birth weight. Conduct disorder, on the other hand, was not linked with deficient inhibitory control but was associated with psychosocial adversity. Psychosocial adversity in CD was indicated by factors such as overcrowded housing and low family income. Children comorbid for both disorders exhibited a hybrid set of symptoms including problems with inhibitory control, psychosocial stressors and learning problems.

Other research by Schachar and Tannock (1993) lends additional support to the idea of unique and distinct underlying features of AD/HD vs CD. Despite the fact that both CD and AD/HD groups were characterized by clinical impulsivity, only children with pervasive AD/HD were found to be deficient in inhibiting responses in a *stop* and *go* task. Children in the AD/HD group were also found to be significantly slower in their overall responses and more variable in their mean latencies to the stimuli.

Inhibition

A major function of the frontal lobes appears to be the mediating of response inhibition (Heilman, Voeller, & Nadeau, 1991; Kolb & Whishaw, 1996; Stuss & Benson, 1986). Response inhibition allows individuals to rapidly assess a given situation and thereby organize themselves to either withhold or execute a response as indicated by the demands of the situation. In normal children, inhibition appears to develop throughout childhood and into early adulthood (Becker et al., 1987; Passler et al., 1985; Schachar & Logan, 1990b). Between six and eight years of age, inhibitory control appears well developed (Schachar & Logan, 1990b). No differences in inhibitory control across gender have been documented in a study using a large community sample (Williams, Ponesse, Schachar, Logan, Tannock, 1998).

As mentioned previously, the ability to inhibit is postulated as the major deficit in AD/HD, resulting in the impulsivity that is so characteristic of children with AD/HD. Countering the idea that impulsivity is linked to neuropsychological processes of disinhibition is the "delay aversion theory" (Sonuga-Barke, Taylor, & Heptinstall, 1992). This theory posits that what appears as impulsivity on some tasks may be the result of a fast paced approach reflecting an unwillingness (rather than an inability) to withhold responses unless there is some advantage to the delay. Findings from later work based on the delay aversion theory noted that while AD/HD children may be able to withhold responses when rewarded, they did not use the time gained to produce greater accuracy of response (Sonuga-Barke, Williams, Hall, & Saxton, 1996). Aspects of neuropsychological processing are offered as a possible explanation for the discrepancy between the functioning of AD/HD and normal children when inhibition is measured over an extended period of time.

Other researchers have endeavored to explicate the nature of inhibition by focusing on the precise measurement of the components of response involved in a single act requiring inhibition. Among the tests of response inhibition that have been used to distinguish AD/HD from normal children and from children diagnosed with other psychiatric disorders, (Barkley et al., 1992; Casey et al., 1997; Korkman & Pesonen) the Stop Task appears particularly promising (1994; Schachar & Logan, 1990b; Schachar et al., 1993; Schachar et al., 1995a). The stop-signal paradigm gave rise to a laboratory analogue task that required the child to respond to computer generated visual (letter X or O) and auditory (tone) stimuli. The child was instructed to press the button on a response box corresponding to the letter stimulus. The task involved repeated letter stimulus trials, a quarter of which were randomly distributed stop-trials where a tone sounded alerting the child that they should inhibit their go response and try to refrain from pushing the button. Timing for the presentation of the stop trial was based on the go time for the previous block, minus a given interval that was set to decrease at specified intervals as the task proceeded. The task resulted in a precise measure of response speed (go time) and inhibitory speed (stop signal time). Using this task children with AD/HD have clearly been distinguished from normal controls and other children with other childhood disorders.

The link between AD/HD and inhibition has been variably explained (Barkley, 1997; Logan, Cowan, & Davis, 1984; Quay, 1997; Sonuga-Barke, Houlberg, & Hall, 1994). Logan (1994) proposes a "race model" in which response and response inhibition are pitted against each other. For example, a child sitting through a classroom lesson may be struck by the urge to focus on a bird building a nest outside the classroom window, or by the desire to move around the classroom or to call out while the teacher is talking. Response inhibition will allow the child to determine the appropriateness of these responses and allow the situationally functional response to prevail. Lack of response inhibition means that impulses "win the race" despite the child's ability to later discern the problematic nature of such responses. Children with AD/HD and hyperactivity appear less able to inhibit responses despite effort and intentionality (Schachar et al., 1993; Schachar et al., 1995a). No data are available regarding the performance of the inattentive subtypes on the stop-signal paradigm.

Visual Spatial Ability

In most individuals the right hemisphere is responsible for the processing of nonverbal information (Lezak, 1995) and for facilitating the ability to sustain a motor activity (Kertesz, Nicholson, & Cancelliere, 1985). A combination of the ability to process nonverbal information and persist in motor activities allows an individual to make visual and tactile recognition of objects or shapes, to perceive spatial orientation, to copy geometric designs or to construct three dimensional models. Compromised right hemispheric function has been reported in samples of AD/HD children and adults (Heilman et al., 1991). For example, children with AD/HD and patients with known right hemispheric lesions performed similarly on a paper and pencil cancellation task. Both groups showed more frequent left side cancellation failures (Voeller & Heilman, 1988).

Visual spatial abilities are implicated in numerical operations. For example, Benbow & Benbow (1984) report that links between mathematical ability and spatial ability have been found. They suggest that both mental abilities may involve similar right hemispheric cognitive processes and depend upon similar problem-solving strategies. Subtypes of children with AD/HD have been seen to differ on their arithmetic ability. Predominantly inattentive children show greater difficulty with arithmetic than AD/HD children with hyperactivity (Carlson, Lahey, & Neeper, 1986; Hynd et al., 1991). Some tests of visual spatial ability show potential for discriminating attention deficit disorder with and without hyperactivity (Carlson et al., 1986; Garcia-Sanchez et al., 1997). On WAIS block design and Benton's Line Orientation test, greater differences have been found between subjects with attention deficit disorder without hyperactivity and controls than is apparent when comparing hyperactive subjects with controls (Garcia-Sanchez et al., 1997). Contrasted with these results are findings that nonsignificant differences are observed between the AD/HD subtypes on the Developmental Test of Visual-Motor Integration (VMI) (Carlson et al., 1986). Previous findings that both hyperactive and inattentive groups are likely to have compromised motor responses (Barkley et al., 1990) means that the strong motor component required for the completion of this test may have rendered both groups equally impaired. Such findings underscore the point that attempts to measure visual spatial skills in groups of AD/HD children need to control for motor involvement.

A pattern of differences between females and males has emerged on tests of visual material. Females have been found to be relatively weaker than males on visual spatial tasks (Lezak, 1995). The gender difference in performance is explained by way of biological differences in concert with socialization factors. From a biological perspective, a greater lateralization of visual spatial functions in males and a more diffuse presentation of visual spatial function in females have been hypothesized. Specificity of lateralization in males is supported by findings that males with unilateral damage to the right hemisphere suffer more severe impairment than women with similar lesions (Harris, 1978). In support of the theory of reduced hemispheric specialization in females, women are observed to suffer less loss of visual spatial functions as a result of right-sided lesions, and are found to recover a greater amount of function following strokes regardless of side of lesion (Lezak, 1995).

While male/female differences in visual spatial abilities are commonly acknowledged (Benton et al., 1994; Mazaux et al., 1995), it is important to note that gender differences are typically small, accounting for less than one-half of a standard deviation, " so that the overlap in the distribution of male and female scores is much greater than the distance between them" (Lezak, 1983, p.220). Even the small gender differences in visual spatial abilities have been observed to be in decline over the last 40 years as socialization and educational practices have allowed females more access to activities involving construction and numerical reasoning (Lezak, 1995).

One strand of investigation into the correlates of AD/HD suggests that children with AD/HD may exhibit similar deficits to patients with known right sided cortical lesions, including visual spatial left neglect and defective response inhibition (Garcia-Sanchez et al., 1997; Heilman et al., 1991; Semrud-Clikeman, 1990). If girls are more able to draw on both hemispheres for the processing of visual spatial information and response inhibition, tests that tap these skills may not show the same deficit in girls with AD/HD as compared to boys.

A lack of an apparent right-sided deficit could be translated into evidence for reduced overall impairment in girls with AD/HD, despite the possibility that they may be significantly impaired in other ways when compared to normal girls. In other words, if girls by nature have a more diffuse pattern of visual spatial cerebral organization, and if AD/HD can be seen to correspond to right-sided deficits, AD/HD girls may be expected to appear less impaired because of a naturally occurring compensatory cerebral organization. Comparing AD/HD girls with normally developing girls appears to be an important strategy for disentangling effects of gender from effects of the disorder. Alternatively, it is possible that girls are indeed more inclined toward a milder form of the disorder.

Processing Speed

Processing speed is measured in terms of reaction time. Slowed reaction time often shows up as poor concentration, distractibility and difficulty doing more than one thing at a time (Lezak, 1995). Goal directed behavior required to produce a specific rapid motor response has long been linked to the prefrontal cortex and its associated executive functions (Barkley, 1998). AD/HD children have been found to have slower processing times than normal children (Carte, Nigg, & Hinshaw, 1996; Grodzinsky & Diamond, 1992). Processing speed is a cognitive measure also found to distinguish AD/HD subtypes. Some data indicate that while AD/HD children with hyperactivity do not differ from normal controls on timed measures of verbal and visual spatial processing, children classified as AD/HD without hyperactivity are significantly slower than controls on such tasks (Barkley et al., 1990). Children with AD/HD - PI have been described as having a sluggish cognitive tempo and problems with focusing attention on the task at hand (Barkley et al., 1990; Goodyear & Hynd, 1992; Lahey et al., 1988; Sergeant & Scholten, 1985; Stanford & Hynd, 1994). For example, Sergeant and Sholten (1985) found that non-hyperactive boys with attention deficit disorder were slower in the search phase of a high speed visual search task than controls, whereas hyperactive boys had additional deficits related to encoding and decision making.

Likewise, children with attention deficit disorder without hyperactivity were found to be slower than those with hyperactivity on tasks requiring the rapid naming of familiar stimuli (Hynd et al., 1991). In this study two kinds of naming tasks were employed: 1) requiring rapid automatized naming where children were asked to name 50 alternating colors (black, red, yellow, green, blue), and 2) requiring rapid alternating stimuli where children were asked to name alternating stimuli (colors, numbers, letters). Children with ADDnoH were found to be slower on both kinds of naming tasks. While differences in processing speed are indicated from these findings, small sample sizes and the general exclusion of females from these studies weaken the generalizability of the results.

Goals and Hypotheses

Research Objectives

This study set out to examine neuropsychological aspects of AD/HD using female and male subtype groups. To date no previous work involving neuropsychological investigation has incorporated any specific information on the subtype by gender presentation of the disorder. The study objective was to employ empirically validated assessment procedures for determining circumscribed aspects of neuropsychological functioning. The design incorporated both female and male AD/HD groups, including delineated sub-groups of the disorder: AD/HD - Predominantly inattentive (PI), AD/HD - Hyperactive Impulsive (HI), and AD/HD - Combined (C).

Goals

The goals of the study were focused on increasing the present knowledge base regarding subtype and gender presentations of AD/HD. Specifically, the study was designed to:

1. Determine whether differences exist across AD/HD subtypes with respect to response inhibition, processing speed, and visual spatial abilities.
2. Provide information on the presence or absence of gender differences on measures of response inhibition, processing speed, and visual spatial abilities.
3. Explore any interactions related to subtype and gender that emerge from the dependent measures.

Hypotheses

Regarding Subtyping:

1. Deficits in response inhibition will not be evidenced by children with AD/HD-PI

when compared to children with AD/HD-HI and AD/HD-C.

2. Slower processing speed will be evident in AD/HD-PI groups when compared to AD/HD-HI, AD/HD-C, and control groups.
3. Children with AD/HD-PI will show weaker visual spatial abilities than children with AD/HD-HI or AD/HD-C.

Regarding Gender:

1. A gender effect will not be evident on measures of inhibition, or processing speed.
2. Girls across experimental groups will show weaker visual spatial abilities than boys.

METHODS

Participants

Children with AD/HD and control children aged 7 - 13 years were recruited simultaneously from three sources: a) the existing subject pool of the Behavioral Research Unit (BRU) located at the Alberta Children's Hospital, b) the Calgary chapter of Children and Adults with Attention Deficit Disorder (CHADD), and c) other community contacts including a rural elementary school.

The initial intent of the study was to obtain the majority of participants from the BRU database. While the subject pool of the BRU is extensive, AD/HD subtype is not clearly designated for children in the pool. In addition, as the database ages, some children in it are now older than the age range designated for the study and younger age groups are under-represented. Given that the present study design required approximately equal numbers of children from the AD/HD subtypes, as well as children across the designated age range, further avenues for gaining participants were sought.

A poster describing the research was presented at the annual CHADD fair (see Appendix A). Parents who were potentially interested in having their children participate in the study were given a handout regarding the nature and requirements of the study. A tear-off section of the handout enabled parents to leave their name and phone number for further contact. The investigator subsequently contacted these parents and children, resulting in many becoming part of the sample group.

A rural school expressed an interest in providing space for the research project with the understanding that children and families in the school could choose to be involved in the study and receive some general feedback regarding the information gained. The investigator met with the Principal and Special Education Teacher to explain the research design. School staff were in favor of having the study located in the school and a quiet testing space was allocated. The Special Education Teacher served as a first point of contact with parents of children who might be eligible for the study. Parents who expressed an interest in participating (and having their children participate) offered their phone numbers for further contact from the investigator.

Parents of children from the BRU database had given permission to be contacted regarding ongoing research activities connected to the unit. Parents whose children were likely to fit the age range and subtype categorization needs of the study were contacted.

A total of 132 children participated in the study. Seventy-four children and their parents were gained through contact with the rural school, while 58 children and their parents came from either CHADD, the BRU, or community contacts within the city.

Exclusionary criteria

Children of average intellectual ability where sought for the study. Two scales of the Wechsler Intelligence Scale for Children-III (WISC-III), Block Design and Vocabulary were used to estimate IQ (Wechsler, 1991). These two subtests have excellent reliability (.91) and correlate highly with the Full-Scale assessment over a wide range of ages (Sattler, 1992). The use of a short form IQ is a suitable alternative to full scale administration when IQ is used as an exclusionary criterion for research purposes (Sattler, 1992). Due to possible misclassification errors resulting in the use of the short form, a definition of average intelligence was accorded to children scoring at or above an

IQ score of 80. This cutoff score has been used as an exclusionary criterion in previous studies of AD/HD children (Schachar & Logan, 1990a; Schachar & Logan, 1990b). No children were excluded from the study due to obtaining a short form IQ of less than 80. All children were within the average range of intelligence. IQ scores for participants ranged from 80 to 149, with an average of 109.

The Behavioral Assessment System for Children – Parent Rating System (BASC – PRS) (Reynolds & Kamphaus, 1992) was used as a screening measure. Children being considered for inclusion in the control group were excluded from the study if screening using the BASC indicated clinical levels of disturbance in any area or a conglomerate of two or more areas "at risk" for disturbance. Ten children were excluded when the screening criteria were applied and one child who was initially interested in being part of the control group later declined to take part in the experimental tasks. Families of children excluded from the control group due to suspected psychopathology were informed regarding such findings and referral information was supplied.

Participants were assigned to groups based on the diagnostic status indicated by the Diagnostic Interview for Children and Adolescents – IV (DICA – IV) (Reich, Welner, & Herjanic, 1997) which incorporates the diagnostic criteria for AD/HD as outlined in the DSM - IV. Children assigned to the AD/HD – PI group were required to have at least six symptoms of inattention and not more than five symptoms of hyperactivity/impulsivity. Children in the AD/HD – C were required to have at least six symptoms of inattention and at least six symptoms of hyperactivity/impulsivity. Both groups were required to have verification of impairment in two or more settings and an onset of symptomatology before age seven. Control children did not meet criteria for AD/HD as indicated by either the BASC or the DICA – IV. Children in the control group had less than 6 symptoms of hyperactivity/impulsivity and inattention and did not meet other DSM – IV criteria for AD/HD.

Proposed and Actual Sample Groups

In the initial study design, three AD/HD sample groups were proposed: AD/HD Predominantly Inattentive (PI), AD/HD Hyperactive Impulsive (HI) and AD/HD Combined (C). The AD/HD – HI subtype are regarded as a developmentally early stage of the disorder (Barkley, 1998; Lahey et al., 1998). It was hoped that extending the lower age limit to seven years would enable the inclusion of the AD/HD – HI group. Of the 132 children screened for the study, only two met criteria for the AD/HD – HI group. Difficulty in obtaining children with AD/HD-HI is consistent with a large scale community study where this subtype was found to be less prevalent than the other subtypes (Wolraich et al., 1996). Given the under representation of this subtype in the sample, these children were not included in the data analysis.

The final sample comprised a total of 119 children, including 40 children in the AD/HD-PI group, 39 children in the AD/HD-C group and 40 children in the control group. Of the 40 AD/HD-PI group, 22 were boys and 18 were girls. Within the AD/HD-C group there were 19 girls and 20 boys. The control group contained 20 boys and 20 girls.

Measures

Screening

Screening for the study was carried out using the Summary AD/HD Checklist (SAC) (Kaplan, Humphreys, Crawford, & Fisher, 1997), and The Behavior Assessment System for Children - Parenting Rating Scale (BASC-PRS).

Summary AD/HD Checklist

Every child approached for the study was screened via the Summary AD/HD Checklist (SAC). The SAC gives an initial indication regarding the presence or absence of AD/HD symptomatology. The SAC consists of 25 questions arranged in a 4-point Likert scale response format. Questions on the SAC were formed from a composite of DSM – IV criteria and questions from six other standardized instruments. Parents were asked to indicate the presence or absence of specific behaviors based on observations of their child over the previous six months. Response categories were anchored at 0 = not at all, 1 = just a little, 2 = pretty much, and 3 = very much. Questions are designed to offer some initial information regarding the presence or absence of hyperactivity, impulsivity, inattention and misconduct (see Appendix B). Compared to the Diagnostic Interview Scale for Children (DISC), the SAC has been shown to have a sensitivity of 81.8% for the positive selection of children definitely affected by AD/HD. This screening device was used with parents in the initial telephone contact. Completion time was approximately 10 minutes. All children screened with the SAC were considered for one of the study groups. If AD/HD was not considered probable they became candidates for the control group. The probability of AD/HD being present was calculated by adding overall scores on the SAC. Scores were interpreted as follows: 0-9 = "not at all," 9-14 = "probably not," 14-21 = "uncertain," 22-35 = "probably," and 35+ = definitely.

Behavior Assessment System for Children - Parent Rating Scale

The Behavior Assessment System for Children - Parenting Rating Scale (BASC-PRS) is a DSM-IV based instrument designed to facilitate differential diagnosis by the assessment of adaptive and problem behavior in children 6 -18 years of age (Reynold & Kamphaus, 1992; Sandoval & Echandia, 1994). The BASC is sensitive to age and gender differences in symptomatology and provides a gender and age breakdown in the normative sample and standardized scoring procedure. Internal consistency on the child and adolescent scales of the PRS ranges from .42 to .89, averaging in the mid to upper .70s, with composite scores ranging from the mid .80s to the low .90s. The BASC scales show convergent validity with the Child Behavior Checklist (Achenbach, 1991) ranging from .65 to .84. Scales named similarly on both measures have the highest correlation.

A unique feature of BASC rating scale is the inclusion of validity indicators. An F scale identifies parent informants who may be reporting on their child's symptomatology in an invalid manner. The validity indicator was considered particularly important as parents were the only adults being asked to rate their child(ren)'s behavior. Children whose PRS show an unexplained F score of three or above were to be excluded from the study. No children were excluded from the study based on an unexplained elevation of the F score. Scoring procedures are also sensitive to missed items or response bias.

The BASC separates symptoms of hyperactivity and inattention and as such has potential to be a particularly useful aid in AD/HD subtype categorization. This screening measure was used to indicate the likely presence of other disorders, which, if present in the control group, became the basis for exclusion.

Diagnostic Categorization

Diagnostic Interview for Children and Adolescents – IV (DICA-IV)

Clinical interview data from parents were sought by way of the Diagnostic Interview for Children and Adolescents - IV (DICA-IV; Reich et al., 1997). The DICA - IV is a widely used, computer based, psychiatric interview based on a strict adherence to the diagnostic rules of the DSM-IV (Szatmari et al., 1990). Completion time for the DICA-IV was approximately 45 minutes. The DICA – IV can be used to gain diagnostic information on a range of disorders. In this case only information on the presence or absence of AD/HD symptomatology was acquired. Parents read and answered the relevant questions directly onto the computer. The investigator prepared parents for the computerized format by taking them through a short tutorial and continued to be available for answering any questions the parent might have as the interview progressed.

Each stage of the screening process served a unique purpose. The SAC was used to indicate probable control or AD/HD status. The BASC was used to rule out psychopathology in control children, and the DICA was used to confirm AD/HD symptomatology and to assign children to experimental groups. Agreement between scales on ratings of AD/HD symptomatology was not sought given that only the DICA-IV provided a comprehensive presentation of DSV-IV criteria for AD/HD. In order for children to be placed in an AD/HD group, endorsement of all DSM-IV criteria, including pervasiveness, was required.

Dependent Measures

Aspects of neuropsychological functioning were investigated with the use of the dependent measures included in the study design. Dependent measures were incorporated to assess inhibition, processing speed and visual spatial skills.

Criteria for the Selection of Dependent Measures

1. Laboratory measures of AD/HD have been criticized for their lack of generalizability (Barkley, 1991). To counter this design criticism, a combination of laboratory and ecologically valid instruments were incorporated for the measurement of inhibition, processing speed and visual spatial ability.
2. Multiple data sources are recommended in order to gain the most comprehensive assessment of the functioning being considered. Valid parent information, gained from two instruments, was used in conjunction with multiple child performance tasks.
3. Given the motivation deficiency and well-recognized lack of persistence in ADHD children, tasks were chosen that would be maximally engaging and provide the most data in the least amount of time.
4. Considering the age and characteristics of the children being tested, a maximum testing time of one and one half-hours was considered optimal.

Measures of Inhibition

The Stop Task

The Stop Task emanates from the stop-signal paradigm, a theoretically driven model for conceptualizing and testing processes hypothesized to be involved in carrying out or inhibiting completion of an action (Logan, 1994; Logan, Schachar, & Tannock, 1997). As discussed in the previous chapter, a central feature of how AD/HD is understood is the observation that persons with the disorder typically exhibit deficient inhibitory control (Barkley, 1997; Schachar, Tannock, Marriott, & Logan, 1995b). The Stop Task is a laboratory measure designed to simulate real life activities that call for quick and precise decision making processes regarding the execution or inhibition of selected actions.

Task Description

The Stop Task consists of a primary task, called a "go task," in which the participant is required to attend to the computerized visual presentation of an "X" and an "O". Each letter is paired with a particular response button located on a hand held response box. The individual is instructed to press the corresponding response button when the letter appears on the screen. At given times during the presentation of the letters a tone, known as "stop signal," sounds. The tone indicates that normal responding should be withheld. Children are instructed to "try not to push the button" once they hear the tone. Children are instructed to respond as quickly and accurately as possible to the visual and auditory stimuli. The withholding or stopping signal is presented on one quarter of all trials. Presentation of the stop signal is programmed so that it is automatically adjusted online for each individual, thus enabling approximately half of all stop signals to be responded to successfully.

Figure 1 gives a visual presentation of how the Stop Task functions. Each trial of the Stop Task begins with the presentation of a fixation point in the form of a round white dot on a black screen (500ms). The fixation point gives the child time to allocate their attention to the screen. After the fixation point has been presented, the screen remains clear for 34ms and then the stimulus (either X or O) is presented. The stimulus remains on the screen for 1000ms.

At random times throughout the test block, a tone (the stop-signal) sounded indicating that the child should try and withhold their response. The first presentation of the stop signal came 250 ms after the stimulus. If the child was not able to inhibit on the first stop signal, the next stop signal was presented 50ms closer to the letter stimulus. If the child was still unable to inhibit, the tone continued to move toward the stimulus in 50ms intervals. The tone moved 50ms closer to the letter stimuli with each successive trial until the child was able to successfully inhibit. If the child successfully inhibited on a given stop signal, the following stop signal would be presented 50ms later than previous one. In this manner the computer program "searches" for the child's optimal inhibitory time allowing each child to receive stop signals that they are able to inhibit approximately 50% of the time.

The Stop Task

Initial Stimulus Trial

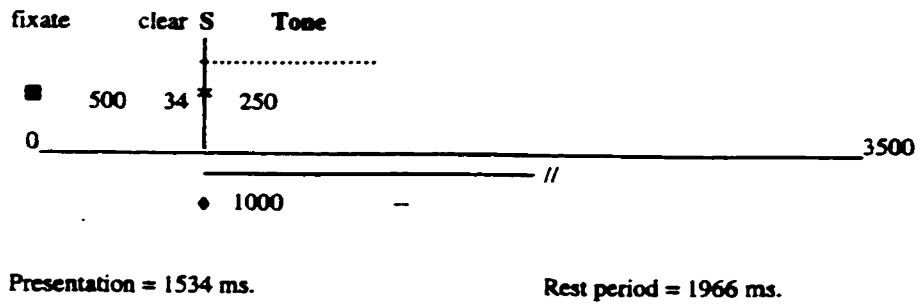


Figure 1. Initial stimulus trial of the stop signal task

Two practice blocks, of 32 stimuli each, are followed by eight test blocks each consisting of 24 stimuli without stop signals and 8 stimuli with stop signals. Thus the performance of each participant is assessed using 192 stimuli without stop signals and 64 stimuli with stop signals. Test completion time is approximately 25 minutes.

The version of the Stop Task used in the present investigation is an altered version of an earlier stopping task (Schachar & Logan, 1990b). The earlier version of the task involved more blocks (9 rather than 8), more trials per block (48 trials rather than 32), and less frequent breaks (3 rather than 6). Overall, the original task created a longer and more demanding task for children. Other design characteristics of the task, such as stimulus presentation and response mode have remained constant across earlier and later versions of the task. The task used in the present study had been used in research with young adults and in on-going research with children at the Hospital for Sick Children in Toronto (Logan et al., 1997).

Measures obtained using the Stop Task

Based on Logan's " horse race" model of inhibitory control (see Logan et al., 1984), two measures are obtained with the stop task: (1) speed of response (go reaction time) based on the mean reaction time (MRT) for the latency of the response to the go signal, and (2) inhibitory control measured by stop-signal reaction time (SSRT) based on the latency of the response to the stop-signal (Logan et al., 1997).

Mean reaction time (MRT) records the latency between stimulus and response for each "go" stimulus averaged over all trials. The tracking algorithm of the stop-signal means that every time a child is able to successfully inhibit a response, the next stop-signal comes more quickly after the of the next visual stimulus, thus making inhibition more difficult. The difficulty of the stopping response is adjusted on-line for each child so that approximately 50% of all stop signals can be responded to accurately by every child. When 50% of the stop-signals have been correctly responded to, the experimenter can be sure that the child was working consistently with the task. Thus the optimal stopping time for each child can be calculated. Stop-signal reaction time (SSRT) is calculated by averaging the stop signal reaction time for each of the test blocks. SSRT is based on responses to the successfully inhibited responses. The ability to inhibit a response indicates the degree of impulse control (Logan et al., 1997). Children with AD/HD have been shown to inhibit less often than control children and to have longer SSRTs than either control children or children with other psychopathological constellations such as AD/HD plus Conduct Disorder (Schachar & Logan, 1990b; Schachar et al., 1995a).

A Second Measure of Inhibition

The Test of Everyday Attention (TEA) has been developed as an ecologically sound measure of attentional problems in adults (Roberstson, Ward, Ridgeway, & Nimmo-Smith, 1996). A children's version of the test, Test of Everyday Attention for Children (TEACh), has been recently developed and normed (Manly, 1998). The Walk Don't Walk subtest of the TEACh has been designed to test children's ability to inhibit responses. Children were instructed to "take footsteps" (marking with a highlighter) along a paper path (see Appendix C) in response to a tape-recorded tone. Children must remain vigilant noting that one tone, incorporating a human voice, ends differently from all the others, and indicates that a step must not be taken. Correctly inhibited responses were totaled and converted to a scaled score. The test contains 20 trials with a variable number of signals in each trial. Each trial is presented at a reliable interval but at a speed slightly faster than the previous trial, thereby increasing the difficulty of the task as it progresses. Children are thus required to inhibit a response to an auditory signal. This subtest provides a second measure of inhibition in a format that reflects the everyday demands placed on children. This test took approximately five minutes.

Measures of processing speed

Processing speed, a factor used to discriminate AD/HD subtypes, was assessed with the use of three measures: (a) the mean reaction time (MRT) of the Stop Task, (b) Opposite Worlds (OPPOSITE), and (c) Same Worlds (SAME). Opposite Worlds and Same Worlds are subtests of the TEACh. As explained above, MRT is a computer-generated score produced as a result of time taken to respond to a visual stimulus.

Opposite Worlds/Same Worlds is a timed test in which numbers are presented in an irregular pattern on a laminated card (see Appendix D). Children must produce a verbal response of "one" or "two" to the visual presentation of the same or "opposite" numeral. Thus in the Same Worlds task, if the child sees the number one (s)he must respond by saying "one." In the Opposite Worlds tasks the child is required to say the number two if the number one is presented.

Same Worlds/Opposite Worlds yields two scores: one score indicates the speed of responding to a familiar number by saying its name. This score is labeled SAME. A second score, labeled OPPOSITE, was gained by recording the time taken to say the "opposite" number when either the number one or two is presented. Scores for SAME and OPPOSITE were gained as a result of two trials for each part of the test. Each trial requires a response on 24 numerals. Scaled scores based on a normative sample of 293 children are available for children aged 6 to 18 years. Test re-test reliability is .87 for Same Worlds and .85 for Opposite Worlds (Manly, 1998).

The time taken for completion of SAME and OPPOSITE measured cognitive speed for processing and responding to visually presented information. This test required approximately five minutes to complete.

Measures of visual spatial ability

Tests of visual spatial ability have been useful in identifying children with possible learning and neurological deficits (Sattler, 1992; Szatmari et al., 1990) and have pointed to potential differences between AD/HD subtypes (Garcia-Sanchez et al., 1997). To avoid a confound with processing speed or motor skills, the visual spatial measures utilized in this study were untimed and free of motor involvement.

Benton's Judgment of Line Orientation

Benton's Judgment of Line Orientation test is a pure measure of spatial perception that has proved extremely useful in discriminating individuals with right hemispheric dysfunction from normal controls and those with left hemispheric dysfunction (Benton et al., 1994). There is some evidence to suggest that AD/HD subtypes may be distinguished with the use of this measure (Garcia-Sanchez et al., 1997; Lorys et al., 1990).

Children are required to view a series of straight-line configurations (see Appendix E for a sample). The items are presented in a spiral bound book arranged with the stimulus lines on the upper page and the multiple choice response pattern on the lower page. Items are presented in ascending order of difficulty. Each trial contains two lines (stimulus) presented at varying angles to each other. The child is asked to look at the two lines presented and then indicate by pointing or by saying the number used to label the lines below, which lines in the array correspond to the two lines being presented. Each line in the array is 3.8cm long, labeled "1" through "11"and is drawn at 18 degree intervals from the point of origin. The test incorporates five practice items followed by 30 two-line patterns that must be identified. Each child's score is based on the number of correctly identified pairs converted to an age-normed scaled score. Split-half reliability is .94 and test-retest reliability is .90. Norms are available for children aged 7-14 years (Benton et al., 1994). Administration takes approximately 15 minutes.

TEACh - Sky Search and Sky Search Motor Control

Sky Search and Sky Search Motor Control are two short tests of visual search. The child is required to scan a space theme picture, identifying identical pairs of spaceships from mixed distracter pairs. The number of correctly identified spaceships yields a target score for each child. Each target score is converted to a scaled score yielding a measure called TARGETSC. The visual search score (TARGETSC) can be weighted by the motor component, so that a motor free score is obtained. This Sky Search Motor Controlled score is then scaled according to age norms. The resulting dependent measure is labeled SSMCSC. About 5 minutes are required for completion of Sky Search (TARGETSC) and Sky Search Motor Control (SSMCSC).

Procedure

Participant Recruitment

Parents of children heard about the study from a poster display, word of mouth, school personnel, or Behavioral Research Unit personnel. Once parents had indicated a desire to hear more about the study, they were contacted by phone and the project was explained to them. If parents and children indicated a desire for further involvement, an initial telephone screen was conducted. Children who appeared to fit any of the experimental groupings were then invited to continue in the study and an appointment was booked for the parent and child to complete the testing procedure.

Establishing the Testing Environment

Given the stress that parents of AD/HD children experience, it was anticipated that in order to facilitate parent and child involvement it would be necessary for children to be seen in their homes. Alternate testing space was available at the university and at the rural school involved. Given the variety of possible venues it was considered important to establish a working environment that could be held constant across all settings. Consideration was given to maintaining a consistent auditory, visual and kinesthetic environment.

To maintain a constant auditory environment a transportable pink noise sound masker was employed (Scamp Sound Masking Model PLM 6). The sound masker produces an unobtrusive sound comparable to softly blowing air. It is a system commonly employed in office settings to ensure speech privacy for employees working in shared office space. The 1.6-kg unit is completely self contained and transportable with noise generator, equalizer, amplifier, volume and spectrum adjustments. Output adjustments include a 15dB external volume control plus additional internal controls. The system was set to produce approximately 13 dB of sound. The unit is enclosed in an electroplated steel housing 155mm in height and powered by a 16V AC outlet. It comes with a mounting chain that was attached to a telescoping rod on a heavy tripod base. A constant height of 336 cm was maintained for testing purposes. Thus the unit was easily disassembled for moving from location to location and effectively blocked out voices and other potentially intrusive sounds.

Maintaining a constant visual environment was accomplished by the use of two large, white, folding cardboard screens, each 288 cm in height by 576 cm in length. The screens were easily folded for transport, and could be quickly erected to block out all visual distractions.

Other equipment included: a) a folding table and chair unit, ensuring that each child sat in the same position, at the same table while completing tasks, b) a small desk light providing constant lighting, c) a portable computer for children to use at the table, and d) a portable tape recorder. Thus, regardless of location, a constant testing environment was maintained. As a further check for potentially distracting environmental elements, an Environmental Rating Scale was constructed (see Appendix F). The scale allows for the rating of visual distractions, auditory distractions, lighting quality and air quality. The scale was filled in by the investigator in the event of any distracting conditions.

A total of 9 children were seen in their homes (4 control and 5 AD/HD children). All other children were seen at the university or in a specially designated testing room at the school. The above mentioned equipment was employed in each setting, and with every child. The use of the Environmental Rating Scale indicated that the testing environment was held constant across settings. No intrusive conditions were noted.

Forming Experimental Groups

Experimental groups were formed on the basis of DSM-IV criteria reflected in the parent responses given on the DICA-IV. Children in the Predominantly Inattentive subtype group were designated by the presence of at least six symptoms of inattention and not more than five symptoms of hyperactivity/impulsivity. Children in the Hyperactive Impulsive subtype group were designated by the presence of six or more symptoms of hyperactivity/impulsivity and no more than five symptoms of inattention. Children in the Combined subtype were designated by the presence of at least six symptoms of inattention plus at least six symptoms of hyperactivity/impulsivity.

Confirmation of Impairment in Multiple Settings

DSM-IV diagnostic categorization requires that impairment in functioning be evident in two or more settings, which was confirmed from parent interview data. While teachers are a further important potential source of confirmatory data (Achenbach, McConaughty, & Howell, 1987; Barkley, 1998; Bauermeister et al., 1995), information from teachers was not formally sought since the age range and educational placement of the children meant that not all participants had close contact with a given teacher who could reliably comment on their general school performance. Informal information was available from teachers for over half of the children involved in the study, as all of the rural children were recommended to the study by school personnel.

DSM-IV field trials employed the strategy of considering a symptom to be present if reported by *either* parent or teacher (Lahey et al., 1994). A positive diagnosis based on parent report has been shown to have a 90% probability of being confirmed by teacher report (Biederman, Farone, Milberger, & Doyle, 1993). Parent ratings have the advantage of being based on observations of a given child over a lengthy period of time and across diverse situations (Sattler, 1992). In addition, parent report has been regarded as particularly useful in terms of identifying internalizing disorders (Loeber, Green, & Lahey, 1990; Phares, 1997). Internalizing disorders have been linked to AD/HD-PI, which is also the most likely female presentation of the disorder. Given the subtype and gender focus of the present study parent data were considered a priority. In the majority of cases (n = 108) parental information was gained from the child's mother. A small number of fathers (n = 9), and other custodial relatives (n = 2) completed the questionaries given to parents. Given that mothers may be more likely than fathers to witness AD/HD symptoms (Barkley, 1998), the large proportion of mothers as parent respondents in the present study may have contributed to increased accuracy of parent responses.

Testing Procedure

Testing was carried out by the primary investigator who was blind to subtype categorization given that subtype categorization could not be ascertained until the parent had completed the DICA-R. The DICA-R was completed simultaneously to child testing. Children and parents who came for testing were oriented to the process and purposes of the project. The investigator explained the experimental tasks and any questions were answered. After written consent was gained (see Appendix G), parents were seated on the other side of the folding screen to complete their part of the tasks. In this way, parents were able to hear what their children were doing without being a distraction. The screens were arranged so that, if they wished, parents could also "check" on what their child was doing without being seen by the child.

Random order presentation of the tasks was accomplished by having the task names printed on colored, laminated cardboard (see Appendix G). The task cards were then placed in a cloth bag and each child was asked to choose the order of the tasks by pulling the task cards out one by one. Each card was backed with a Velcro patch enabling the child to attach the labels to the screen so that the titles remained at the child's eye level. The "game" of choosing the tasks was an enjoyable way to engage the child's cooperation and to establish rapport. As each task was completed, the child was asked to remove the corresponding task card from the screen. In this way children could monitor how many tasks they had completed and look forward to the tasks to come. Children appeared to enjoy the "sticking" and "unsticking" procedure.

Children progressed through the experimental tasks at their own rate, taking breaks as needed. Each child was given a personalized "Honorary Scientist" certificate (see Appendix I) as a tangible recognition of contribution to the project. As children were engaging in the experimental tasks, parents were completing the DICA-IV and BASC questionnaires.

Test Administration

Stop Task

The Stop Task was administered using a Toshiba 300 CDS laptop computer with 16 MG of memory, a Pentium 166 MMX processor and a 12.1-inch DSTN LCD display screen. The task was explained to each child using standardized instruction (see Appendix J). A visual diagram explaining the two practice blocks and eight test blocks of the task was hand drawn for each child. On the first practice block, children were instructed to respond to the letter stimulus by pressing the appropriate button on the hand held response box. Appropriate use of the response box was acknowledged and any problems corrected. On the second practice block, children were instructed to respond to both the letter stimulus and the stop signal (beep). After competency in both the "go" task and the "stop" task was acquired, the testing began. The "go" score for each block was hand written into the appropriate block on the child's diagram as the child progressed. This running record helped the child judge how much of the task had been completed and to gauge the consistency of their performance. The task was programmed to stop after every block so children could be apprised of their score and task instructions could be reinforced. Two scores were computed from the data. Stop signal-reaction time

(SSRT) was computed by disregarding the first test block and averaging the response time on the correctly inhibited trials across the remaining seven blocks. The first block was excluded from the calculations based on the fact that the stop-signal delay is reset to 250 ms. after each practice is complete. Once the tracking algorithm is reset, a few trials are required to catch up to the individual's response pattern (R. Tannock, personal communication, February 11, 1998). Mean reaction time (MRT) was calculated by averaging the latency between stimulus and response for each correctly identified"go" stimulus across the seven test blocks.

TEACh – Walk Don't Walk

Walk Don't Walk (WALKSC) was administered using standardized instructions (see Appendix K). Children listened to instructions and then watched as the investigator performed the first practice block with the tape recorder running. A wide-tipped florescent marker was used to mark on the footstep pathway (See Appendix C). After the practice blocks the tape recorder was stopped and children were questioned regarding their understanding of the task instructions. The tape was restarted and remained running till the end of the task with no intervention from the investigator. The investigator kept a running record of the child's performance on each block. Raw scores were converted to age-normed scaled scores.

TEACh - Sky Search and Sky Search Motor Control

The task instruction was delivered in a standardized format (see Appendix L). A practice page consisted of a blue, laminated 29 cm by 19 cm sheet with 8 matching black spaceship pairs as well as 12 distractor pairs (see Appendix M for a photo reduced sample of the practice block). The investigator modeled how the "real spaceships" should be circled using a washable felt tipped pen. Children then completed the practice page and received encouragement for accurate engagement. The Sky Search task was presented using a 38-cm by 28 cm laminated page. The task contained 10 target spaceships on the left side of the page and 10 target space ships on the right side of the page. The investigator combined the number of target spaceships correctly identified on the left and right sides and converted each raw score to a scaled score (TARGETSC). A timed score was also recorded.

A third laminated page, containing only the 20-target space ship pairs, was presented last. The target pairs were located in exactly the same position as they had been in the previous page, but on this presentation no distractor pairs were included. Children were asked to circle the target pairs as quickly as they could. After all the target pairs were circled, the time taken to complete the third sheet was subtracted from the time taken to complete the second sheet, revealing a motor free score for visual search. The raw score was then translated into an age normed scaled score (SSMCSC)

TEACh – Opposite Worlds/Same Worlds

The Opposite Worlds/Same Worlds subtest consists of five laminated 29 cm by 19 cm cards each containing a black space ship background with 24 white boxes containing black numbers (1 and 2). The boxed numbers were arranged in an irregular caterpillar like formation. One card contained a small version of both the Same and Opposite Worlds task, and was used for instruction and practice. Of the four remaining cards two were designed for the same world task and two were designed for the Opposite Worlds task. The task was explained via standardized instructions (see Appendix N). After practicing both "opposite" and "same" worlds in an untimed situation, the test was administered alternating Same and Opposite World tasks. The time on each task was recorded by adding the two same world times to obtain a composite same world score and by likewise adding the two opposite world times to obtain a composite opposite worlds score. These raw scores were then converted to age normed scaled scores (SAME and OPPOSITE) indicating the time required to process simple visual information.

Benton's Line Orientation

Benton's Line Orientation test contains five practice items that are used to help children learn how to respond to the test items. During the practice items children were informed if their answers were correct and instructions were given to help them correct any mistakes. Coaching was offered regarding how to obtain more accurate answers. If children were able to get at least two of the practice items correct they were considered able to perform the test. Once the test began, encouragement for effort was given, but no feedback regarding the accuracy of answers was provided. The raw score was gained by totaling the number of correct answers. The raw score was then converted to a standard scaled score based on age and gender.

WISC-III Screen

A short form WISC-III (Vocabulary and Block Design) was administered at a convenient time in the testing session. For instance, if the child was ready to do the Stop-

Task on the computer, and the parent was still using the computer to complete the DICA-IV, the time that would otherwise be spent waiting was utilized to do the WISC-III. Alternatively, if it was clear that the child tasks could progress without waiting for the computer, the WISC-III was completed at the beginning or end of the testing session. Standardized testing procedure was followed and the scaled scores of the two subtests were converted to a full-scale score (Sattler, 1992).

Other Conditions

Parents of children with AD/HD were asked to ensure that their children were free of psychostimulant medication for at least 12 hours prior to the time of testing. Testing times were organized so that children and parents would be minimally inconvenienced by this short discontinuation of medication.

RESULTS

Included here is a description of relevant sample parameters followed by results for Multivariate Analysis of Variance (MANOVA) with a descriptive discriminant function analysis used as a follow-up. The significance level for all analyses was set at .05. Statistical Package for the Social Sciences (SPSS 8.0) was used to conduct all analyses.

Description of the Sample

One hundred and nineteen children and their parents participated in the study. Fifty-eight participants were girls and 61 were boys. The three grouping variables contained nearly even numbers of girls and boys. The AD/HD PI group contained 22 boys and 18 girls, the AD/HD – C group contained 20 boys and 19 girls, and the control group was comprised of 19 boys and 21 girls (see Table 1).

Children were placed in one of three groups depending on the presence or absence of AD/HD symptomatology. Symptom clusters for each group were distinct. Children with AD/HD-C averaged 9 symptoms of hyperactivity/impulsivity and 8 symptoms of inattention. In contrast, children with AD/HD-PI had an average of 9 symptoms of inattention and only 3 symptoms of hyperactivity/impulsivity. Control children averaged 2 symptoms of hyperactivity/impulsivity and 0.6 symptoms of inattention.

Children were from 7 to 13 years of age with a mean age of 9.97. Age of girls and boys across groups was analyzed with a one-way (group, three levels) analysis of variance (ANOVA) which indicated that there were no significant differences between the groups with respect to age (F (2,116) = 2.629, $p > .05$). Examination of a stem

Table 1

Sample Size by Subtype and Gender

	Gender		
Group	Boys	Girls	Combined
AD/HD – PI	22	18	40
AD/HD – C	20	19	39
Control	19	21	40

and leaf plot indicates a bimodal distribution with the largest number of children in the 8 and 11 year-old categories. Using an independent samples t-test, no gender differences on age were found (t (117) = -1.894, $p > .05$). For descriptive statistics see Table 2.

All children included in the sample were required to be of normal intellectual ability. Mean IQ of participants was 109 (SD = 15.90). Potential differences in intellectual function across experimental groups was investigated by employing a one-way (group, three levels) ANOVA which revealed no group differences in IQ across experimental groups (F (2,116) = 1.053, $p > .05$). Using an independent samples t-test, no gender differences in IQ were found (t (117) = -.082, $p > .05$). See Table 3 for descriptive statistics regarding IQ.

Parents were asked if their children had received any kind of special help (home or school tutoring, special classroom help etc.) for educational issues. Despite average intellectual functioning across the sample, academic problems were indicated in 50% of the AD/HD – PI group, 67% of the AD/HD – C group and 8% of the control group.

A unique feature of the sample was their diversity in terms of geographical location. In order to ascertain potential differences in symptomatology across location, scores on the 11 subscales of the BASC were investigated with a multivariate analyses of variance (MANOVA). Although participants were from two geographical locations, group differences on scales of the screening measure (BASC) did not vary with respect to location (F (11,103) = .947 $p > .05$).

Table 2

Mean Age of Participants

Group	Gender			
	Girls		Boys	
	M	SD	M	SD
Inattentive	10.99	2.07	10.04	2.08
Combined	9.56	1.87	9.49	1.67
Control	10.38	1.80	9.41	1.31

Table 3

Mean IQ of Participant

Group	Gender				Total	
	Girls		Boys			
	M	SD	M	SD	M	SD
Inattentive	106.28	17.38	109.55	15.35	108.07	16.16
Combined	107.79	15.77	106.55	16.17	107.15	15.78
Control	113.05	18.54	110.89	12.28	112.03	15.72
Total	109.22	17.27	108.98	14.62	109.10	15.90

Of the children categorized as AD/HD, some came to the study with a confirmed diagnosis of AD/HD. Others were interested to be part of the study even though no diagnostic category had been previously established. A two-way chi-square was performed to investigate whether there was a significant difference between AD/HD – PI and AD/HD - C groups regarding previous diagnosis. Results revealed a significant relationship between AD/HD group (PI or C) and previous diagnostic categorization (no previous diagnosis or previous diagnosis), χ^2 (1, $\underline{N}$ = 79) = 15.099, $\underline{p}$ < .05. There was no difference between the number of boys and girls previously diagnosed as AD/HD. However, as shown in Table 4, more AD/HD – C than AD/HD - PI children were likely to have received a previous confirmation of AD/HD. Of the AD/HD children not diagnosed, 89.5% were from the AD/HD - PI group whereas only 10.5% of the AD/HD – C group had not received a previous diagnosis.

Overview of MANOVA Results

In order to determine potential group differences across the three domains of functioning being investigated (inhibition, visual spatial skills and processing speed), a MANOVA was performed using a total of eight dependent variables. Two dependent variables measured inhibition: (a) Stop-Signal Reaction Time (SSRT), and (b) Walk-Don't -Walk (WALKSC). Three dependent variables measured processing speed: (a) number naming (SAME), (b) number naming with interference (OPPOSITE), and (c) the Mean Reaction Time taken from the stop-task (MRT). Three dependent variables measured visual spatial ability: (a) Benton's Line Orientation (BLO), (b) Sky

Table 4

Frequency of Previous Diagnosis for AD/HD – PI and AD/HD – C Groups

	Gender		
Group	Girls N (%)	Boys N (%)	Total N (%)
Diagnosed – PI	12 (20%)	11 (18.3%)	23 (38.3%)
Diagnosed – C	18 (30%)	19 (31.7%)	37 (61.7%)
Undiagnosed – PI	6 (31.6%)	11 (57.9%)	17 (89.5%)
Undiagnosed – C	1 (5.3%)	1 (5.3%)	2 (10.5%)

Search Motor Control (SSMCSC), and (c) Sky Search Targets (TARGETSC). Independent variables were gender (male and female) and groups (AD/HD – PI, AD/HD C, and control).

There were no univariate or multivariate within-cell outliers at $p = .001$. Results of evaluation of assumptions of normality, homogeneity of variance, linearity and multicollinearity were satisfactory given that sample size produced more than 20 degrees of freedom for errors, and that group sizes are equal (Tabachnick & Fidell, 1996). Correlations between the dependent variables are noted in Table 5 and group means for all dependent variable are given in Table 6.

MANOVA Results

The MANOVA revealed a significant main effect for group, Wilks' Lambda criterion $F(16,212) = 3.19$, $p < .05$. Likewise, a significant effect for gender was obtained, $F(8, 106) = 2.58$, $p < .05$. No significant group by gender effect was obtained ($F(16, 212) = 1.63$, $p > .05$). See Table 7 for multivariate results.

Group Differences Using Descriptive Discriminant Function Analysis as a Follow-up to MANOVA

The significant main effects for group and gender were followed-up with a descriptive discriminant function analysis. Descriptive discriminant function analysis was chosen as a follow-up to help interpret the pattern of differences among the

Table 5.

Correlations Between All Dependent Variables

	SSRT	WALKSC	BLO	SSMCSC	TARGETSC	MRT	SAME
Inhibition (WALKSC)	-.45**						
Benton's Line Orientation (BLO)	-.27**	.37**					
Sky Search Motor Control (SSMCSC)	-.32**	.29**	.21*				
Sky Search Targets (TARGETSC)	-.31**	.26**	.17	.33**			
Mean reaction time (MRT)	.47**	.37**	-.34**	-.39**	-.15		
Processing speed unconflicted (SAME)	-.41**	.44**	.34**	.45**	.27**	-.47**	
Processing speed conflicted (OPPOSITE)	-.33**	.37**	.26**	.44**	.26**	-.38**	.79**

*$p < .05$ **$p < .01$

Table 6

Group Means for Dependent Variables

	Group											
	Inattentive				Combined				Control			
	Girls		Boys		Girls		Boys		Girls		Boys	
Dependent Measures	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
SSRT	309.22	204.25	382.64	161.11	470.54	310.25	360.74	174.98	329.09	199.84	265.60	85.89
WALKSC	6.33	3.80	4.77	2.91	4.16	2.80	5.65	·3.08	5.68	3.32	5.79	2.76
BLO	21.89	3.94	21.41	4.93	17.53	3.84	19.55	4.14	20.57	4.81	23.42	3.12
SSMCSC	9.17	2.04	8.86	2.87	8.58	2.74	9.70	2.90	9.48	1.78	9.42	2.52
TARGETSC	10.44	2.62	10.00	3.18	10.11	3.57	10.45	2.61	11.57	2.46	10.79	3.21
MRT	624.75	115.15	651.94	166.34	748.95	138.93	665.64	138.38	596.27	101.35	647.48	127.07
SAME	9.89	3.27	8.32	3.63	9.21	1.81	9.95	3.03	10.10	3.30	10.26	2.77
OPPOSITE	9.39	2.64	7.32	3.48	8.68	1.92	10.05	3.27	11.62	2.25	9.32	3.42

Metric for SSRT and MRT = ms, all other figures are scaled scores.

Table 7

Multivariate Analysis of Variance for Inhibition, Processing Speed and Visual Spatial Skills

Source	Wilks'Lambda	df hypothesis	df error	Multivariate F
Group	.649	16	212	3.19*
Gender	.837	8	106	2.58*
Gender*Group	.793	16	212	1.63

- $p<.05$

dependent variable as it offers a profile of the dimensions along which groups differ. While the categorical approach of using ANOVA follow-ups is more common in the published literature, descriptive discriminant function analysis was considered preferable given the theoretical interest in how AD/HD subtypes may vary along the neuropsychological dimensions under investigation.

A discriminant follow-up for group differences yielded two functions arranged in order of decreasing importance with a combined $\chi^2 (16, N = 119) = 45.96$, $p < .05$. After removal of the first function there was still a strong association between groups and variables, $\chi^2 (7, N = 119) = 20.09$, $p < .05$.

As shown in Table 8, the centroids revealed that Function 1, the most important function in this analysis, maximally separated children with AD/HD from control children. Function 1 gave an indication of how AD/HD and non-AD/HD children differ on the variables under investigation. While the centroids in Function 1 showed the largest distance between the AD/HD-C and control groups, the AD/HD-PI group centroid shared a positive valence with the AD/HD-C group reflecting the body of empirical evidence which indicates that children with AD/HD are more like each other than children who are not affected by AD/HD. Function 2 maximally separated AD/HD groups from each other. That is, Function 2 gave an indication of how AD/HD-PI children differ from AD/HD-C children. The centroids for this function indicated that the greatest separation was between the AD/HD-PI and AD/HD-C groups. The centroid for the control group occupied a midpoint position sharing a positive valence with

Table 8

Functions at Group Centroids for AD/HD and Control Groups

	Function	
Group	1	2
Inattentive	.18	-.59
Combined	.51	.44
Control	-.68	.16

the AD/HD-C group indicating that, compared to controls, AD/HD-PI children may exhibit more marked differences than AD/HD-C children on the variables under investigation.

Function 1 with an eigenvalue of .259 accounted for 56.9% of the between-group variance[3]. Function 2 with an eigenvalue of .404 accounted for 43.1% of the between-group variance. The canonical correlations measured the between-group separation provided by each discriminant function indicating the strength of association between group membership and scores on the discriminate function. The canonical correlations revealed that group membership explained approximately 21% of the variance in Function 1 and approximately 16% of the variance in Function 2.

The standardized discriminant function coefficients and structure coefficients generated from the descriptive discriminant function analysis were examined for each variable in Function 1. Interpretation of the variables was based on a value of .30 being achieved on both standardized discriminant coefficients and structure coefficients (Huberty, 1994). As shown in Table 9, the structure coefficients for inhibition (SSRT and WALKSC), processing speed (MRT, SAME, and, OPPOSITE), and visual spatial skills (BLO) all had absolute values greater than .30, indicating their significant contribution to the function. The standardized discriminant function coefficient .75 was the largest for inhibition as measured by the stop signal reaction time (SSRT), which reflects that it made the largest contribution to discriminating between children with AD/HD and controls. The positive value of the discriminant function for SSRT indicated

Table 9

Descriptive Discriminant Function Analysis for Group Differences

Predictor Variable	Function 1		Function 2	
	Discriminant Function Coefficient	Structure Coefficient	Discriminant Function Coefficient	Structure Coefficient
SSRT	.75*	.84*	-.01	.07
WALKSC	.04	-.43*	-.09	-.03
BLO	-.15	-.41*	-.65*	-.51*
TARGETSC	-.08	-.29	.08	.12
SSMCSC	.39*	-.12	.02	.10
OPPOSITE	.15	-.43*	.59 *	.50*
SAME	-.63*	-.65*	.44*	.38*
MRT	.02	.46*	.59*	.33*

* >.30

that as SSRT scores go up so did the likelihood of the child's placement in the AD/HD group.

The positive value of the discriminant function for SSRT needs to be interpreted in light of whether or not the stop-signal task data can be deemed reliable. As seen in Table 10, children in the experimental group performed in a proficient manner. The mean accuracy of the go-task was 91.5% (SD 6.5%). The mean probability of inhibition given a stop signal was 49.2% (SD 4.5%), indicating that the tracking mechanism worked as expected to "tie" the race between "stopping" and "going," allowing approximately half of the possible stop-signals to be inhibited. Examination of the distribution of scores reveals that MRT was normally distributed and that SSRT was somewhat positively skewed.

Hypothesis 1 regarding subtyping predicted that AD/HD – PI children would exhibit a pattern of noncompromised inhibition, similar to control children, and that only AD/HD – C children would show compromised inhibition. Contrary to Hypothesis 1 both AD/HD – PI and AD/HD – C groups were significantly different from control children on inhibition as measured by SSRT. Thus Hypothesis 1 was not supported by these data.

The next most important variable for discriminating between AD/HD and control children was a measure of processing speed (SAME) with a standardized discriminant function coefficient of -.63. The negative value of the discriminant function coefficient indicated that as the processing speed score, as measured by SAME, increased so did

Table 10

Patterns of Response on the Stop-Task

		SSRT		MRT		P(I/S)		Correct %	
Group	n	M	SD	M	SD	M	SD	M	SD
AD/HD-PI	40	345.93	182.68	638.35	140.75	49.7	4.1	91.8	7.4
AD/HD-C	39	415.64	242.62	707.30	138.66	48.4	4.9	89.5	6.7
Control	40	297.35	142.87	621.88	114.21	49.6	4.5	93.4	5.2
Total	119	352.93	189.39	655.84	131.21	49.2	4.5	91.5	6.5

P(I/S) = probability of inhibition given a stop-signal

Correct % = accuracy of go-task responding (MRT) the likelihood of the child's membership in the control group.

In Hypothesis 2, slower processing speed was predicted in the AD/HD – PI group when compared with AD/HD – C and control groups. The findings for SAME revealed that when responding in a timely fashion to simple digits both AD/HD – PI and AD/HD – C groups were slower than control children. The processing speed variable SAME was useful for separating AD/HD and control groups.

A third measure, the visual spatial task (SSMCSC), had a discriminant function coefficient of .39, however the structure matrix revealed that this task was not correlated with the function and therefore was not clearly useful in separating AD/HD and control children.

The large structure coefficients for the other measures of inhibition (WALKSC), processing speed (MRT and OPPOSITE), and visual spatial skills (SSMCSC and TARGETSC) indicate the correlation of these variables to the other dependent measures in Function1. The standardized discriminant function coefficients for each of these measures (< .30) indicated that they did not contribute significantly to discriminating AD/HD children from controls given the particular set of variables.

Overall, one measure in each of the domains of inhibition and visual spatial skill was useful for distinguishing between AD/HD and control children. While inhibition, as measured by SSRT, appeared to be the most salient measure, processing speed also separated AD/HD and control children. AD/HD children appeared more impaired than control children on measures showing a significant difference.

Given the study hypotheses regarding subtype differences, Function 2, which separated AD/HD subtypes, was of particular interest. The most important variable for discriminating between AD/HD groups appeared to be BLO, a measure of visual spatial skills. The discriminant function coefficient for BLO (-.65) indicated that as BLO scores went down, the likelihood of belonging to the AD/HD - C group increased. Decreased visual spatial skills for the combined group was contrary to Hypothesis 3 for subtyping, which predicted that the AD/HD - PI group would show greater visual spatial deficits.

A post hoc analysis of a non-random sample of participants was conducted to ascertain if scores on BLO might have been effected by task involvement rather than by visual spatial skills per se. Seven children from each group (AD/HD – PI, AD/HD – C and control) were asked to review a subset of the BLO items at the completion of the test. The review subset was tailored for each individual and consisted of items that had been identified incorrectly during the BLO test. Given an opportunity for reconsideration of incorrectly answered items, control children increased their overall correct score by an average of 2.7 points. AD/HD – PI children increased their score by an average of 2.6 points. AD/HD – C children increased their score by an average of 5.4 points, nearly doubling the improvement score of the other two groups.

On measures of processing speed, all three variables contributed to the function. Discriminant function coefficients for the three measures of processing speed were extremely similar (OPPOSITE .59, MRT .59, and SAME .44) indicating that all three measures were useful in discriminating AD/HD subtypes. However, slower processing speed scores on MRT, were not in the direction hypothesized. On MRT AD/HD-C children were found to be slower than AD/HD – PI, who were not dissimilar to normal children. On SAME, AD/HD-PI children were slower than the AD/HD-C group. Given that SAME was significant on both Functions 1 and 2, it appeared that when responding to rapid naming of familiar digits, all AD/HD children are slower than controls, but AD/HD – PI children are slower than AD/HD – C children.

In the same fashion, scores on OPPOSITE, a conflicted digit naming task, AD/HD – PI children were slower than AD/HD – C children. Hypothesis 2 for subtyping is supported by differences between AD/HD groups found on this variable

The discriminant function coefficient of -.01 for SSRT indicates that the AD/HD – PI and AD/HD – C groups were not significantly different on measures of inhibition. Likewise the other measure of inhibition (WALKSC -.09) did not separate the two AD/HD groups. Thus, contrary to Hypothesis 1 for subtyping, AD/HD groups could not be separated on the measures of inhibition employed.

In summary, group differences did not appear where they were hypothesized on measures of inhibition, and for measures of processing speed the differences that were identified were not always in the direction predicted. Visual spatial skills did not appear more compromised in AD/HD – PI children as predicted.

Gender Differences Using Descriptive Discriminant Function Analysis as a Follow-up to MANOVA

The follow-up descriptive discriminant function analysis for gender revealed one significant function $\chi^2(16, N = 119) = 17.41$, $p < .05$. The centroids for Function 1 (male, -.395; female, .415) reveal that the function is useful in separating male and female children in the sample. An eigenvalue of .167 and a canonical correlation of .378 indicated that gender explains 14% of the variance on the function[3].

As seen in Table 11, the standardized discriminant function coefficient for the visual spatial task BLO is -.83 which indicates that it made the largest contribution to discriminating between boys and girls. In line with Hypothesis 2 for gender, boys appear to have significantly stronger visual spatial skills as measured by this task. The negative value of the discriminant function indicates that scores on BLO were higher for boys in the sample.

The next most important variable for distinguishing boys from girls appears to be the processing speed variable SAME. The standardized discriminant function coefficient of .76 indicates that scores on SAME were higher for girls. Contrary to Hypothesis 1 for gender, which predicted no gender difference for processing speed, girls appeared faster on this one measure of processing speed.

Discriminant function coefficients revealed that the inhibition measures, SSRT and WALK, both have absolute values of less than .30. As predicted in Hypothesis 1 for gender, neither dependent measure for inhibition contributed to Function 1 where gender differences are identified. Likewise, two variables measuring processing speed, MRT and OPPOSITE, with discriminant function coefficients of .07 and .23 respectively, did not indicate gender differences. The results that indicated no gender differences in processing speed were in line with Hypothesis 1 that predicted the absence of gender differences on this dimension.

Table 11

Descriptive Discriminant Function Analysis for Gender Differences

	Function 1	
Predictor Variable	Discriminant Function Coefficient	Structure Coefficient
SSRT	-.01	-.13
WALKSC	.27	.23
BLO	-.83*	-.46*
TARGETSC	-.08	.15
SSMCSC	-.50*	-.11
OPPOSITE	.23	.45*
SAME	.76*	.50*
MRT	.07	.00

*> .30

Overall, gender differences were mostly in line with the stated hypotheses; that is, no gender differences were found for measures of inhibition, and on two of the measures of processing speed. One measure of processing speed, SAME, showed an unexpected processing speed advantage for girls. The hypothesized male advantage in visual spatial skills was supported.

DISCUSSION

In the present study girls and boys categorized as AD/HD – PI and AD/HD – C were compared with control girls and boys on measures of response inhibition, visual spatial skills, and processing speed. Inhibition, widely regarded as the core of the disorder, has been proposed to be unimpaired in the AD/HD – PI presentation of the disorder. If AD/HD – PI children could be identified as lacking the core deficit of the disorder, weight could be added to the assertion that the inattentive subtype is a separate disorder. On the other hand, if AD/HD – PI children were found to share a common deficit in response inhibition with the other AD/HD subtypes, the validity of the AD/HD – PI subtype as a legitimate expression of AD/HD would be supported. Processing speed and visual spatial skills are other dimensions along which AD/HD subtypes have been found to differ, thus offering potential information regarding subtype differences. Given that AD/HD – PI is the most common presentation of the disorder for females, information on the presence or absence of gender differences across groups and neuropsychological domains was also sought.

Implications of Findings Regarding Subtyping

Inhibition

In line with recent literature, Hypothesis 1 predicted that AD/HD – PI children would display increased capacity for response inhibition when compared to AD/HD – C children. The present findings do not support the hypothesis that AD/HD – PI children lack the core deficit of response inhibition found in AD/HD – C children. Both AD/HD groups were found to be significantly impaired on response inhibition when compared to control children.

The study employed two measures of response inhibition. One measure, Walk Don't Walk (WALKSC) taken from the Test of Everyday Attention for Children, failed to show significant differences between any of the groups. In comparison, the Stop Signal Task (SSRT) indicated that AD/HD subtypes differed from controls but not from each other. Differences between the requirements of each task may account for the lack of consistency across findings.

Walk Don't Walk is an interesting task which the children in the study enjoyed performing. Children across the age span of the study were successfully engaged by trying to avoid being tricked by the voice on the tape recording. Unlike many of the other study tasks, where constant encouragement for engagement was required, only one child in the study had to be coaxed to persevere with this particular task. Overall, AD/HD children did not perform more poorly than control children. The scores of inattentive girls, who showed the highest and most variable scores of all groups, acted to elevate the scores of the AD/HD groups. Published literature to date does not provide an explanation regarding why AD/HD – PI girls would have performed in a manner superior to other AD/HD children. It is possible that this task, which served to normalize the response patterns of all AD/HD children, was particularly engaging for AD/HD – PI girls; however, the higher score variability of AD/HD – PI girls suggests that only a subset of AD/HD – PI girls were more successful on this task than other AD/HD – PI girls. Alternatively, the present results should serve as a reminder of the commonly reported variability in AD/HD samples.

Low task complexity and uniformity in the presentation of the inhibitory stimuli may have affected the outcome measure for WALKSC. Observation of task performance revealed that some AD/HD children immediately developed a strategy to avoid "walking" on the don't walk squares. Given that the don't walk signal came at reliable intervals, children could: (a) develop a rhythm that allowed them to respond appropriately by keeping track of the rhythm rather than keeping track of when to stop, or (b) move their hand away from the paper so that, even if they responded too quickly to the sound, their initial response would not be recorded on their paper because of the delay in bringing their pen to the page. Using this last strategy, some children who appeared extremely impulsive were able to avoid a score that reflected their initial response. As response strategies were not systematically recorded, it is not possible to determine how task complexity and strategy formation may have, together or in isolation, affected the outcome on this measure.

An alternative explanation for the lack of difference between groups for WALKSC is that when AD/HD children are sufficiently engaged in a task, thereby allocating their attention appropriately, they are able to withhold their impulsive responses in a manner similar to normal children. This idea is supported by the finding that if AD/HD children are rewarded for delayed action, they can indeed delay their action (Sonuga-Barke et al., 1994). Thus, a given context or task may appear to normalize AD/HD responding. If responding were normalized by task demands, it would be feasible that similar response patterns would be apparent across both subtypes of AD/HD, and that the scores of AD/HD children would be similar to the control group. It is possible that an examination of the task demands of inhibitory tasks such as WALKSC, that produce no differences across AD/HD and control groups, may offer clues to the contextual variables that facilitate developmentally appropriate behavior.

However, apparent similarities in the response patterns of AD/HD and control children do not necessarily indicate that the two groups are processing the task in a similar manner. No overt differences between AD/HD and control children have been observed on other stopping tasks when indeed an investigation of covert cerebral processes reveals a distinctly different pattern of event related potentials between AD/HD and control children, with AD/HD children exhibiting problems related to the orienting of attention prior to inhibition (Brandeis et al., 1998). Following this line of reasoning, while overt responses of children on WALKSC showed no differences, it is possible that an analysis of more covert processes would reveal group differences.

Recognition of the distinction between observed behavior and less visible processing strategies is essential to understanding important differences that may underlie a disorder or subtypes of a disorder. It is possible that a task such as Walk Don't Walk may produce no observable differences in inhibitory control because some part of the task has successfully engaged the attention of the AD/HD children so that the engagement prior to inhibition has set the stage for successful inhibition. Distinct processing pathways may be involved in the inhibition or lack thereof in AD/HD and normal children. Understanding the unique processing difficulties of AD/HD children (and subtypes) may significantly impact assessment and treatment strategies. For example, if fine grained analysis of response patterns in children with AD/HD can be consistently linked to deficient patterns of orienting attention prior to the execution of a response (such as inhibiting an action), developing and employing tools for the assessment and remediation of problems with orienting would be an important research and clinical endeavor.

The other measure of impulsivity employed in the study was the precisely calibrated Stop Task (SSRT). In this task children were not able to use a consistent strategy to avoid "failing" to stop. Task design ensured that children would not be able to stop at least half of the time. Task instructions aimed to decrease any impact on self-efficacy by stressing that the child was not expected to be able to stop after every stop signal.

In contrast to the other measure of inhibition, Walk Don't Walk, when children were engaged in the Stop Task, many of them required constant encouragement to keep attending. Despite initial enthusiasm for the task, generated by the novelty of using a lap top computer, enthusiasm for continuation past the first two practice blocks was not common. AD/HD – C children were particularly vocal in registering their disinterest in the task. Control children were more willing to complete the task with the acknowledgment that science requires repeated trials for accurate information. Despite different approaches to the task across groups, SSRT was equally compromised across both AD/HD subtypes and contributed most to classifying AD/HD vs control children.

One explanation for the present findings regarding a similar deficit in inhibitory control for both AD/HD – PI and AD/HD – C groups on the Stop Task, is that both groups may be similarly impulsive at a cognitive processing level. It is possible that a unique type of cognitive impulsivity underlies both inattention and hyperactivity. Using this explanation, inattention might be regarded as a less visible, perhaps covert or silent, kind of impulsivity. For example, in a classroom situation the AD/HD - PI child may not be running around or calling out, nonetheless her thoughts may be "running around" and she may be responding to a myriad of sensations calling out for her attention. The nature of this type of inner impulsivity is exemplified by one AD/HD - PI child in the study who remarked " I feel like I have all these thoughts…..and I need a butterfly net to catch them all."

As the AD/HD - PI child "impulsively" gives over her attention to the fluctuating sensations and thoughts that impose themselves on her awareness, she may be as impaired, or in some situations even more impaired, in her efforts to accomplish everyday tasks as the hyperactive child. On the Stop Task, the AD/HD - PI child gazing blankly at the screen or the response buttons had as much trouble inhibiting a response to the stop signal as the AD/HD - C child who was fidgeting and talking throughout the task.

It is possible that, while less visible, this "silent impulsivity" may be quietly destroying self-esteem, self-efficacy, social proficiency and academic attainment. In a similar fashion to internalizing disorders such as depression and anxiety, this less obvious manifestation of AD/HD may be causing the child significant but less recognizable suffering.

Alternatively, it may be argued that although AD/HD – PI and AD/HD – C children appeared equally impaired when compared to normal controls, their apparent shared inhibitory deficit may be the result of different processing strategies which express themselves in a similar end point. Auditory event related potentials comparing AD/HD children with and without hyperactivity do not support this contention: that is, evidence suggests that both subtypes are processing information in a similar rather than dissimilar manner. Both AD/HD groups have been found to differ from controls in the overall amplitude of evoked response to a task requiring inhibition (Holcomb et al., 1986).

Processing Speed

Throughout the literature on AD/HD the predominantly inattentive type is described as sluggish, daydreamy and as having a slower cognitive tempo. Three measures of processing speed were used to determine potential differences across AD/HD and control groups. In line with behavioral descriptions, Hypothesis 2 predicted that AD/HD – PI children would show decreased processing speed when compared to either AD/HD – C or control children.

Two measures, SAME and OPPOSITE, evaluated speed for rapid naming of familiar digits under different conditions, and the third measure, MRT, calculated response execution speed to a computerized presentation of a letter stimulus. Each measure presented a slightly different picture of processing speed across experimental groups. Mean reaction time (MRT) for the *go* stimuli of the stop task produced findings contrary to the hypothesized slower processing speed for AD/HD – PI children. In contrast, the other two measures of rapid digit naming using a conflicted response (OPPOSITE), and a nonconflicted response (SAME) produced findings in line with the proposed slower processing speed for the AD/HD – PI group.

Findings regarding slower MRT scores for AD/HD – C indicated that this group of children appeared more impaired than AD/HD - PI on rapid responding to a visual stimulus. These findings are in contrast to teacher reports that AD/HD – PI children appear to be more sluggish and have a slower cognitive tempo (Lahey et al., 1985). MRT offers a precise measure of processing speed that is calibrated to the millisecond, and as such may be a more reliable indicator of cognitive processing than observational measures based on teacher report. Results averaged across over more than190 trials add weight to the findings. Consistent with these results are previous findings that AD/HD – C children accomplished fewer math questions, in a set time period, than AD/HD – PI children (Barkley et al., 1990), despite that fact that AD/HD – PI children have been rated as more impaired in mathematical ability (Hynd et al., 1991).

Responses to the dependent variable SAME revealed that on a task of simple digit naming both AD/HD groups were impaired compared to control children. In addition, scores on SAME contributed to the separation of AD/HD groups, with AD/HD – PI children having a marginally slower processing time than AD/HD – C children. These findings are consistent with the results of other studies where AD/HD – PI children have been found to be slower than AD/HD – C children on test of rapid naming. Three suggestions are offered as possible explanations for the robustness of these findings.

First, although differences in selection procedures for the present study may have created a different sample from some other studies, finding were similar. The present sample group was drawn from children in normal classrooms and may not be equivalent to samples taken from a clinical population. Given the historical disregard for the inattentive subtype it is possible that inattentive children seen in clinical settings, especially children seen during the era of DSM-III-R, may have represented a particularly impaired group. Indeed, using DSM-III-R criteria, it was difficult for children with AD/HD - PI to be recognized, let alone diagnosed.

A consideration of the incidence of learning difficulties in the present sample gives weight to the suggestion that this group, taken from normal school classrooms, may represent a cohort with different characteristics than a clinical group yet AD/HD –PI children in both sample groups appear slower. In one study using DSM-III-R criteria, six of the 10 children diagnosed as AD/HD - PI (60%) had a comorbid diagnosis of Learning Disorder (LD) while four AD/HD – C children (40%) had a comorbid diagnosis of LD (Hynd et al., 1991). Inattentive children in the present study (with a sample group nearly four times as large) may represent a comparatively less impaired group with 50% indicating significant academic problems compared to 67% of AD/HD – C children. It is possible that even AD/HD – PI children who are able to function in normal classrooms are characterized by slower responding time.

Second, it is possible that response times on this task belie different response patterns. Observation of the inattentive children revealed that they appeared to approach the task in a slow but steady manner. By contrast AD/HD – C children often appeared to rush at the task and then spend time backtracking to correct mistakes. Contrary to the tortoise and hare story, the slow and steady inattentive subtype did not win the race. It is possible that if individual units of response could be analyzed, the processing speed of AD/HD – PI children may be slower to carry out each unit of response or slower to initiate responses.

Third, processing speed across AD/HD groups may have been influenced by the pace set by the experimenter. While children were encouraged to proceed with naming the digits at their own pace, practice examples, completed first by the experimenter, modeled a pace which may have been copied by the children, thereby masking underlying group differences. This explanation is probably the least tenable in that experimenter pace would be expected to have been copied equally across all three groups, in which case, group differences between AD/HD and control children would not have emerged.

The dependent variable OPPOSITE, measuring speeded response in terms of rapid naming of conflicted familiar digits also produced findings in line with the hypothesized slower functioning of AD/HD – PI children. The task requires children to first recognize either the number "one" or the number "two" and then withhold, or stop, the automatic naming response elicited by the number and instead produce the "opposite" number name. Thus the task is not a straightforward speeded naming task, but rather it includes an inhibitory process in the retrieval and production of the appropriate response. Thus, tasks employing simple digit naming or a combination of processing speed for rapid digit naming and a required inhibitory response produced a slower response time for AD/HD – PI children. Tasks such as OPPOSITE and SAME may hold promise for explicating subtype differences.

Visual spatial skills

Hypothesis 3, regarding decreased visual spatial skills in AD/HD – PI children, was not supported. The measures used either failed to produce a significant difference between AD/HD and control children or else produced a difference between AD/HD subtypes contrary to that which was hypothesized.

A limitation in task complexity may have contributed to nonsignificant findings on tests of visual spatial skills. It is possible that the level of task complexity represented in searching for space ship pairs on the dependent variables SSMCSC and TARGETSC was insufficient to elicit group differences in visual spatial skill. This line of reasoning is supported by the finding that Benton's Line Orientation, a task presenting a more complex visual discrimination procedure, produced a difference in scores between AD/HD groups.

The finding that the AD/HD - C group showed more impaired performance on Benton's Line Orientation was surprising and is contrary to other findings where AD/HD – PI children were found to be more impaired on this task (Garcia-Sanchez et al., 1997). Benton's Line orientation (BLO) was the second longest task in the testing session. AD/HD – C children were observed to be more resistant to performing the task, frequently asking if they had to do the whole book, yawning, looking around, or answering without taking careful notice of the configuration. The first complaint about the task frequently appeared within the first five configurations. It may be that boredom, resistance, and overt impulsivity adversely affected the scores of AD/HD – C children, thus their lower score may not really represent more impaired visual spatial skills, but rather less engagement with the task. Children employed in the present sample were younger than the sample employed in the previously cited study, and it is possible that developmental issues related to social expectations, or strategies for dealing with boredom, may have differentially impacted the findings in the two studies. Younger children who are hyperactive may have less well-developed strategies for dealing with a non-stimulating, repetitive task than older hyperactive children.

To test the idea that factors other than visual spatial ability may have been affecting scores on the BLO, a subset of children in each of the three groups were asked to reassess the configurations that they answered incorrectly. These participants were not informed that they had answered incorrectly on the first exposure, but at the completion of the test they were simply asked to have a look at several of the patterns for a second time. When given a chance for reconsideration, AD/HD – C children improved their scores more than AD/HD – PI children, suggesting that their mistakes were less likely due to visual spatial misperception and more likely the result of low task involvement. This observation was not strictly randomized and was employed in a post hoc manner after non-engagement with the task was observed in AD/HD – C children; therefore, it offers only preliminary support for the idea that lack of task engagement may have adversely affected scores for AD/HD – C children.

Implication of Findings Regarding Gender

Sizable groups of AD/HD girls have been difficult to obtain in research settings. The present sample group of approximately 60 girls represents a unique opportunity to compare girls and boys across AD/HD subtypes and neuropsychological domains. Predominantly inattentive girls have been particularly difficult to obtain, making the present findings regarding subtype and gender differences of particular interest.

Two study hypotheses regarding gender are addressed by the preceding results. The findings obtained offer support for both of the study hypotheses. First, the lack of a gender effect on measures of inhibition was confirmed. In addition, it was hypothesized that there would be no gender differences with regard to processing speed, and this hypothesis was supported by two of the tasks used to measure processing speed: MRT and OPPOSITE. Second, girls were predicted to show weaker visual spatial skills than boys and this hypothesis was supported by the one task, BLO, that showed gender differences on visual spatial skills.

The data that gender differences do not appear across measures of inhibition are consistent with other data (Gaub & Carlson, 1997b), and indicate that girls and boys found to be either AD/HD – PI or AD/HD – C are likely to experience similar levels of difficulty with day to day tasks calling for the inhibition of actions. While girls may experience more stringent socializing effects, where less leeway is given for boisterous or high activity behavior, they do not, by nature, appear to have more control over their disinhibited behavior. Therefore, it is possible that AD/HD girls, especially AD/HD – C girls, may bear a greater burden for their behavior than AD/HD - C boys whose behavior may be partly excused by a "boys will be boys" mentality.

If replicated, the findings that boys and girls have similarly compromised inhibitory ability suggest that treatment for girls and boys may proceed along similar lines. However, special consideration for the impact of potentially different social milieu of girls and boys should be noted.

Present study findings are largely consistent with the hypothesis that boys and girls do not show differences on measures of processing speed. On MRT and OPPOSITE no differences between girls and boys were noted. Girls and boys within each subtype of AD/HD appeared to have similarly compromised difficulties with processing speed and both AD/HD subtypes were found to be slower than control children. On the dependent measure SAME, scores for girls were faster than those of boys. Mean scores for boys across groups were lowered by the considerably slower time of AD/HD - PI boys. No previous work has identified AD/HD – PI boys as being particularly slow in comparison to other AD/HD groups. Thus it is possible that this finding is unique to the present study sample.

The second hypothesis predicted gender differences in the visual spatial domain. Consistent with previous findings, girls were found to perform more poorly on Benton's Line Orientation (BLO) (Garcia-Sanchez et al., 1997). It is possible that certain tests of visual spatial skills that have been useful in discriminating between AD/HD subtype groups may be gender sensitive. Overall, girls categorized as AD/HD – C appeared to be the most impaired on this measure while control boys received the highest score. Visual spatial tasks have been found to rely on right hemispheric functioning in particular (Kolb & Whishaw, 1996). The results of poorer visual spatial performance in AD/HD girls is supported by positron emission tomographic study revealing lower right hemisphere cerebral metabolic rate in a small sample of girls (Ernst et al., 1994). The present finding that girls, regardless of the presence or absence of AD/HD, may have weaker visual spatial skills than boys suggests that gender specific abilities may contribute to task performance and should be considered when gender representation in sample groups is reported. For instance, in studies utilizing the common practice of mixed but unequal gender representation across groups, a control group containing more girls than are represented in the other experimental groups could mask deficits in AD/HD functioning by rendering the overall score of the control group lower than it would be with equal gender ratios across groups.

Strengths and Limitations of the Findings

Sampling Parameters

Four parameters of the present sample are somewhat unique in the published literature on AD/HD. First, the sample used in the study is a non-referred sample and offers a contrast to studies utilizing clinical samples. Second, the inclusion of nearly equal numbers of girls and boys is in contrast to the predominantly male literature on AD/HD. Third, a sizable sample of AD/HD – PI children is included, making subtype comparisons viable. Fourth, attention to medication status of participants, renders a clearer understanding of neuropsychological functioning in AD/HD children when they are not on medication.

The non-referred nature of the sample renders results applicable to children managing within the normal school population. For example, it appears that AD/HD children in normal classrooms may have equal trouble inhibiting their responses despite well-recognized behavioral differences between the subtypes.

Unique to the sample was the finding that IQ scores across the sample were somewhat higher than expected. Children in the study sample, while not significantly different across groups, showed somewhat elevated IQ scores when compared to the norm. At least three factors may have contributed to the heightened scores either singularly or in an additive fashion. First, the demand characteristics of the study attracted parents interested in contributing to research and willing to invest their time to this end. It is possible that the study cohort may represent a brighter or more educated parent /child sample than found in typical clinical settings. Second, if Canadian norms were applied to the sample group, IQ scores would be reduced on average by approximately three to four points, thus bringing the sample group closer to the expected norm (Wechsler, 1996). Given that a Canadian short form WISC - III extrapolation is not available, American norms were utilized, possibly rendering somewhat inflated scores. Third, since children with an IQ of below 80 were not included in the study, the slightly elevated average IQ of the sample could be a function of the study design that placed no restrictions on elevated IQs while imposing an artificial floor not found in the population as a whole. It is possible that the study sample is representative of the intellectual ability of children in normal school classrooms.

Similarity in IQ scores across AD/HD and control groups is consistent with a literature review of potential subtype differences where the combined findings across inattentive, hyperactive, and control children revealed no significant differences in IQ (Goodyear & Hynd, 1992). Findings of similarity in IQ scores for boys and girls are in contrast to reported findings from a meta-analysis of clinic-referred children where girls were found to have lower IQ scores than boys (Gaub & Carlson, 1997b). The present findings are likely to generalize to both boys and girls from a non-referred population.

A condition of the present study was that children be medication free at the time of testing. A previous study that set out to report on gender differences in neuropsychological functioning failed to control for medication status, rendering the results difficult to interpret (Seidman et al., 1997). Understanding how different groups of AD/HD children perform without the aid of medication is of importance for guiding educational and clinical intervention. For example, while AD/HD – PI children may appear less impaired and behave in a less disrupting manner they may be equally challenged by the demands of a normal classroom that call for attention to content and context.

Methodological Issues

The findings reported for this study must be viewed in light of inherent methodological limitations. Diagnostic categorization, the scope of neuropsychological measures used, and the sample of AD/HD children that participated: each presents unique limitations.

Following participant screening using the SAC and BASC report forms, results of structured interviews with parents, usually the mother, were used as the criteria for diagnostic categorization. Confirmation of impairment at home and school was gained via parent report. Ideally, diagnostic categorization would employ a multi-method *and* multi-informant strategy. The inclusion of teacher information was deemed impractical at the time of data collection, given that city teachers were involved in a collective bargaining that prohibited their involvement in educational activities other than direct teaching. "Work to rule" directives mandated that teachers complete only essential educational activities.

Shortcomings regarding standardized teacher input were partly mitigated by the informal input of both classroom and special education teachers in the rural setting. Educational personnel were instrumental in the identification of children thought to be at risk for attentional problems, as well as children who were thought to be satisfactory control participants. Thus, while parent input was used for the group placement of children, for more than two thirds of the participants, teachers had identified the problematic nature (or lack thereof) of the child's school presentation.

Given that the study involved the voluntary participation of AD/HD children and their parents, it was deemed essential to keep the testing time to within one and one-half-hours per participant. The inclusion of neuropsychological measures for each domain of functioning was thus limited by the time constraints deemed reasonable for young children and by the balancing of measures requiring longer time periods for completion. Parents and children did not receive ongoing clinical attention and were not directly advantaged by their participation. As such, a second testing session was deemed neither practical nor ethical.

The AD/HD children whose results were analyzed in the present study did not include all three subtype groups as had been originally proposed for the study. The small number of AD/HD – HI children in the sample meant that the unique characteristics of this subtype could not be addressed in the discussion of subtype differences. While regrettable, the small number of hyperactive/impulsive children identified may have been a natural consequence of the age range of participants. Studies wishing to include the AD/HD – HI subtype may need to extend the age range to include younger children.

Directions for Further Research

An important finding from this study suggested that both AD/HD – PI and AD/HD – C children share what is currently regarded as the core deficit in AD/HD: that is, both groups appeared equally impaired on the Stop Task, which is widely regarded as a precise measure of response inhibition. It is important to note, however, that the measure employed in this study represents an altered version of the task that originally showed differences in performance between children with AD/HD, normal controls and children with other disorders. Validation of this revised task, comparing the performance of AD/HD children and controls, is necessary before the present findings can be fully appreciated. Specificity of the present version of the Stop Task also needs to be determined. Findings of a meta-analysis published after the inception of the present study call into question the specificity of the earlier version of the Stop Task (Oosterlan, Logan, & Sergeant, 1998), thus making data regarding the present version of the task essential.

The revised task has been found to differentiate impulsive from non-impulsive young adults, but information on the exact nature of response patterns for children with AD/HD and other disorders needs to be gathered. The revised Stop Task is essentially the same as the original task with only minor alterations in task demands and would therefore be expected to produce findings similar to the original task.

Mixed findings on the two tasks (SSRT and WALKSC), that were included to tap inhibition, suggest that further research is needed to illuminate where inhibition fits in the scheme of information processing activities. It is possible that AD/HD children can overtly inhibit on some tasks but still show altered processing mechanisms when compared to normal children.

Following the very recent findings of Brandeis et al. (1998) using event related potentials (ERPs), future work in determining the core deficit of AD/HD may move away from the concept of response inhibition as the core of the disorder, and instead focus on orienting mechanisms as the precursors of response inhibition. An investigation of a sequence of neuroelectric microstates revealed that, on the stop task, children with AD/HD (defined as subclinical) and control children showed similar overall inhibition but distinct patterns of responding to the stop signal. The timing of the divergent responses was too early to reflect actual stop signal processing. Children with AD/HD showed stop failures preceded by failures to orient to the cued stimulus coinciding with increased frontal lobe activation but decreased parietal activation. Control children did not show a similar problem with orienting to the cued stimulus. Both groups showed increased frontal activity with the presentation of the cued stimulus, but the control group did not show decreased parietal activation. As suggested by Brandeis and his colleagues, it is possible that processes related to an early automatically induced form of orienting, linked to a posterior attention system, might hold an important key for understanding AD/HD. The orienting of attention is considered as a precursor to the executive functioning of inhibition. The utilization of a variety of inhibiting tasks may add understanding to the analysis of mechanisms involved in orienting versus inhibition. To date, AD/HD sample groups used for these investigations have been small, male and hyperactive. Including adequate subtype and gender representation in such investigations would be an important design characteristic in delineating the scope and nature of the disorder.

Findings regarding poorer visual spatial skill in AD/HD – C children on Benton's Line Orientation are contrary to previous findings of poorer performance for a predominantly male adolescent AD/HD – PI sample. In considering the age and gender differences between these two samples, further research using gender-balanced samples may clarify developmental trajectories for visual spatial skills in AD/HD children. The finding that SSMCSC, requiring a visual search for space ships, did not load on the function that separated AD/HD and control children but had a significant structure coefficient, suggests that more work is needed to identify how this measure might contribute to understanding AD/HD. Given that AD/HD children were seen to perform more poorly on SSMCSC than control children, it is possible for instance that placement in a different group of dependent variables would render this measure useful in discriminating AD/HD and control children.

While the present findings suggest that some of the vast information that is available regarding the combined subtype may apply to the inattentive subtype, many questions remain unanswered. For instance, if both subtypes share a similar core deficit, why is response to stimulant medication not more similar across subtypes? One avenue for addressing this question requires careful attention to patterns of comorbidity within and between subtypes. For instance, it may be that the presence or absence of other comorbid conditions such as anxiety, create a more variable response to stimulants than the presence or absence of hyperactivity. Studies of stimulant response that utilize research designs incorporating sizable subtype groups in concert with a focus on patterns of comorbidity will help to untangle this question.

Clinical and Educational Implications

Inhibition tasks such as WALKSC, which render AD/HD children and control children indistinguishable, may hold an important key for understanding contextual factors that may help to produce adaptive functioning in AD/HD children. Observation revealed that the Walk Don't Walk test appeared to engage the children with novel and humorous, tape recorded sounds that piqued their curiosity. The progressively increasing speed of the task created continually changing task demands. In addition, children were able to keep an easily understood visual record of their progress using brightly colored pens. Factors such as variation in voice tone, humor, novelty, color, or ongoing feedback may give children with attentional problems enough advantage to allow them to normalize their responses. If strategies for developing adaptive patterns through contextual adjustments can be discovered, AD/HD children may be encouraged to greater success in educational and interpersonal settings. Thus, instead of looking for significant differences in task performance, researchers may inform clinical and educational practice by altering the contextual factors in a search for conditions that normalize the functioning of AD/HD children. If employed with young children, the application of strategies to improve home and school adaptation may in turn improve self-efficacy and effect long term outcomes.

In addition to contextual adjustments that may normalize functioning, there may also be characteristics of AD/HD children that can be enlisted to enhance development. To date, research has understandably focused on describing and quantifying the deficit. A further field of investigation, which would be of interest to the clinical and educational community, would employ methods for determining how strengths (individual or subtype) may be recognized and utilized to affirm the child and enlist the child's participation in normalizing their own behavior.

If the core issue separating the subtypes is not response inhibition, attention must be given to the investigation of other underlying deficits that may separate the subtypes. Results from OPPOSITE and SAME, showing slower processing speed for AD/HD – PI children, are intriguing and if replicated, may offer clues for the direction of a more fine grained analysis of processing tasks with the potential for revealing subtype differences. For example, present findings suggest that the inattentive type may have more trouble with speeded naming tasks when conflicting material is embedded in the task. To determine if this finding is an artifact of the present study or representative of a unique processing difficulty for AD/HD – PI, other studies employing speeded and conflicted response options will be useful.

As a result of the finding that AD/HD - PI children were more impaired on a speeded naming task (SAME), and appeared to approach the task in a manner quite different from in AD/HD-C children, further work aimed at breaking down the elements of speeded naming tasks may shed light on the potentially different factors that lead to impaired performance in both groups. For instance, it may be that inattentive children are slower at producing each response and are not able to finish as quickly because of lack of sustained focus, and that AD/HD – C children start out faster and are able to maintain the pace throughout. Different strategies for task completion may underlie overt behavior. AD/HD – PI children may work slowly but consistently while AD/HD – C children may work erratically with but sill finish in a more timely fashion. Data on subtype differences regarding how tasks are approached and completed could be extremely helpful for informing classroom strategies that would facilitate academic success for children with AD/HD in its various forms. It is possible that AD/HD – C children may need contingencies that keep them focused on the task while AD/HD – PI children may need reduced task volume and rewards for completion.

Concluding Remarks

The present results showed a similar inhibitory deficit between inattentive and combined AD/HD children. If replicated, this difference may alert clinicians and researchers towards a new awareness of the inattentive subtype of the disorder.

Overactive children have long been regarded as impulsive children. The present results indicated that inattentive children might also be regarded as characterized by a kind of covert impulsivity whereby they are equally impaired in providing an inhibitory response to situational demands. These findings call into question the theory that the inattentive subtype is not a legitimate expression of AD/HD.

The "holy trinity" of AD/HD, namely attention, hyperactivity, and impulsivity, may represent a still unfolding concept of essential unity. The three aspects of the disorder may together, or separately, account for the "AD/HDness" of a given child, with unique symptomatology subsumed under either inattention, hyperactivity or impulsivity. Historically, scientific focus has given each aspect of the disorder preeminence. The variety of clinical presentations continues to call the scientific community to either find clear reason to separate the subtypes into different disorders, or alternatively, to look for a rational explanation regarding unity. The present findings support the idea that AD/HD in its various subtypes is a unified disorder.

Another explanation for the present findings is that some underlying mechanism may be driving the impairment of inhibitory control in both subtypes of the disorder. Inhibition, regarded as an aspect of higher order or executive function, may have important links to underlying areas of functioning that may better explain the deficit. An underlying deficit may provide a more parsimonious explanation for the variation in phenotypic expression. Whether an underlying mechanism can be identified or not, at the very least, these results support the DSM-IV inclusion of AD/HD - PI as a legitimate expression of the disorder.

At least part of the discussion regarding the inattentive subtype in AD/HD must focus on the familiar difficulty of recognizing internalizing versus externalizing disorders in childhood. Typically, research on subtyping has concluded that hyperactive children who are more active and more at risk for conduct problems represent a more serious and pervasive manifestation of the disorder (Barkley et al., 1991). It is important for professionals who work with children to think carefully about this claim. Deciding that one disorder or one subtype is more "serious" than another may be a naïve and value-laden conclusion, inappropriate in both child and adult psychopathology.

The present social and economic climate is such that many children with psychopathology still go untreated. In the battle that ensues for the existing limited resources, less visible difficulties can translate into "clinical blindness" for children with significant attention problems but without hyperactivity. It may be argued that psychologists are ethically bound to use their substantial knowledge base and research skills to relieve human suffering *especially* when it has gone largely unrecognized.

Hyperactive children are hard to miss and given the information explosion regarding AD/HD, they are the ones most likely to receive treatment. Inattentive children appear to be equally, although not identically, impaired and as such provide a challenge to the clinical and research community. Anomalies often move science forward (Kuhn, 1970). It is possible that the inattentive subtype may provide the anomalous presentation of the disorder that will open up avenues for building a clearer picture of the disorder as a whole.

FOOTNOTES

1. DSM –IV Symptoms of AD/HD

Inattention

(a) often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities

(b) often has difficulty sustaining attention in tasks or play activities

(c) often does not seem to listen when spoken to directly

(d) often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions)

(e) often has difficulty organizing tasks and activities

(f) often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or home work)

(g) often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)

(h) is often forgetful in daily activities

Hyperactivity/impulsivity

Hyperactivity

(a) often fidgets with hands or feet or squirms in seat

(b) often leaves seat in classroom or in other situations in which remaining seated is expected

(c) often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)

(d) often had difficulty playing or engaging in leisure activities quietly

(e) is often "on the go" or often acts as if "driven by a motor"

(f) often talks excessively

Impulsivity

(g) often blurts out answers before questions have been completed

(h) often has difficulty awaiting turn

(i) often interrupts or intrudes on others (e.g., butts into conversations or games)

2.Changes to DSM conceptualization of AD/HD

DSM-III listed three symptom cluster or dimensions as characteristic of the disorder, including five symptoms of inattention, five symptoms of impulsivity, and four symptoms of hyperactivity were listed. Children with at least three symptoms of both inattention and impulsivity, in addition to two symptoms of hyperactivity were given the diagnosis of ADD/H. If only inattention and impulsivity were present, children were given the diagnosis of "Attention Deficit Disorder without Hyperactivity" (ADD/WO).

DSM-III-R reconceptualized the disorder as comprising a single dimension incorporating 14 symptoms of inattention, impulsivity, and hyperactivity. It is interesting to note that the symptom list comprised four of the symptoms of inattention from DSM-III plus an additional symptom making a total of 5 symptoms of inattention. Three of DSM-III symptoms of impulsivity were retained and another two were added making a total of five. Two symptoms of hyperactivity were retained from DSM-III and two more were added making a total of four. Children were required to have any combination of at least 8 of the symptoms listed, and were given the diagnosis of AD/HD. Given the constellation of symptoms listed, it was possible for children with symptoms of inattention and impulsivity (but without hyperactivity) to be diagnosed as AD/HD. A new category was created for children with only symptoms of inattention and labeled undifferentiated ADD (UADD). This diagnostic category had no previous parallel but foreshadowed one possible presentation of AD/HD –PI in DSM-IV.

Thus children diagnosed as ADD/WO during DSM-III could not be considered synonymous with children diagnosed as UADD, who, by definition, did not exhibit impulsivity. It is likely that children who would have been diagnosed as ADD/WO using DSM-III criteria were absorbed into the DSM-III-R category of AD/HD.

DSM-IV reinstated a conceptualization of the disorder that was closer to the pattern of DSM-III, designating symptoms of inattention, hyperactivity, and impulsivity. However, DSM-IV differs from DSM-III by combining the 6 symptoms of hyperactivity and the three symptoms of impulsivity into a single dimension of hyperactivity-impulsivity. According to DSM-IV, children with at least 6 symptoms of inattention and not more than five symptoms of hyperactivity-impulsivity can be diagnosed as AD/HD PI. Children categorized as AD/HD-PI could thus mirror either ADD/WO, having symptoms of inattention and some symptoms of impulsivity (DSM-III), or UADD having only symptoms of inattention (DSM-III-R), or AD/HD having a combination of inattention and impulsivity (DSM-III-R).

3. Summary of Eigenvalues for Descriptive Discriminant Functions

Discriminant Function for AD/HD Group

Function	Eigenvalue	Percent of Variance	Cumulative Percent	Canonical Correlation
1	.259	56.9	56.9	.453
2	.196	43.1	100.0	.404

Discriminant Function for Gender

Function	Eigenvalue	Percent of Variance	Cumulative Percent	Canonical Correlation
1	.167	100.0	100.0	.378

REFERENCES

Achenbach, T. M. (1991). Manual for the Child Behavior Checklist/4-18 and 1991 profile. Burlington: University of Vermont Department of Psychiatry.

Achenbach, T. M., McConaughty, S. H., & Howell, C. T. (1987). Child/adolescent behavioral and emotional problems: Implications of cross-informant correlations for situational specificity. Psychological Bulletin, 101, 213-232.

Ackerman, P. T., Anhalt, J. M., Holcomb, p. J., & Dykman, R. (1986). Presumable innate and acquired automatic processes in children with attention and /or reading disorders. Journal of Child Psychology and Psychiatry, 27, 513-529.

American Psychiatric Association. (1968). Diagnostic and statistical manual of mental disorders. (2nd ed.). Washington DC: Author.

American Psychiatric Association. (1980). Diagnostic and statistical manual of mental disorders. (3rd ed.). Washington DC: Author.

American Psychiatric Association. (1987). Diagnostic and statistical manual of mental disorders. (Rev. 3rd ed.). Washington DC: Author.

American Psychiatric Association. (1994). Diagnostic and statistical manual of mental disorders. (4th ed.). Washington DC: Author.

Anderson, J. C., Williams, S., & McGee, R. (1987). DSM-III disorders in preadolescent children: Prevalence in a large sample from the general population. Archives of General Psychiatry, 44, 69-76.

Arnold, L. E. (1996). Sex differences in ADHD: Conference summary. Journal of Abnormal Child Psychology, 24, 555-569.

Barkley, R. A. (1990). Attention deficit disorder: A handbook for diagnosis and treatment. New York: Guilford Press.

Barkley, R. A. (1991). The ecological validity of laboratory and analogue assessment methods of ADHD symptoms. Journal of Abnormal Child Psychology, 19, 149-178.

Barkley, R. A. (1994a). Can neuropsychological tests help diagnosis ADD/AD/HD. ADHD Report, 2(February), 1-3.

Barkley, R. A. (1994b). Can neuropsychological tests help diagnosis ADD/AD/HD. ADHD Report, 2(February), 1-3.

Barkley, R. A. (1996). Linkages between attention and executive function. In G. R. Lyon & N. A. Krasnegor (Eds.), Attention, Memory and Executive Function (pp. 307-326). Baltimore: Paul H Brookes Publishing Company.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention and executive functions: Constructing a unifying theory of ADHD. Psychological Bulletin, 121, 65-94.

Barkley, R. A. (1998). Attention - deficit hyperactivity disorder. (2nd ed.). New York: Guilford Press.

Barkley, R. A., DuPaul, G. J., & McMurray, M. B. (1990). Comprehensive evaluation of attention deficit disorder with and without hyperactivity as defined by research criteria. Journal of Consulting and Clinical Psychology, 58, 775-789.

Barkley, R. A., DuPaul, G. J., & McMurray, M. B. (1991). Attention deficit disorder with and without hyperactivity: Clinical response to three dose levels of methylphenidate. Pediatrics, 87, 519 - 531.

Barkley, R. A., Grodzinsky, G., & DuPaul, G. (1992). Frontal lobe functions in attention deficit disorder with and without hyperactivity: A review and research report. Journal of Abnormal Child Psychology, 20, 163-188.

Bauermeister, J. J., Bird, H. R., Canino, G., Rubio-Stipec, M., Bravo, M., & Alegria, M. (1995). Dimensions of attention deficit hyperactivity disorder: Findings from teacher and parent reports in a community sample. Journal of Clinical Child Psychology, 24, 264-271.

Baumgaertel, A., Wolraich, M., & Dietrich, M. (1995). Comparison of diagnostic criteria for attention deficit disorders in German elementary school sample. Journal of the American Academy of child and Adolescent Psychiatry, 34, 629-638.

Becker, M. G., Issac, W., & Hynd, G. W. (1987). Neuropsychological development of nonverbal behaviors attributed to "frontal lobe" functioning. Developmental Neuropsychology, 3, 275-298.

Benbow, C.P., & Benbow, R.M. (1984). Biological correlates of high mathematical reasoning ability. In G.J. De vries et al. (Eds.), Progress in Brain Research (pp.469-491). Amsterdam: Elsevier Science Publishers.

Benton, A. L., Sivan, A. B., Hamsher, K. d., Varney, N. R., & Spreen, O. (1994). Judgment of line orientation, Contributions to neurological assessment (2nd ed., pp. 53-63). New York: Oxford University Press.

Berry, C. A., Shaywitz, S. E., & Shaywitz, B. A. (1985). Girls with attention deficit disorder: A silent minority? A report on behavioral and cognitive characteristics. Pediatrics, 76, 801-809.

Biederman, J., Farone, S. V., Milberger, S., & Doyle, A. (1993). Diagnosis of attention-deficit hyperactivity disorder from parent reports predict diagnosis based on teacher report. Journal of the American Academy of Child and Adolescent Psychiatry, 32, 315-317.

Biederman, J., Farone, S. V., Wilens, T., Mick, E., & Lapey, K. A. (1994). Gender differences in a sample of adults with attention deficit disorder. Psychiatry Research, 53, 13-29.

Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety and other disorders. American Journal of Psychiatry, 148, 564-577.

Boucugnani, L. L., & Jones, R. W. (1989). Behaviors analogous to frontal lobe dysfunction in children with attention deficit hyperactivity disorder. Archives of Clinical Neuropsychology, 4, 161-173.

Brandeis, D., Leeuwen, T. H. v., Rubia, K., Vitacco, D., Steger, J., Pascual-Marqui, R. D., & Steinhausen, H.-C. (1998). Neuroelectric mapping reveals precursor of stop failures in children with attention deficits. Behavioural Brain Research, 94, 111-125.

Carlson, C. L., Lahey, B. B., Frame, C. L., Walker, J., & Hynd, G. W. (1987). Sociometric status of clinic-referred children with attention deficit disorders with and without hyperactivity. Journal of Abnormal child Psychology, 15, 537-547.

Carlson, C. L., Lahey, B. B., & Neeper, R. (1986). Direct assessment of the cognitive correlates of attention deficit disorders with and without hyperactivity. Journal of Psychopathology and Behavioral Assessment, 8, 69-86.

Carte, E., Nigg, J. T., & Hinshaw, S. P. (1996). Neuropsychological functioning, motor speed and language processing in boys with and without ADHD. Journal of Abnormal Child Psychology, 24, 481 - 498.

Casey, B. J., Castellanos, X., Giedd, J., Marsh, W., Hamburger, S., Schubert, A., Vauss, Y., Vaituzis, A. C., Dickstein, D., Sarfatti, S., & Rapoport, J. L. (1997). Implications of right frontostriatal circuitry in response inhibition and attention-deficit/hyperactivity disorder. Journal of the American Academy of Child and Adolescent Psychiatry, 36, 374-383.

Castelllanos, F. X., Giedd, J. N., Eckburg, B. S., Marsh, B. A., Vaituzis, C. A., Kaysen, C. A., Hamburger, S. D., & Rapoport, J. L. (1994). Quantitative morphology of the caudate nucleus in attention deficit hyperactivity disorder. American Journal of Psychiatry, 12, 1791-1796.

Chelune, G. J., Ferguson, W., Koon, R., & Dickey, T. O. (1986). Frontal lobe disinhibition in attention deficit disorder. Child Psychiatry and Human Development, 16, 221-234.

Conte, R., Kinsbourne, M., Swanson, J., Zirk, H., & Samuels, M. (1986). Presentation rate effects on paired associate learning by attention deficit disordered children. Child Development, 57, 681-687.

Copeland, E. D. (1991). Medication for attention disorders (ADHD/ADD) and related medical problems. Atlanta: SPI Press.

Denckla, M. B. (1996). Biological correlates of learning and attention: What is relevant to learning disability and attention-deficit hyperactivity disorder? Developmental and Behavioral Pediatrics, 17, 114-119.

Dykman, R. A., & Ackerman, P. T. (1991). Attention deficit disorder and specific reading disability: Separate but often overlapping disorders. Journal of Learning Disabilities, 96-103.

Dykman, R. A., Ackerman, P. T., & McCray, D. S. (1980). Effects of methylphenidate on selective and sustained attention in hyperactive, reading disabled, and presumably attention-disordered boys. Journal of Nervous and Mental Disease, 168.

Edelbrock, C., Costello, A. J., & Kessler, M. D. (1984). Empirical corroboration of attention deficit disorder. American Academy of Child Psychiatry, 23, 285-290.

Eiraldi, R. B., Power, T. J., & Nezu, C. M. (1997). Patterns of comorbidity associated with subtypes of attention-deficit/hyperactivity disorder among 6- to 12- year-old children. Journal of the American Academy of Child and Adolescent Psychiatry, 36, 503-514.

Ernst, M., Liebenauer, L., King, A. C., Fitzgerald, G. A., Cohen, R., & Zametkin, A. J. (1994). Reduced brain metabolism in hyperactive girls. Journal of the American Academy of Child and Adolescent Psychiatry, 33, 858-870.

Faraone, S. V., Beiderman, J., Weber, W., & Russell, R. L. (1998). Psychiatric, neuropsychological, and psychosocial features of DSM-IV subtypes of attention-deficit/hyperactivity disorder: Results from a clinically referred sample. Journal of the American Academy of Child and Adolescent Psychiatry, 37, 185-193.

Faraone, S. V., Biederman, J., Lehman, N. K., Keenan, K., Norman, D., Seidman, L., Kolodny, R., Kraus, I., Perrin, J., & Chen, W. J. (1993b). Evidence for the independent familial transmission of attention deficit hyperactivity disorder and learning disabilities: Results form a family genetic study. American Journal of Psychiatry, 150, 891-638.

Faraone, S. V., Biederman, J., Lehman, N. K., Keenan, K., Norman, D., Seidman, L., Kolodny, R., Kraus, I., Perrin, J., & Chen, W. J. (1993a). Evidence for the independent familial transmission of attention deficit hyperactivity disorder and learning disabilities: Results form a family genetic study. American Journal of Psychiatry, 150, 891-638.

Fisher, M., Barkley, R. A., Edelbrock, C. S., & Smallish, L. (1990.). The adolescent outcome of hyperactive children diagnosed by research criteria: II. Academic, attentional, and neuropsychological status. Journal of Consulting and Clinical Psychology, 58, 580-588.

Frank, Y., & Ben-Nun, Y. (1988). Toward a clinical subgrouping of hyperactive and nonhyperactive attention deficit disorder. American Journal of Diseases of Children, 142, 153-155.

Garcia-Sanchez, C., Estevez-Gonzalez, A., Emulia-Romero, E., & Junque, C. (1997). Right hemisphere dysfunction in subjects with attention-deficit disorder with and without hyperactivity. Journal of Child Neurology, 12, 107-115.

Gaub, M., & Carlson, C. L. (1997a). Behavioral characteristics of DSM-IV ADHD subtypes in a school-based population. Journal of Abnormal Child Psychology, 25, 103-111.

Gaub, M., & Carlson, C. L. (1997b). Gender differences in AD/HD: A meta-analysis and critical review. Journal of the American Academy of Child and Adolescent Psychiatry, 36, 1036 - 1045.

Goodyear, P., & Hynd, G. W. (1992). Attention-deficit disorder with (ADD/H) and without (ADD/Wo) hyperactivity: Behavioral and neuropsychological differentiation. Journal of Clinical and Child Psychology, 21, 273-305.

Gordon, M. (1996). Must ADHD be an equal opportunity disorder? The ADHD report, 4, 1-3.

Gorenstein, E. E., Mammato, C. A., & Sandy, J. M. (1989). Performance of inattentive-overactive children on selected measures of prefrontal-type function. Journal of Clinical Psychology, 45, 619-632.

Grodzinsky, G. M., & Diamond, R. (1992). Frontal lobe functioning in boys with attention-deficit hyperactivity disorder. Developmental Neuropsychology, 8, 427-445.

Harris, L. J. (1978). Sex differences in spatial ability: Possible environmental genetic and neurological factors. In M. Kinsbourne (Ed.), Asymmetrical functions of the brain . Cambridge: Cambridge University Press.

Heilman, K. M., Voeller, K. S. K., & Nadeau, S. E. (1991). A possible pathophysiologic substrate of attention deficit hyperactivity disorder. Journal of Child Neurology, 6, S76-S80.

Holcomb, P. J., Ackerman, P., & Dykman, R. A. (1986). Auditory event-related potentials in attention and reading disabled boys. International Journal of Psychophysiology, 3, 263-273.

Huberty, C. J. (1994). Applied Discriminant Analysis. New York: John Wiley & Sons, Inc.

Hynd, G. W., Lorys, A. R., Semrud-Clikeman, M., Nieves, N., Huettner, M. I. S., & Lahey, B. B. (1991). Attention deficit disorder without hyperactivity: A distinct behavioral and neurocognitive syndrome. Journal of Child Neurology, 6, (Suppl.) S37-S43.

Hynd, G. W., Nieves, N., Connor, R. T., Stone, P. A., Town, P., Becker, M. G., Lahey, B. B., & Lorys, A. R. (1989). Attention deficit disorder with and without hyperactivity: Reaction time and speed of cognitive processing. Journal of Learning Disabilities, 22, 573-580.

Hynd, G. W., Semrud-Clikeman, M., Lorys, A. R., Novey, E. S., & Eliopulos, D. (1990). Brain morphology in developmental dyslexia and attention deficit disorder/hyperactivity. Archives of Neurology, 47, 919-926.

Kaplan, B. J., Humphreys, R., Crawford, S., & Fisher, G. (1997, June 11-14). Sensitivity and specificity of a short interview for AD/HD. Paper presented at the Canadian Psychological Association Annual Convention, Toronto, Ontario.

Kertesz, A., Nicholson, I., & Cancelliere, A. (1985). Motor impersistence: A right hemispheric syndrome. Neurology, 35, 662-666.

King, C., & Young, R. D. (1982). Attention deficits with and without hyperactivity: Teacher and peer perceptions. Journal of Abnormal Child Psychology. 10, 4-83-496.

Kolb, B., & Whishaw, I. Q. (1996). Fundamentals of human neuropsychology. (4th ed.). New York: Freeman and Company.

Korkman, M., & Pesonen, A. E. (1994). A comparison of neuropsychological test profiles of children with attention deficit-hyperactivity disorder and /or learning disorder. Journal of Learning Disabilities, 27, 383-392.

Kuhn, T. S. (1970). The structure of scientific revolution. (2nd ed.). Chicago: Chicago Press.

Lahey, B. B., Applegate, B., McBurnett, K., Biederman, J., Greenhill, L., Hynd, G. W., Barkley, R. A., Newcorn, J., Jensen, P., Richters, J., Garfinkel, B., Kerdyk, L., Frick, P. J., Ollendick, T., Perez, D., Hart, E., Waldman, I., & Shaffer, D. (1994). DSM-IV field trials for attention deficit hyperactivity disorder in children and adolescents. American Journal of Psychiatry, 151, 1673-1685.

Lahey, B. B., & Carlson, C. L. (1991). Validity of the diagnostic category of attention deficit disorder without hyperactivity: A review of the literature. Journal of Learning Disabilities, 24, 110-120.

Lahey, B. B., Pelham, W. E., Shaughency, E. A., Atkins, M. S., Murphy, H. A., Hynd, G. W., Russo, M., Hartagen, S., & Lorys-Vernon, A. (1988). Dimensions and types of attention deficit disorder. Journal of the American Academy of Child and Adolescent Psychiatry, 27, 330-335.

Lahey, B. B., Pelham, W. E., Stein, M. A., Loney, J., Trapani, C., Nugent, K., Kipp, H., Schmidt, E., Lee, S., Cale, M., Gold, E., Hartung, C., Willcutt, E., & Baumann, B. (1998). Validity of DSM-IV attention-deficit/hyperactivity disorder for young children. Journal of the American Academy of Adolescent Psychiatry, 37, 695-702.

Lahey, B. B., Schaughency, E. A., Frame, C. L., & Strauss, C. C. (1985). Teacher ratings of attention problems in children experimentally classified as exhibiting attention deficit disorders with and without hyperactivity. Journal of the American Academy of Child and Adolescent Psychiatry, 24, 613-616.

Lahey, B. B., Schaughency, E. A., Strauss, C., & Frame, C. L. (1984). Are attention deficit disorder with and without hyperactivity similar or dissimilar disorders? Journal of the American Academy of Child Psychiatry, 23, 302-309.

Lahey, B. B., Schaughency, W. A., Hynd, G. W., Carlson, C. L., & Nieves, N. (1987). Attention deficit disorder with and without hyperactivity: Comparison of behavioral characteristics of clinic referred children. Journal of the American Academy of Child and Adolescent Psychiatry, 26, 718-723.

Lezak, M. D. (1983). Neuropsychological assessment. (2nd ed.). New York: Oxford University Press.

Lezak, M. D. (1995). Neuropsychological Assessment. (3rd ed.). New York: Oxford University Press.

Loeber, R., Green, S. M., & Lahey, B. B. (1990). Mental health professionals' perception of the utility of children, mothers and teachers as informants on childhood psychopathology. Journal of Clinical Child Psychopathology, 19, 136-143.

Logan, G. D. (1994). On the ability to inhibit thought and action: A user's guide to the stop signal paradigm. In D. Dagenbach & T. H. Carr (Eds.), Inhibitory processes in attention, memory and language (pp. 189-239). San Diego: Academic Press.

Logan, G. D., Cowan, W. B., & Davis, K. A. (1984). On the ability to inhibit simple and choice reaction time responses: A model and a method. Journal of Experimental Psychology, 10, 276-291.

Logan, G. D., Schachar, R. J., & Tannock, R. (1997). Impulsivity and inhibitory control. Psychological Science, 8, 60-64.

Lorys, A. R., Hynd, G. W., & Lahey, B. B. (1990). Do neurocognitive measures differentiate attention deficit disorder (ADD) with and without hyperactivity? Archives of Clinical Neuropsychology, 5, 119-135.

Lou, H. C., Henriksen, L., & Bruhn, P. (1984). Focal cerebral hypoperfusion in children with dysphasia and/or attention deficit disorder. Archives of Neurology, 41, 825-829.

Luria, A. R. (1959). Experimental study of the higher nervous activity of the abnormal child. Journal of Mental Deficiency Research, 4, 1-22.

Luria, A. R. (1966). Higher cortical functions in man. New York: Basic Books.

Manly, T. (1998). Test of Everyday Attention for Children : (Available from the Medical Research Council, Box 58 Addenbrooke's Hospital, Hills Road, Cambridge CB2 2QQ).

Matochick, J. A., Liebenauer, L. L., King, C. A., Szumanski, H. V., Cohen, R. M., & Zametkin, A. J. (1994a). Corpus callosum morphology in attention deficit hyperactivity disorder: Morphometric analysis of MRI. Journal of Learning Disabilities, 24, 142-146.

Matochick, J. A., Liebenauer, L. L., King, C. A., Szymanski, H. V., Cohen, R. M., & Zametkin, A. J. (1994b). Cerebral glucose metabolism in adults with attention deficit hyperactivity disorder after chronic stimulation treatment. American Journal of Psychiatry, 151, 658-664.

Mattes, A. J. (1980). The role of frontal lobe dysfunction in childhood hyperkenesis. Comprehensive Psychiatry, 17, 358-369.

Mazaux, J. M., Daritgues, J. F., Letenneur, L., Darriet, D., Wiart, L., Gagnon, M., Commenges, D., & Boller, F. (1995). Visuo-spatial attention and psychomotor performance in elderly community residents: Effects of age, gender, and education. Journal of Clinical and Experimental Neuropsychology, 17, 71-81.

McGee, R., & Feehan, M. (1991). Are girls with problems of attention underrecognized? Journal of Psychopathology and Behavioral Assessment, 13, 187-197.

Morgan, A. E., Hynd, G. W., Riccio, C. A., & Hall, J. (1996). Validity of DSM-IV ADHD predominantly inattentive and combined types: Relationship to previous DSM diagnosis/subtype differences. Journal of the American Academy of Child and Adolescent Psychiatry, 35, 325-333.

Nezu, A. M., & Nezu, C. M. (1993). Identifying and selecting target problems for clinical interventions: A problem solving model. Psychological Assessment, 5, 254-263.

Offord, D. R., Boyle, M. H., Szatmari, P., Rae-Grant, N., Links, P., Cadman, D. T., Byles, J. A., Crawford, J. N., Blum, H. M., Byrne, C., Thomas, H., & Woodward, C.

(1987). Ontario health study II. A six month prevalence of disorder and rates of service utilization. Archives of General Psychiatry, 44, 832-835.

Oosterlan, J., Logan, G. D., & Sergeant, J. A. (1998). Response inhibition in AD/HD, CD Comorbid AD/HD + CD, Anxious, and Control Children: A meta-analysis of studies with the Stop Task. Journal of Child Psychology and Psychiatry, 39, 411- 425.

Passler, M. A., Isaac, W., & Hynd, G. W. (1985). Neuropsychological development of behavior attributed to frontal lobe functioning in children. Developmental Neuropsychology, 1, 349-370.

Pennington, B. P., & Ozonoff, S. (1996). Executive function and developmental psychopathology. Journal of Child Psychology and Psychiatry, 37, 51-87.

Phares, V. (1997). Accuracy of informants: Do parents think that mother knows best? Journal of Abnormal Child Psychology, 25, 165-171.

Quay, H. C. (1997). Inhibition and attention deficit hyperactivity disorder. Journal of Abnormal Child Psychology, 25, 7-13.

Reich, W. R., Welner, Z., & Herjanic, B. (1997). Diagnostic Interview for Children and Adolescents-IV. North Tonawanda NY: Multi Health Systems Inc.

Reynold, C. R., & Kamphaus, R. W. (1992). Behavior assessment system for children: Manual. Circle Pines: American Guidance Service.

Reynolds, C. R., & Kamphaus, R. W. (1992). Behavioral Assessment System for Children manual. Circle Pines MN: American Guidance Service.

Roberstson, I., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1996). The structure of normal human attention: The Test of Everyday Attention. Journal of International Neuropsychological Society, 2, 525-534.

Robins, S. (1992). A comparison of behavioral and attentional functioning in children diagnosed as hyperactive or learning-disabled. Journal of Abnormal Child Psychology, 20, 65-82.

Rubenstein, R. A., & Brown, R. T. (1984). An evaluation of the validity of the diagnostic category of attention deficit disorder. American Journal of Orthopsychiatry, 54, 398-414.

Safer, D. J., & Krager, J. M. (1988). A survey of medication treatment for hyperactive/inattentive students. Journal of the American Medical Association, 260, 2256-2258.

Sandoval, J., & Echandia, A. (1994). Behavior assessment system for children. Journal of School Psychology, 32, 419-425.

Sattler, J. M. (1992). Assessment of Children. (3rd ed.). San Diego: Jerome M. Sattler.

Schachar, R. (1991). Childhood hyperactivity. Journal of Child and Adolescent Psychiatry, 32, 155-191.

Schachar, R., & Logan, G. (1990a). Are hyperactive children deficient in attentional capacity. Journal of Abnormal Child Psychology, 18, 493-513.

Schachar, R., & Logan, G. (1990b). Impulsivity and inhibitory control in normal development and childhood psychopathology. Developmental Psychology, 26, 710-720.

Schachar, R., & Tannock, R. (1995). Test of four hypotheses for the comorbidity of attention-deficit hyperactivity disorder and conduct disorder. Journal of the American Academy of Child and Adolescent Psychiatry, 34, 639-648.

Schachar, R., Tannock, R., & Logan, G. (1993). Inhibitory control, impulsiveness, and attention deficit hyperactivity disorder. Clinical Psychology Review, 13, 721-739.

Schachar, R., Tannock, R., Marriot, M., & Logan, G. (1995a). Deficient inhibitory control in attention deficit hyperactivity disorder. Journal of Abnormal Child Psychology, 23, 411-437.

Schachar, R., Tannock, R., Marriott, M., & Logan, G. (1995b). Deficient inhibitory control in attention deficit hyperactivity disorder. Journal of Abnormal Child Psychology, 23, 411-437.

Schaughency, E. A., Lahey, B. B., Hynd, G. W., Stone, P. A., & Piacnetini, J. C. (1990). Neuropsychological test performance and ADD's: Clinical utility of the Luria-Nebraska Neuropsychological Battery-Children's Revision. Journal of Consulting and Clinical Psychology, 57, 112-116.

Seidman, L. J., Benedict, K. B., Biederman, J., Bernstein, J. H., Seiverd, K., Milberger, S., Norman, D., Mick, E., & Faraone, S. V. (1995). Performance of children with ADHD on the Rey-Osterrieth Complex Figure: A pilot neuropsychological study. Journal of Child Psychology and Psychiatry, 36(1459-1473).

Seidman, L. J., Biederman, J., Farone, S. V., Weber, W., Mennin, D., & Jones, J. (1997). A pilot study of neuropsychological function in girls with ADHD. Journal of the American Academy of Child and Adolescent Psychiatry, 36, 366-373.

Sergeant, J., & Scholten, C. A. (1985). On resource strategy limitations in hyperactivity: Cognitive impulsivity reconsidered. Journal of Child Psychology and Psychiatry, 26, 97-109.

Sergeant, J. A., & Sholten, C. A. (1985). On data limitations in hyperactivity. Journal of Child Psychology and Psychiatry, 26, 111-124.

Shaywitz, S. E., & Shaywitz, B. A. (1987). Attention deficit disorder: Current perspectives. Pediatric Neurology, 3, 129-135.

Sherman, D. K., Iacono, W. G., & Mcgue, M. (1997). Attention-deficit hyperactivity disorder dimensions: A Twin study of inattention and impulsivity-hyperactivity. Journal of the American Academy of Child and Adolescent Psychiatry, 36, 745-753.

Shue, S. L., & Douglas, V. I. (1992). Attention deficit disorder and the frontal lobe syndrome. Brain and Cognition, 20, 104-124.

Silverthorn, P., Frick, P. J., Kuper, K., & Ott, J. (1996). Attention deficit hyperactivity disorder and sex: A test of two etiological models to explain the male predominance. Journal of Clinical Child Psychology, 25, 52-59.

Sonuga-Barke, E. J. S., Houlberg, K., & Hall, M. (1994). When is "impulsiveness" not "impulsive"? The case of hyperactive children's cognitive style. Journal of Child Psychology and Psychiatry, 35, 1247-1253.

Sonuga-Barke, E. J. S., Taylor, E., & Heptinstall, E. (1992). Hyperactivity and delay aversion - II. The effect of self versus externally imposed stimulus presentation periods on memory. Journal of Child Psychology and Psychiatry, 33, 399 - 409.

Sonuga-Barke, E. J. S., Williams, E., Hall, M., & Saxton, T. (1996). Hyperactivity and delay aversion III: The effect on cognitive style of imposing delay after errors. Journal of Child Psychology and Psychiatry, 37, 189-194.

Stanford, L. D., & Hynd, G. W. (1994). Congruence of behavioral symptomatology in children with ADD/H, ADD/WO and learning disabilities. Journal of Learning Disabilities, 27, 243-253.

Stuss, D. T., & Benson, D. F. (1986). The frontal lobes. New York: Raven Press.

Szatmari, P., Offord, D. R., & Boyle, M. H. (1989). Ontario child health study: Prevalence of attention deficit disorder with hyperactivity. Journal of Child Psychology and Psychiatry, 30, 2i9-230.

Szatmari, P., Offord, D. R., Siegal, L. S., Finlayson, M. A. J., & Tuff, L. (1990). The clinical significance of neurocognitive impairments among children and psychiatric disorders: Diagnosis and situational specificity. Journal of Child Psychology and Psychiatry, 31, 287-299.

Tabachnick, B. A., & Fidell, L. S. (1996). Using multivariate statistics. (3rd ed.). New York: Harper Collins College Press.

Tannock, R. (1998). Attention deficit hyperactivity disorder: Advances in cognitive, neurobiological and genetic research. Journal of Child Psychology and Psychiatry, 39, 65-99.

Trommer, B., Hoeppner, J. B., & Zecker, S. G. (1991). The Go-No Go test in attention deficit disorder is sensitive to methylphenidate. Journal of Child Neurology, 6, S128-S131.

Trommer, B. L., Hoeppner, J. B., Lorber, R., & Armstrong, K. L. (1988). The Go-No-Go Test in attention deficit disorder. Annals of Neurology, 24, 610-614.

Van der Meere, J., Shalev, R., Borger, N., & Gross-Tsur, V. (1995). Sustained attention, activation and MPH in ADHD: A research note. Journal of Child Psychology and Psychiatry, 36, 697-703.

Voeller, K. K. S., & Heilman, K. M. (1988). Attention deficit disorder in children: A neglect syndrome? Neurology, 38, 806-808.

Wechsler, D. (1991). Manual for the Wechsler Intelligence Scale for Children - Third Edition. San Antonio: Psychological Corporation.

Wechsler, D. (1996). Wechsler Intelligence Scale for Children - Third Edition: Manuel Canadian Supplement. Toronto: Harcourt Brace and Company.

Weyandt, L. L., & Willis, G. W. (1994). Executive functions in school-aged children: Potential efficacy of tasks in discrimination of clinical groups. Developmental Neuropsychology, 19, 17-38.

Williams, B. R., Ponesse, J. S., Schachar, R. J., Logan, G. D., & Tannock, R. (1998). Development of inhibitory control across the life span. Developmental Psychology, 35, 205-213.

Wolraich, M. L., Hannah, J. N., Pinnock, T. Y., Baumgaertel, A., & Brown, J. (1996). Comparison of diagnostic criteria for attention deficit hyperactivity disorder in a country-wide sample. Journal of the American Academy of Child and Adolescent Psychiatry, 35, 391-324.

Zametkin, A. J., Liebenauer, L. L., Fitzgerald, G. A., King, A. C., Minkunas, D. V., Herscovitch, P., Yamanda, E. M., & Cohen, R. (1993). Brain metabolism in teenagers with attention-deficit hyperactivity disorder. Archives of General Psychiatry, 50, 333-340.

Zametkin, A. J., Nordahl, T. E., Gross, M., King, A. C., Semple, W. E., Rumsey, J., Hamburger, S., & Cohen, R. (1990). Cerebral glucose metabolism in adults with hyperactivity of childhood onset. The New England Journal of Medicine, 323, 1361-1366.

Zametkin, A. J., & Rapoport, J. L. (1987). The neurobiology of attention deficit disorder: Where have we come in 50 years? Journal of the American Academy of Child and Adolescent Psychiatry, 26, 678-696.

APPENDIX A

Participant Recruitment Advertising Brochure

Impulsivity and Attention Deficit Disorder

A study approved by:

The University of Calgary and

Alberta Children's Hospital

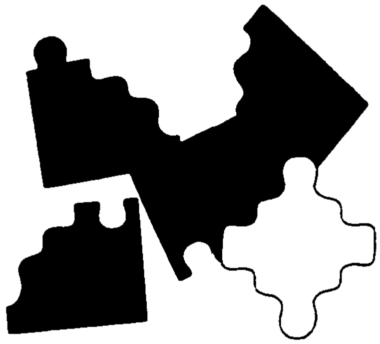
Are girls with attentional problems different from boys?

Are inattentive children different from hyperactive children in terms of the impulsivity they show?

These are some of the questions to which we are seeking answers.

Can you help us?

We are looking for children - especially girls - with attentional problems. Very rarely has AD/HD research focused on girls. We want to help break the silence regarding girls and AD/HD.
We are also looking for both boys and girls who have ADD (without hyperactivity). This is another group who have been largely overlooked in previous research.
We will also be including children who are hyperactive and children with no attentional problems to help us build a comparison.



Putting the Puzzle Together

We already know a lot about AD/HD, but we are not sure about the exact nature of the underlying difficulties. We are still putting the puzzle together. It is important to know about the underlying difficulties because it may improve the accuracy of diagnosis and help in developing more effective treatment for these problems.

We believe that one of the main underlying difficulties in children with attention and behavior problems is their **inability to stop and plan before acting**. In this study we will be investigating how children stop, search, and manage timed activities.

Your child may be eligible for the study because you suspect, or your child's teacher, doctor, or school psychologist suspects, that your child has problems in attention or behavior. Your child may also be eligible for the study because you are fairly sure your child does **not** have any of these problems.

If you have a child between the ages of 7 and 13 and would like to be involved in helping us find answers to these important questions, please call us at 220 - 5568 and leave your name on our voice mail, or come and see us at the CH.A.D.D. Fair.

We are at the Alberta Children's Hospital Display if you 'd like to talk to us or leave your name for us to call you.

Dr. Bonnie Kaplan	Phyllis Prout, M.A.
Research Supervisor	Principal Investigator

I'd like to hear more about your study and consider being involved.
Parent's Name:____
Child's name_____________________________ Child's Age________
Phone:_________________________

APPENDIX B

Symptom AD/HD Checklist

Subject Name ______ Date of Birth ______ ID Number ______

Person Interviewed ______ Interviewer ______ Date ______

ATTENTION DEFICIT DISORDER CHECKLIST

Consider these characteristics as having persisted over time:	Not at all 0	Just a little 1	Pretty much 2	Very much 3
1. Difficulty sitting still for long periods of time; "on the go"				
2. Feelings of restlessness; fidgety				
3. Feels unsatisfied; complains of boredom; seeks stimulation or novelty				
4. Difficulty sustaining attention; shifts activities or topics in conversation; does multiple activities at same time; mind wanders				
5. Difficulty following verbal directions; does not seem to be listening when spoken to; needs reminders				
6. Easily distracted by sounds or sights				
7. Making too quick judgements or decisions; (safety concerns as child)				
8. Poor self-monitoring; fails to give attention to important details; careless mistakes				
9. Difficulty waiting turn; impatient; easily frustrated				
10. Blurts out; makes irrelevant comments or talks off topic; difficulty playing quietly; interrupts				
11. Difficulty sustaining relationships/keeping friends				
12. Problems making friends				
13. Sits quietly and daydreams				
14. Hard to get started on tasks or avoids tasks requiring sustained mental effort (e.g., chores, homework); procrastinates				
15. Difficulty completing tasks				
16. Loses or misplaces things; does not return things to usual place				

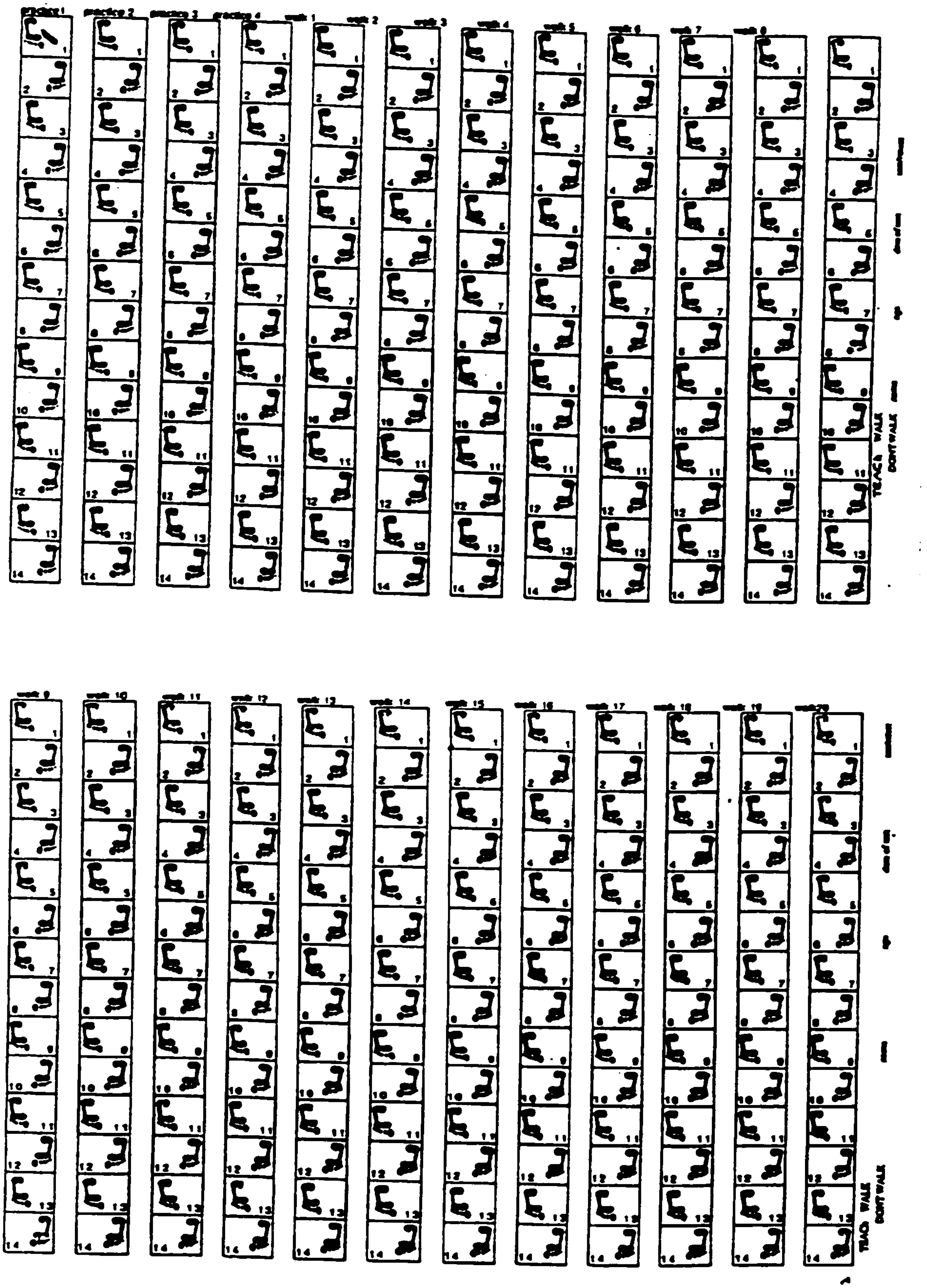
Consider these characteristics as having persisted over time:	Not at all 0	Just a little 1	Pretty much 2	Very Much 3
18. Resistant to change; intense/rigid thinking				
19. Mood swings; irritability, over-reacts emotionally				
20. Sense of underachievement or not meeting one's goals, low self-esteem				
21. Inconsistent academic performance				
22. Refuses to do things; argumentative				
23. Quick at finding fault; blames others				
24. Gets into trouble; fights				
25. Steals, tells lies, problems with law				

—Kaplan & Humphreys, October 1995

Adapted for research purposes from DSM IV, Achenbach Child Behavior Checklist, Wender's Utah Rating Scale for ADHD Adults, the ADHD Rating Scale by George DuPaul, Barkley's Interview Form and Rating Scales for ADHD Adults, Levine's Anser Forms, and the DISC (Diagnostic Interview Schedules for Children) modules on Attention, Conduct Disorders, and Oppositional/Defiant Disorders.

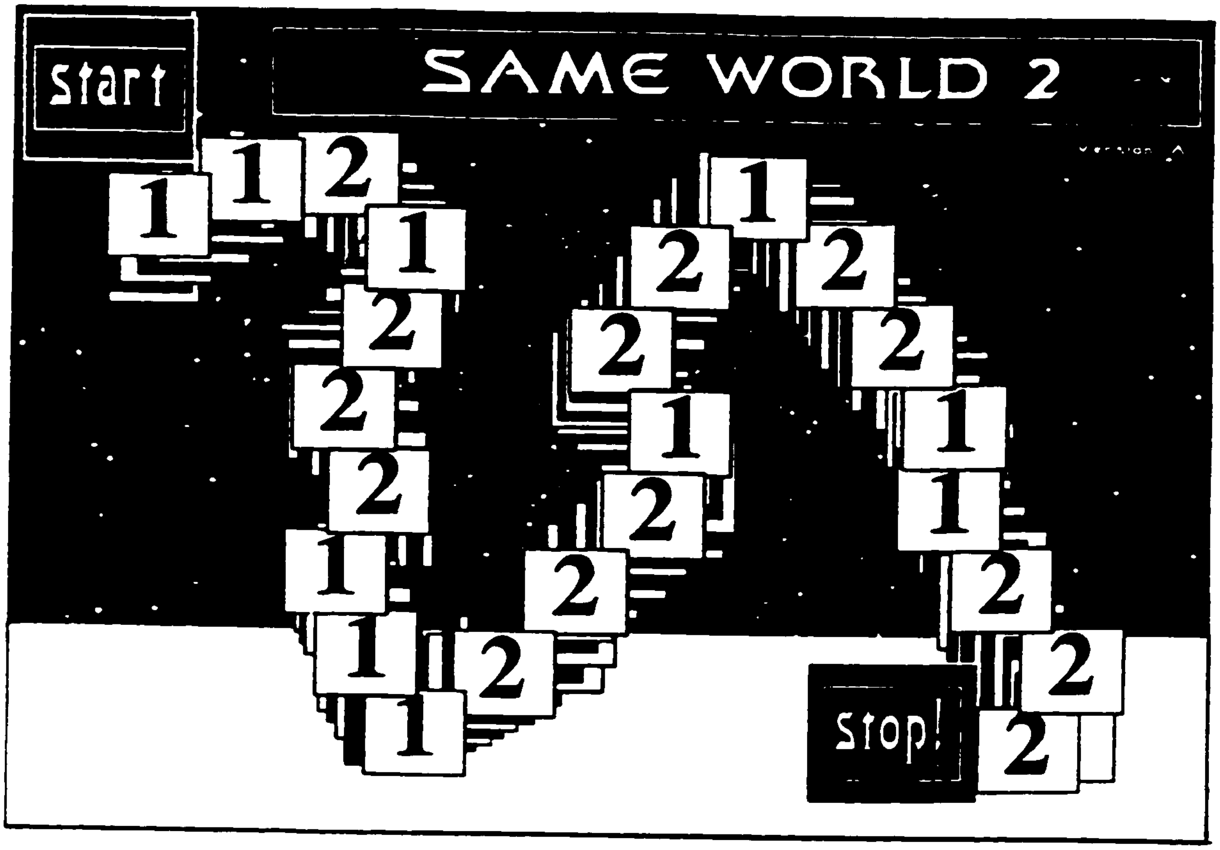
APPENDIX C

Walk Don't Walk Sample



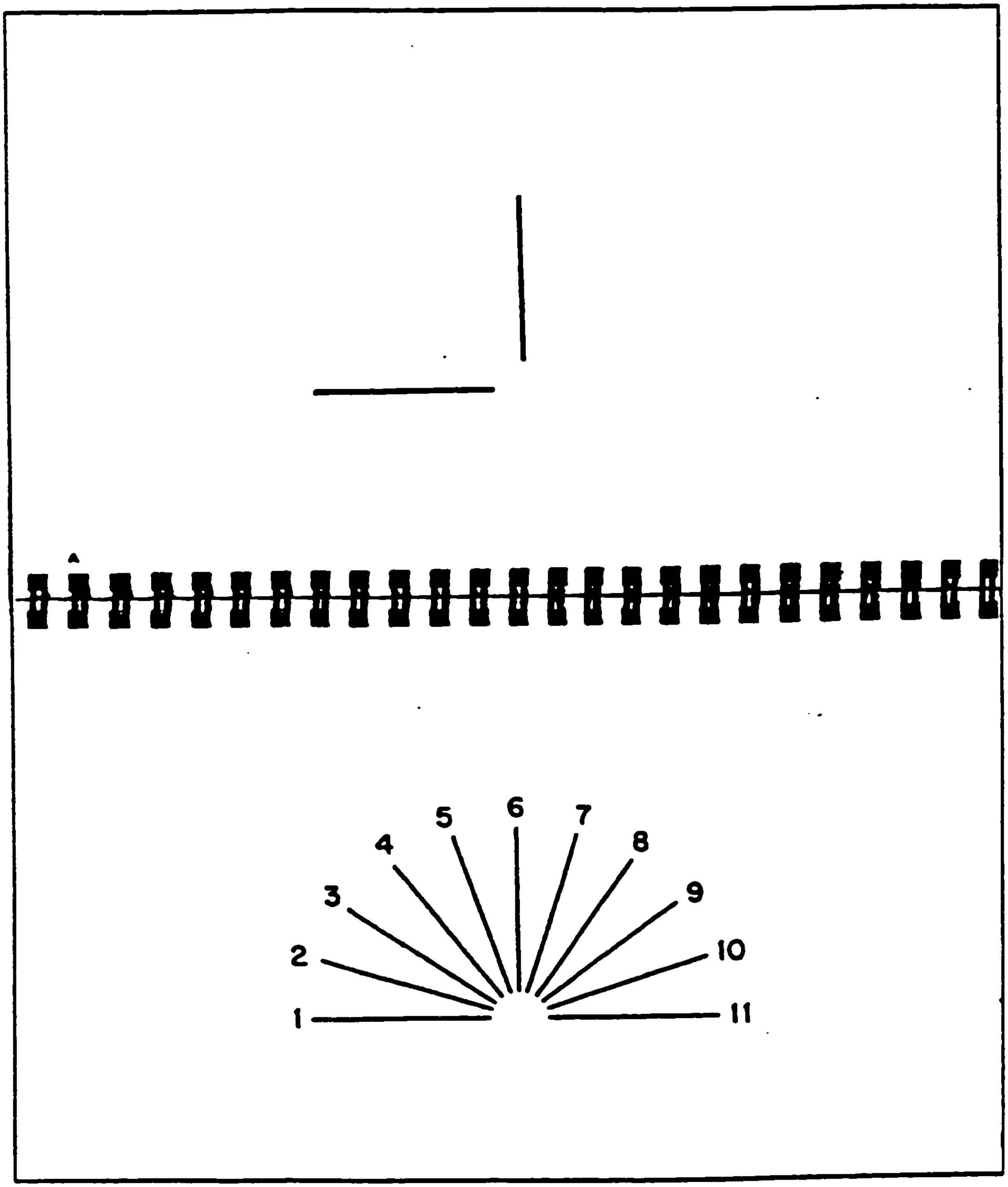
APPENDIX D

Opposite Worlds / Same Worlds Sample



APPENDIX E

Benton's Line Orientation Sample



APPENDIX F

Environmental Rating Scale

TESTING ENVIRONMENT RATING SCALE

DEGREE TO WHICH ENVIRONMENT IS PROBLEMATIC				
	Very	**Somewhat**	**Slightly**	**Not**
Visual Distractions				
Auditory Distraction				
Lighting Quality				
Air Quality				

VERY PROBLEMATIC: This issue was a seriously disruptive problem during the testing and is likely to have impacted test results

SOMEWHAT PROBLEMATIC: This issue caused a problem at more than one point during the testing, and may have impacted the score of one or more test

SLIGHTLY PROBLEMATIC: This issue caused a problem at one point during the testing, but test results are unlikely to be affected by it

NOT PROBLEMATIC: This issue caused no interruption or impediment to testing

NATURE OF THE PROBLEM:

APPENDIX G

Study Consent Form

Consent Form

Title of Research Project: Subtype and Gender Differences in AD/HD: An Investigation of Three Neuropsychological Variables

Investigator: Phyllis Prout, M.A. & Bonnie Kaplan, Ph.D.

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

PURPOSE OF THE RESEARCH: We are trying to understand girls and boys who have problems in attention, impulsivity and hyperactivity. We already know a lot about these problems, but we are not sure about the exact nature of the underlying difficulties. This is important to know, because it may improve the accuracy of diagnosis and help in developing more effective treatment for these problems.

We believe that one of the main underlying difficulties in children with attention and behavior problems is in stopping and planning before acting. In this study we will be investigating how children stop, search and manage timed activities.

Your child may be eligible for the study because you suspect, or your child's teacher, doctor, or school psychologist suspeçts that your child has problems in attention, or behavior. Your child may also be eligible for the study because you are fairly sure your child does not have any of these problems. It is important to compare children with attentional problems to children who do not have these problems so that we can understand how these two groups of children are different.

DESCRIPTION OF THE RESEARCH: We want to determine whether your child does have problems in attention, hyperactivity or impulsivity. We will do this in two stages. First we will ask you a few simple questions about your child's behavior. These screening questions can be asked over the telephone. If your child is eligible, we will then ask you to fill in a short questionnaire that will take about ten minutes to complete. The questionnaire asks about your child's development and behavior. If your child has been tested by a registered psychologist within the last year we will ask your permission to obtain the results, otherwise we will measure your child's verbal and spatial abilities. This can be done at your house if necessary. This testing will tell us if your child is still eligible for the study. If s/he is still eligible, we will go on to the next part of the study.

For the second stage, we need to see you and your child for about one and a half hours. The first and second stages can be done during one appointment if you prefer. We will make an appointment for you to bring your child at a time that is convenient for you, or the testing can be done in your home if that is easier for you. During this visit, you and your child will meet with the researcher, Phyllis Prout. If your child is being treated with medication, such as Ritalin, for his/her attention problems, we ask you to stop your child's medicine at least 24 hours before coming. As you know, it will not harm your child to stop taking Ritalin for this short period of time.

You will spend approximately one and a half hours with the researcher who will show you how to answer some computerized questions about your child's history, current problems and how your child gets on at home, with friends, and at school. During this time, we will ask your child to do several different tasks involving concentration and planning. Other tasks, presented in a game format will allow us to see how your child searches for visual information and how quickly s/he works.

When we have scored your child's work we will let you know if we think there is a problem of which you may not be aware. At the end of the study, when all the children have been tested, we will let you know what we were able to learn from this investigation.

POTENTIAL HARM: There are no known harms associated with the tasks we ask your child to do. Your child may find some tasks easy and others somewhat difficult. It is also possible that your child may become bored or tired doing the tasks. To reduce this possibility, we schedule frequent breaks and provide encouragement as the children work. Your child will be supervised throughout the activities by the researcher.

POTENTIAL BENIFITS: You and your child may benefit directly from participating in this study. You will be informed if specific attentional, behavioral, or other problems are suspected. The information may help you in understanding more about your child's abilities. You and your child will also have an opportunity to learn something about research.

In the future, findings from this study may assist mental health professionals in understanding more about children's problems in attention and over activity and thereby help develop more effective treatment for children with these problems.

CONFIDENTIALITY: The results of the tests described above will be used for research purposes and only in the context of this study. We will not disclose your child's name or any personal information in our research publications. We would require your permission and signed consent before sending any test scores to another professional involved in your child's care. We recommend that the results of these tests, if released, be interpreted only by a registered psychologist

PARTICIPATION: Participation is voluntary. You have the right not to participate in this study. Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project and agree to your child's participation in the research project. In no way does this waive your legal rights nor release the investigators from their legal and professional responsibilities. You are free to withdraw from the study at any time. Your continued participation should be as informed as you initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions, please contact

Dr. Bonnie Kaplan
Phone: 229 - 7365

If you have any questions concerning your rights as a possible participant in this research, please contact the Office of Medical Bioethics, Faculty of Medicine, The University of Calgary, at 220-7990.

_____________________	_____________________
(Name)	(Date)
_____________________	_____________________
(Parent signature)	(Date)
_____________________	_____________________
(Name of witness)	(Date)

A copy of this consent form will be given to you. Please keep it for your records and future reference.

The investigator has explained to your child the research and his or her involvement, and has sought his or her ongoing cooperation throughout the project.

____
(Investigator)

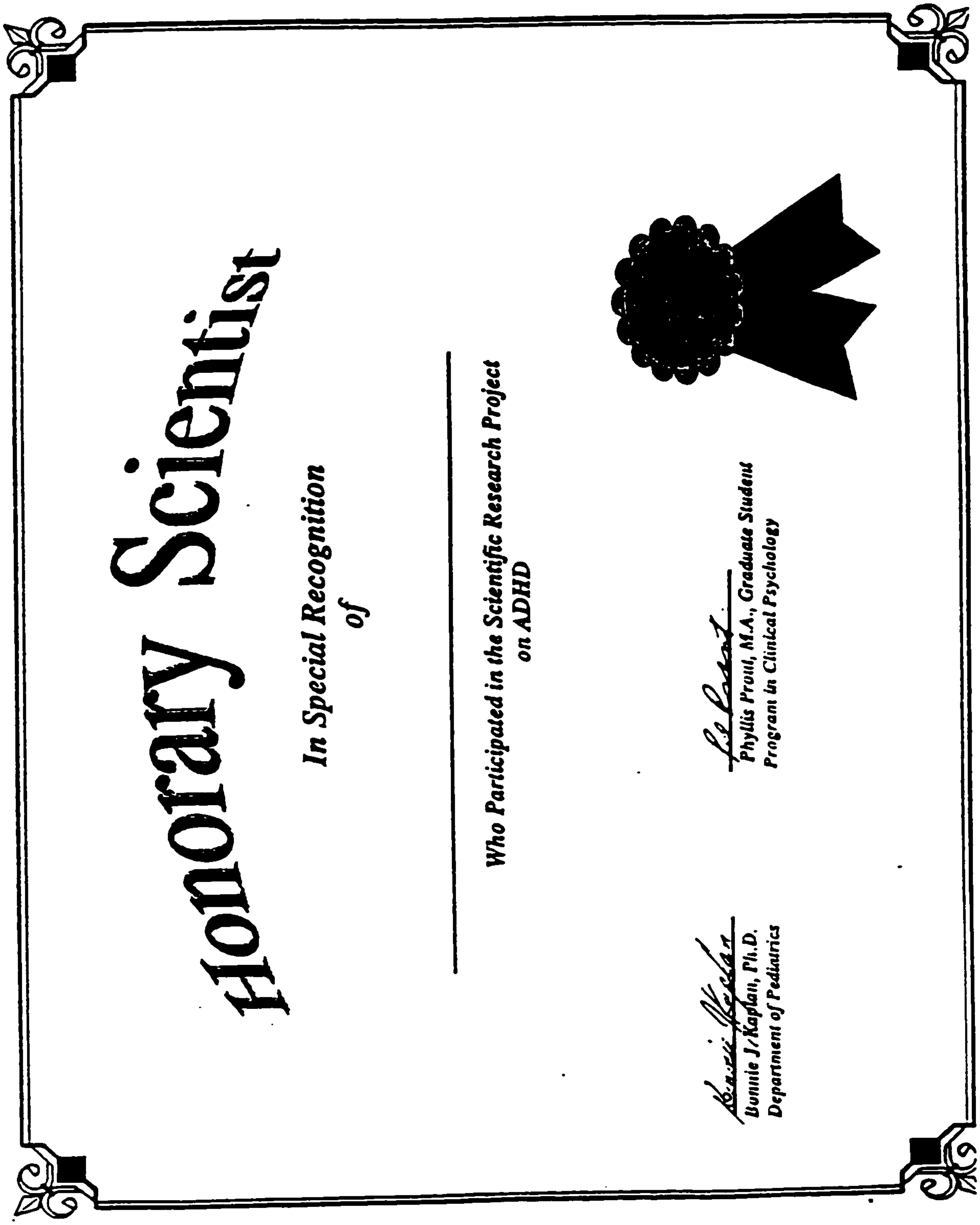
APPENDIX H

Task Cards

Stop
Lines
Walk, Don't Walk
Sky Search
Opposite Worlds

APPENDIX I

Honorary Scientist Award



Honorary Scientist

In Special Recognition

of

Who Participated in the Scientific Research Project

on ADHD

Bonnie J. Kaplan, Ph.D.

Department of Pediatrics

Phyllis Proud, M.A., Graduate Student

Program in Clinical Psychology

APPENDIX J

Standardized Instructions for the Stop Signal Task

Before Practice Phase I

- We are going to divide our time today into three parts – you will do two practices and then the actual job.
- This is your control box. This is the X button and this is the O button.
- Your job will be to watch this computer screen. At first you will see a dot. It is important to look at the dot because when it disappears, you will see a letter – either an X or an O.
- If the letter is an X, then press the X button on your control box, if the letter is an O, then press the O button on the box.
- As soon as you see the letter, push the button as quickly as you can.
- Use your thumbs to push the X and O buttons.
- Go as fast as you can without making mistakes
- Every once in while you will hear a beep.
- I want you to just ignore the beep.
- Are you ready for the first practice phase?

Before Practice Phase 2

- Your job for the second practice is the same as what you have been doing, except that when you hear the beep, I want you to try and stop yourself from pressing the button.
- You will see a letter on the screen, but don't press the button if you hear the beep.

- Sometimes the computer will make it impossible to stop, but sometimes it will be easy for you to stop.
- Just try to stop as often as you can
- The beep won't come too often, so remember to keep pressing the right button as fast as you can when the letters come on the screen.

- So if you see an X what should you do? If you see an X and hear a beep what should you do?
- That's right, and the same goes for the O.

- All right, we are going to start the second practice now.
- Do you have any questions before we start?

Before Test Phase

- All right, we are going to do the actual job now.
- This part is exactly the same as the second practice, except that it will be a lot longer, OK?
- OPTIONAL
- Before we get started, I want you to remember to...(give appropriate instructions to account for any strategy you notice the child using).
- Do you have any questions before we start the final part?

APPENDIX K

Standardized Instructions for Walk Don't Walk

Play the introduction to the test on the tape, stopping just before the first practice.

Show the child the WALK DON'T WALK sheet and say,

- *In this test you have to be very careful where you walk.*

Point to the steps on the path and say,

- *The first part of each path is safe to walk on, the second part isn't. The problem is we don't know where the safe part ends and the dangerous part begins. To be safe we need to listen carefully to the tape. It will play us one sound if the step is safe to walk on and another one when it is dangerous.*

Start the tape and play the examples of the two sounds. They say,

- *OK watch me do the first one so that you can see how to do it.*

Play the first practice example. After each of the tones make a firm mark on each step, lifting the pen off the sheet but by no more than a centimeter after each mark is made. Emphasize in the way that you are doing this that you are waiting until the end of each sound before being sure that you can make the mark. When you completed the first example stop the tape and say,

- *You see, I made this mark on each step – as if I was walking on it. I had to listen carefully to each sound to see whether I should step on each step or not. You have to mark after each sound and before you hear the next sound so that you keep up with the tape. If I had made any mark at all in that last square I would have got it wrong. Watch me the next one.*

Play the second example and perform the task. When you have completed it, hand the pen to the child and say,

- *Can you explain back to me what you have to do in this test?*

Correct any misunderstandings and emphasize the two key rules

1. That one sound means step and the other means don't step.
2. That the step must be taken between on sound and the beginning of the next.

- *You have a practice now. Remember, listen to the sounds carefully before you make each step so that you don't step on the dangerous part of the path. Remember any mark in the dangerous square means that you have walked on it!*

Play the next practice item on the tape and observe that the child is performing the task correctly – in particular that they are keeping up with the tones.

When you happy that the child has understood the task, move onto the items of the test. Just before the start say,

- *OK, lets go on to do the test. You get 20 goes. As we go on, you will notice that the tape gets faster and faster so it gets m ore difficult. People nearly always do step on the wrong square from time to time so don't worry if you do – just go on to the next one when the tape says.*

APPENDIX L

Standardized Instructions for Sky Search

Show the SKY SEARCH practice sheet to the child and say,

- *As you can see, these space ships always travel around in pairs. Your job is to find all the pairs where both ships are the same like these (indicate on the page) and ignore them when they are different (indicate on the page).*
- *In a moment I want you to use this pen to put a circle around all the same ship pairs that you can see on this page.*

Draw a circle rapidly around the first target pair on the sheet and say,

- *You need to do it as quickly as you can while trying not to miss any – so you don't need to be too neat. When you think that you have finished, put a tick in the box at the bottom here as quickly as you can so that I know how long it took you.*
- *Just to make sure I have explained it properly, could you tell me briefly what you have to do in this test?*

Correct any misunderstandings and then say,

- *OK, begin when I say "start". Remember to do it as quickly as you can while not missing any...Start.*

If the child has understood the task say,

- *Well done. Now lets se how well you can do exactly the same thing on the big sheet.*

Place the correct version of the big sheet in front of the child and say,

- *Like before, when I say "start" I want you to put a circle around all the pairs where the ships are both the same. Go as quickly as you can trying not to miss any.... OK ...start.*

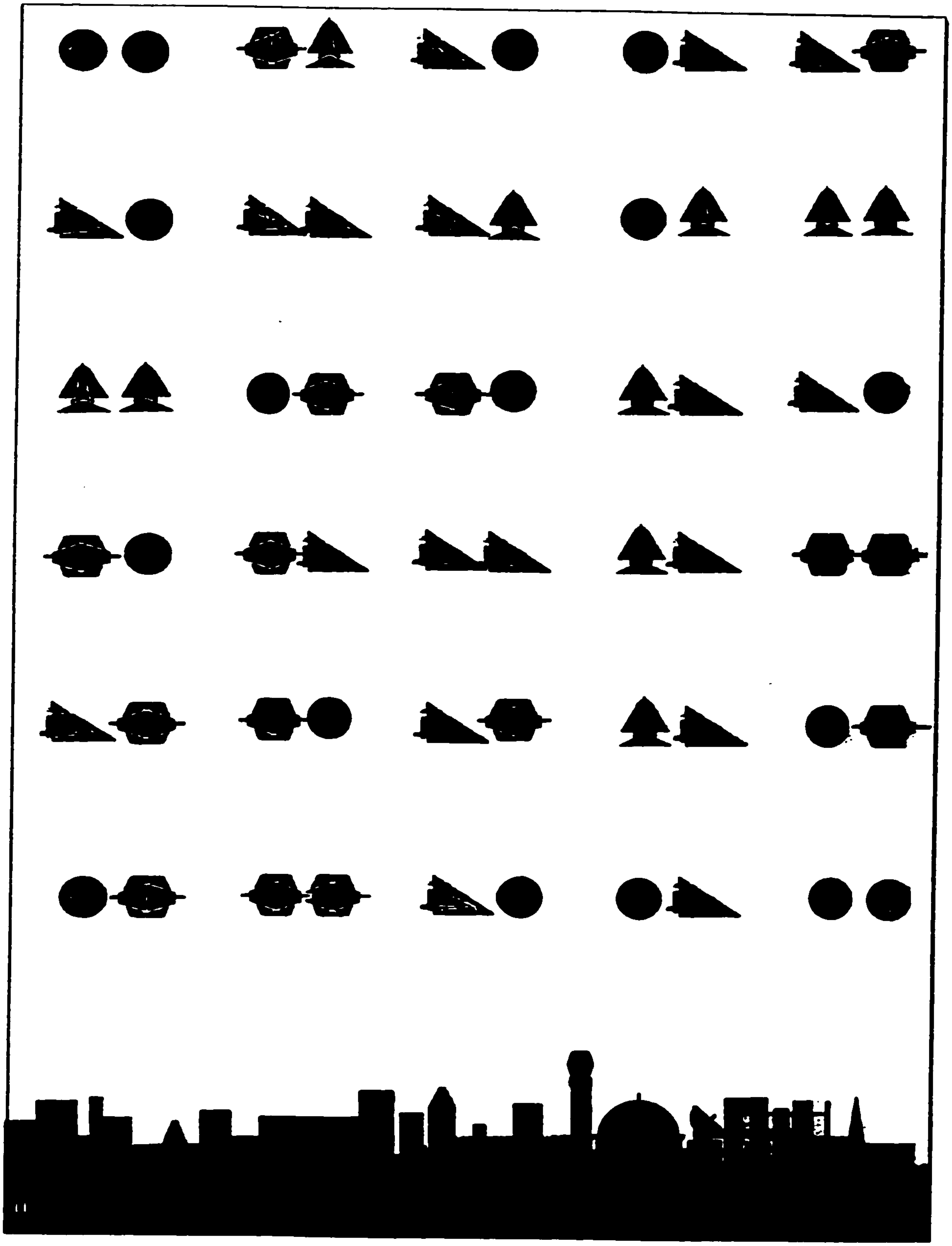
MOTOR CONTROL

Replace the previous sheet with the correct version of the motor control sheet and say,

- *It's even easier now because we only have the real space ships. When I say start I want you to put a circle around all the pairs that you can see. Go as quickly as you can while trying not to miss any. Make sure you tick the box when you have finished. OK? .....Start.*

APPENDIX M

Sky Search Sample



APPENDIX N

Standardized Instructions for Opposite Worlds

Show the child the first example of the OPPOSITE WORLDS test. Point to the number one and say,

- *Can you tell me what number this is?*

Then point to the number 2 and say

- *Can you tell me what number this is?*

If the child can identify both numbers say,

- *In this test there are two sorts of worlds. There is the Same World where everything is as you would say it here and the Opposite World, where you have to say the opposite of what you would say here.*

Point to the beginning of the first number in Same World sample sheet and say,

- *Here I would say "Start...one, one, two, two........Stop."*

Emphasize "stop" and "start" and say,

- *Now you try that one.*

Point to each square of the first practice item (including the Stop and Start) in turn. Do not move on to the next square until the child has said the correct word. Then point to the second item.

- *Now try this one.*

Again, you should point to each square in turn including the Start and Stop moving on a square only if the correct response is given. If the child gets it wrong, repeat what they need to do and demonstrate again if necessary.

Move on to the Opposite World first example. Point to the first one and say,

- *Now we're going to the Opposite Words where we have to say the opposite. Here, when we see a one we have to say "two" and when we see a two we have to say "one." This is how to do it. "Start....one, one, two, one, two......Stop."*

Point to each item as you do them. Ask the child to do the first example, remembering to point and not to move on until the correct response is given. Move onto the second Opposite World practice. When you are sure that the child has understood, say,

- *OK, we're going to Same World first. Remember, in the same world you have to tell me the numbers as they really are.*

Turn to the first Same World Card. Put you finger on "Start." Only move on from the number once the correct verbal response has been given. Then say,

- *Now we're going to Opposite World. Remember that you have to say the opposite. When you see a one say "two" and when you see a two, say "one." Are you ready?*
- *We're going to stay in Opposite Worlds for the next one. Are you ready?*

Choose the last card for Same World and say,

- *Now were going back to Same World. Remember that you say what you see. When you see a one, you say "one" and when you see a two you say "two." Are you ready?*