THE RELATIONSHIP AMONG ATTENTION DEFICIT HYPERACTIVITY DISORDER, LEARNING DISABILITY, AND CENTRAL AUDITORY PROCESSING DISORDER

by

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A thesis submitted in conformity with the requirements
for the degree of Master of Arts
Graduate Department of Education
University of Toronto

0-612-28715-7

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Master of Arts 1996
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Abstract

Confusion and controversy regarding the definitions of attention deficit hyperactivity disorder (ADHD), learning disability (LD), and central auditory processing disorder (CAPD) have persisted despite their frequent use in classifying children in educational settings. Differential diagnosis of CAPD appears to represent a particular concern among a variety of professions, including audiology, speech-language pathology, psychology, and education. This study was conducted to determine if several assessment procedures addressing a child's academic, cognitive, and behavioural status would discriminate children identified with an attention deficit disorder, a learning disability, or a combination of these two disorders. We also attempted to determine if these children could be differentiated on the basis of their performance on measures of central auditory processing abilities. The test battery included the SCAN (a screening test for auditory processing disorders), the Auditory Continuous Performance Test (ACPT), the Children's Auditory Performance Processing Scale (CHAPPS), the Conners Parent Questionnaire, the Wide Range Achievement Test (WRAT-3; Reading and Arithmetic subtests), the Listening Comprehension subtest of the Wechsler Individual Achievement Test, and three subtests of the Wechsler Intelligence Scale for Children - Third Edition. The results indicated that there is a significant, though not mutually inclusive relationship between ADHD and CAPD. Moreover, a proportion of children in all three groups (NA, LD, ADHD) demonstrated auditory processing difficulties. Although there were significant correlations among tests and groups, there was also much variability within each particular group. An interdisciplinary approach to the identification of auditory processing disorders in children with learning difficulties was emphasized.

Acknowledgements

Thank you, Dr. Linda Siegel, my supervisor, for your guidance and constructive comments throughout this research project. Thank you, Dr. Thomas Humphries, my second reader, for your support and clinical insight.

Thank you, Dr. Robert Keith, for your time, knowledge, and accessibility to all my questions. I hope we will meet in person sometime soon.

Thank you, all of the children and parents who participated in this study; as well as any individuals / clinics whose involvement was deeply appreciated in keeping this project moving along, including: dB Audiology, Hearing Health Care Consultant Group, and of course, Scott Lawson of Aim Instrumentation.

Thank you, John Trumpener, for your brilliant help with the statistical analyses.

Thank you, my family and friends, for your continuous support and encouragement; especially Elan, for your patience, generosity, and understanding.

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INTRODUCTION

There does not seem to be consensus regarding the operational definitions of attention deficit hyperactivity disorder (ADHD), learning disability (LD), and central auditory processing disorder (CAPD). Although the Diagnostic and Statistical Manual of the American Psychiatric Association (DSM-IV, 1994) provides definitions for ADHD and LD, there are a number of definitional issues within and between these areas (Barkley, 1990; Cantwell & Baker, 1991; Lahey & Carlson, 1991; McBurnett et al., 1993; Poplin, 1988; Wiener & Heath, 1990). There appears to be even more disagreement regarding the construct of central auditory processing disorders both within and among the fields of audiology, speech-language pathology, psychology, and education (Lasky & Katz, 1983; Sloan, 1991; Willeford & Burleigh, 1985). Although there is much controversy regarding the etiology of CAPD (Chermak & Musiek, 1992), descriptions of performance deficits associated with CAPD are abundant in the literature and have been documented in children with LDs and/or ADHDs. However, the approaches, emphases, and treatment protocols for CAPD have differed with different professional perspectives (Lasky & Katz, 1983). It does not seem surprising therefore that the relationship among ADHD, LD, and CAPD continues to be an issue of discussion.

The American Psychiatric Association presents the most generally accepted definition of ADHD based on current research and clinical practice (McKinney et al., 1991). The most recent version, DSM-IV (1994), describes the essential feature of Attention-Deficit Hyperactivity Disorder as "a persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequent and severe than is typically observed in individuals at a comparable level of development" (p. 78).

A definition of LD is illustrated by the Interagency Committee on Learning

Disabilities (ICLD) (1987) in the United States, as follows:

> Learning disabilities is a generic term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, reading, writing, reasoning, or mathematical abilities, or of social skills. These disorders are intrinsic to the individual and presumed to be due to central nervous system dysfunction. Even though a learning disability may occur concomitantly with other handicapping conditions (e.g., sensory impairment, mental retardation, social and emotional disturbance), with socioenvironmental influences (e.g., cultural differences, insufficient or inappropriate instruction, psychogenic factors) and especially attention deficit disorder, all of which may cause learning problems, a learning disability is not the direct result of those conditions or influences. (p.222)

This definition represents a modified version of the National Joint Committee on Learning Disabilities' (NJCLD) (1981) definition, which had not included the criterion of "social skills" as a significant difficulty or of "attention deficit disorder" as a concomitant condition.

A central auditory processing disorder (CAPD) is a term that may be used to define a group of individuals with communication or learning problems related to listening difficulties (Keith, 1986). More specifically, it is "the inability or impaired ability to attend to, discriminate, recognize, or comprehend information presented auditorily even though the person has normal intelligence and hearing sensitivity...more pronounced when listening to low (distorted) speech, when there are competing sounds, or in poor acoustic environments" (Keith, 1986, p.3). Children with suspected and/or known learning difficulties or disabilities may be referred for evaluation by an audiologist to assess the status of their hearing sensitivity, or peripheral hearing mechanism. In some cases, there is no specific concern regarding the child's hearing and/or listening status and the audiological evaluation is requested to rule out a hearing loss much the same as an eye examination is performed to rule out any visual problems. In other instances, reasons for referral typically include certain behaviours that warrant suspect of a hearing loss or auditory processing disorder (Musiek & Geurkink, 1980). However, many children who present with normal hearing sensitivity and outer/middle ear function still act as if they are hard-of-hearing (Barr, 1976). These children exhibit a variety of observable listening behaviours that warrant concern for central auditory processing difficulties, including difficulty hearing and understanding in background noise and with competing inputs (e.g., visual, tactile), difficulty recalling spoken information (e.g., instructions), and reduced auditory attention span (Smoski et al., 1992). Other behaviours that are often exhibited by children with an auditory processing disorder include distractibility. disinhibition, and hyperactivity (Rampp, 1980).

The literature describes numerous central auditory processes, including auditory attention, auditory discrimination, auditory memory and temporal sequencing, and auditory analysis and synthesis (Rampp, 1980). Abilities underlying these and several other perceptual subskills are presumed to be affected in an individual who presents with an auditory processing disorder. Keith (1986) presented a list of behaviours that may be manifested in a child who is "at-risk" for an auditory processing disorder. These behaviours include:

says "huh" or "what" frequently

gives [in]consistent responses to auditory stimuli

often misunderstands what is said

constantly requests that information be repeated

has poor auditory attention

is easily distracted

has difficulty following oral instructions

has difficulty listening in the presence of background noise

has difficulty with phonics and speech sound discrimination

has poor auditory memory (span and sequence)

has poor receptive and expressive language

gives slow or delayed response to verbal stimuli

has reading, spelling, and other academic problems

learns poorly through the auditory channel

exhibits behaviour problems

Note: These behaviours are listed in Table 1.1 (p.5) in Keith (1986) with references made to Cohen (1980) and Fisher (1980).

Keith (1986) suggested that children who exhibit these behaviours be screened for auditory processing abilities with the SCAN: A Screening Test for Auditory Processing Disorders. Although many of these behaviours may appear self-explanatory, others have either been given different definitions by various sources and/or have not been specifically described. For example, does "auditory memory" refer to memory for digits, words, and/or sentences?; how does one define "auditory attention?" McFarland and Cacace (1995) discuss the complexity of the term attention which may refer to numerous psychological processes. They caution the potential for misdiagnosing central auditory processing problems without first specifying if the difficulties are indeed modality specific, or rather, specific to the auditory modality. As an example, they suggest that

> a deficit in attention could be considered part of a CAPD if it is established that it is modality specific. If however, an attentional deficit is of a more general, supramodal nature, classification as a CAPD is inappropriate... however, the potential for involvement of nonperceptual factors in test outcome does not mean that auditory perception is never a major determinant of performance, but only that results are indeterminate without further investigation (p. 45).

Routine audiological evaluations of the peripheral hearing mechanism are typically performed under quiet environmental conditions and do not include measures of speech perception in which the signal is presented to the listener at a less than optimal level. such as in the various subtests of the SCAN (Keith, 1986, as described in the next section). Therefore complaints that are symptomatic of central auditory processing disorders such as difficulty listening in background noise, may not be adequately addressed and in turn, many individuals with CAPD often go unidentified. Furthermore, many of the behavioural manifestations of CAPD are also exhibited by children with ADHD and/or LD, suggesting that a central auditory processing screening and/or assessment may be a valuable contribution to the test protocol for such children.

Keller (1992) discusses the overlapping symptomatology of ADHD and CAPD and cautions that "a diagnosis of ADHD should not be made without first ruling out the possibility that APD [auditory processing disorder] might be mimicking ADHD....a diagnosis of APD should not be made without first ruling out the possibility that the child's poor performance on central auditory testing may be secondary to the inattention and impulsivity associated with ADHD" (p. 113). Keller indicates that he typically administers the Goldman Fristoe Woodcock Test of Auditory Discrimination and the Selective Attention Test or the SCAN as part of his evaluation of children suspected of ADHD. Referrals for further auditory processing are typically made when the child presents with symptoms that warrant suspicion of CAPD, including: a history of recurrent middle ear infections, speech articulation difficulties, left-hemisphere dysfunction on a neuropsychological evaluation with poor reading and language skills.

A consensus statement on Central Auditory Processing was recently drafted by the American Speech-Language-Hearing Association (ASHA, 1994) Task Force. This statement addresses several issues related to the diagnosis and management of central auditory processing disorders in children and adults, including the nature and assessment of CAPD, the developmental and acquired communication problems associated with CAPD, and the clinical utility of such a diagnosis. Included in this statement is a discussion of the relation between language learning and CAPD. Even within the fields of audiology and speech-language pathology, considerable controversy continues as to the link between auditory processing difficulties and language impairments. For example, Sloan (1991) noted that audiologists traditionally distinguish between hearing disorders of peripheral versus central origin, the former being related to reduced auditory acuity and the latter focusing on difficulties in processing the sensory input received from the peripheral auditory system. Speech-language pathologists, however, distinguish between auditory perception and auditory comprehension, stated otherwise as "are children misperceiving what they hear or failing to understand what they perceive?" (p. 35). Sometimes the multiple descriptions simply reflect differences in jargon. However, there are also varying perspectives on the underlying reasons for difficulties integrating and organizing auditory or verbal information.

Bottom-up Versus Top-down Hypotheses of Language Processing

A review of the literature revealed descriptions of two contrasting hypotheses regarding the influence of lower order perceptual processing and higher order cognitive processing on language and learning disabilities (Keith, 1984; Watkins, 1990). Proponents of the bottom-up or auditory perceptual deficit hypothesis assume that auditory processing deficits are primary to disorders in areas of language, learning, and reading (Breedin, Martin, & Jerger, 1989; Jerger et al., 1987; Leonard, 1989; Tallal & Piercy, 1973, 1974). The top-down or language processing hypothesis advocates that auditory perceptual disorders are related to but not the cause of disorders of language, learning, and reading, promoting cognitive-linguistic factors as primary to CAPD (Rees, 1981). Rees (1981) and Peck et al. (1991) have even questioned whether auditory processing is a meaningful and clinically relevant concept since its definition has not as of yet been clarified. Rees's (1981) questions, as well as those of others such as Butler (1981, 1983), include concerns regarding tasks that are intended to tap exclusively auditory processing skills yet also involve other aptitudes such as attention, motivation, and memory.

An integrative approach has also been suggested in which both specific auditory perceptual deficits and cognitive-linguistic features are considered in the assessment and management of auditory processing problems (Keith, 1984; Young & Protti-Patterson, 1984). Duchan and Katz (1983) describe the contribution of the auditory processing and language processing viewpoint through an interesting analogy between a poor tennis player and a child with language or academic problems:

> The player may be poor because of lack of knowledge of the game, and yet be endowed with sufficient vision, strength, and coordination to be a good tennis player. Alternatively, the player may have sufficient knowledge of the rules but be poor because of weakness in more peripheral abilities such as vision, eye-hand coordination,or strength. Of course, a player may have neither the conceptual knowledge nor the physical abilities to play tennis. It is very likely that there are interactional effects...Physical inability in tennis can be compared to signal processing inabilities in learning-disabled or language-disabled children. Lack of knowledge of the rules of tennis can be seen as paralleling language-disordered children's lack of linguistic knowledge or lack of knowledge about their world. (p. 34)

Children with learning disabilities have been identified with concomitant CAPD through audiologic test batteries involving specific measures of central auditory processing as well as psychological/speech-language test batteries (Breedin et al., 1989; Ferre & Wilber, 1986; Hall et al., 1993; Jerger et al., 1987; Jerger et al., 1991). These auditory test batteries have included electrophysiologic measures such as auditory brainstem response, middle latency response, and late vertex potential (Hall et al., 1993; Jerger et al, 1987); and behavioural auditory processing measures such as dichotic digits, competing sentences, staggered spondaic words (SSW), and pitch pattern sequences (Hall et al., 1993). Experimental auditory perceptual measures have also been used, such as a nonsense syllable detection task (Jerger et al., 1987) and discrimination tasks with nonspeech stimuli that have been acoustically altered to have similar acoustic features to speech (Breedin et al., 1989). Test batteries of linguistic skills have included standardized measures such as the Peabody Picture Vocabulary Test, the WISC-R Vocabulary and Digit Span subtests (Jerger et al., 1987); the Token Test for Children and the Goldman-Fristoe- Woodcock Auditory Sequential Memory and Auditory Discrimination subtests (Ferre & Wilber, 1986); and the Test of Auditory Perceptual Skills (Hall et al., 1993). Tests attempting to measure phonetic-phonologic abilities have included: phoneme or word discrimination/identification tests comparing performance in quiet versus noise; phonologic processing measures (in quiet) such as those assessed with the Goldman-Fristoe-Woodcock (GFW) Sound Symbol (phoneme analysis), Sound Blending (phoneme blending), and Sound Mimicry (phoneme repetition) subtests (Jerger et al., 1987).

It is therefore apparent that a wide range of different test batteries have been used to evaluate auditory processing abilities. Although certain tests or types of tests are more frequently administered, there does not as of yet appear to be a widely accepted standard test battery for auditory processing. Even when the same or a very similar battery is administered, the criteria of acceptable performance varies across test users. There are also inconsistencies in the studies regarding the correlations between psychological and audiological tests of auditory processing abilities (Howard & Hulit, 1992; Keith & Novak, 1984; Keith et al., 1989; Sanger & Deshayes, 1986). Some of these tests appear to test specific auditory perceptual function while others may be more influenced by cognitive and/or language functions. Regardless of which tests are capable of detecting specific auditory perceptual deficits that may be more representative of a true auditory processing disorder, the children with CAPDS represent a heterogeneous group. With this in mind, one might expect to find correlations among tests that are measuring similar auditory processing abilities (e.g., speech in noise) and/or possible combinations of difficulties that might be related to one another (e.g., auditory-phonetic confusions and reading/spelling difficulties). In other words, children with CAPD may or may not have receptive and/or expressive language difficulties and their scores on such tests therefore may or may not reflect such difficulties, respectively (Howard & Hulit, 1992; Keith & Novak, 1984; Keith et al., 1989; Matkin & Hook, 1983; Sanger & DeShayes, 1986). Furthermore, language difficulties associated with CAPDs may only be evident in more difficult listening situations such as in the presence of background noise. Therefore a thorough assessment might consider the signal and its presentation, the environment, required response, and strategies used to respond, as suggested in Lasky's (1983) SPERS model.

There is not sufficient evidence, however, that CAPDs create LDs nor that all LDs involve an auditory source (ASHA, 1994). In some instances, rather than describing auditory perceptual problems as an actual "disorder" or "disability", such difficulties may represent maturational delays in auditory processing abilities that will "catch up" over time (Keith, 1986). However, others have suggested that "children do not grow out of the disorder, although they appear to develop compensatory skills as they get older" (Stach & Loiselle, 1993, p. 294). Studies with learning disabled adults have suggested that auditory perceptual deficits persist into adulthood and may affect an individual's academic, social, and vocational performance (Blalock, 1982; Chermak, Vonhof, & Bendel, 1989).

ADHD and CAPD

Since many of the behaviours observed in children with attention deficit hyperactivity disorder are also found in children with auditory processing disorders, there appears to be a significant overlap between these two groups of children (Ivey & Jerome, 1991; Keller, 1992). As Hall et al. (1993) noted,

> close examination of the diagnostic criteria for ADHD (American Psychiatric Association, 1987) fails to reveal a direct link between ADHD and CAPD. Although the attention-related criteria of ADHD sometimes involve communication activities (e.g., "often does not seem to listen to what is being said"; "has difficulty following through on instructions from others"), none of the criteria specifically addresses auditory skills or performance (p. 260).

Several researchers have questioned whether or not the construct of CAPD even exists (Burd & Fisher, 1986; Gascon et al., 1986; Peck et al., 1991; Rees, 1981). Their concerns/critiques have primarily focused on inadequate CAP test norms; poor specificity of CAP tests, as reflected in the high frequency of CAPD diagnoses; the attention dependent nature of CAPD tests; and the expression of the presumed CAPD symptomatology in children with learning disabilities, behavioral/emotional/psychosocial difficulties, and especially attention deficit disorder. However, despite this scepticism, there have indeed been studies, to be discussed subsequently, which have found children presenting with CAPD/no ADHD, with ADHD/no CAPD, as well as with a combination of CAPD and ADHD. The subjects chosen for inclusion in these studies have included: (i) children referred for CAP testing due to language/learning concerns (Keith et al., 1989); (ii) children with diagnoses of ADD/ADHD (based on specific operational definitions) who were administered a battery of language and/or CAP tests (Cook et al., 1993; Gascon et al., 1986; Keith & Engineer, 1991; Ludlow et al., 1983); (iii) children with diagnoses of CAPD (based on specific operational definitions) who were also evaluated for ADHD (Ivey & Jerome, 1991; McPherson, 1990).

Keith et al. (1989) compared the results of the SCAN with other auditory and language measures in children who were referred for possible auditory or language processing disorders, several of whom had histories of ADHD. The children with ADHD had lower (indicating more difficulty) SCAN scores than those with no history of ADHD, particularly on the Auditory Figure Ground (AFG) and Filtered Words (FW) subtests (most pronounced for AFG).

In another study, Keith and Engineer (1991) found that the performance of children with ADHD improved on the ACPT, an auditory vigilance task, and on the FW and CW subtests of the SCAN when they were taking methylphenidate. As improvements were not statistically significant on the AFG subtest, they suggested that children with ADHD are not affected by relatively uniform background noise (such as that on the AFG subtest) but rather are more affected by changing stimuli. A suggested explanation of the difference in findings between this study and the previous study by Keith et al. (1989) was that the Keith et al. study had a more heterogeneous sample (Keith & Engineer, 1991). Although they indicated that further studies are needed to examine the relationship between environmental noise and distraction, Keith and Engineer (1991) concluded that the AFG subtest may discriminate between children with ADHD and those who have a specific auditory processing disorder and are significantly affected by background noise. They hypothesized that the children's attention problems cause them to have difficulty perceiving auditory information presented at fast rates, and in turn, their academic progress is impeded compared to their classmates. However, although the authors did not include the individual subtest scores, an examination of the results indicated that despite improvement on medication, the averaged scores on the SCAN subtests for all the subjects off medication were within an average range (within one standard deviation of the test mean).

Keith's (1994) rationale for developing the Auditory Continuous Performance Test (ACPT), an auditory vigilance screening measure, thus included its potential use in helping to arrive at a differential diagnosis between deficits in attention (related to attention deficit hyperactivity disorder) versus a central auditory processing disorder specific to figure-ground tasks. Keith (1994) suggests comparing the child's performance on the ACPT and the SCAN (which includes an auditory figure ground subtest). He also suggested that the use of words as test stimuli might be more interesting, familiar, and meaningful for young children as compared to earlier tests using pure tones, letters, or numbers.

Cook et al. (1993) included a non-ADD control group of "average achievers" in their examination of the relationship between central auditory processing disorder and attention deficit disorder. In this double-blind, placebo-controlled study, 6- to 10-year old boys with ADD (this DSM-III term was used to refer to attention deficit hyperactivity disorder in the

DSM-III-R) were compared to a non-ADD group at baseline and after three and six weeks of treatment with methylphenidate. Inclusion in the ADD group required the following: clinical diagnosis of ADD by a paediatrician; DSM-III criteria were met for inattention and impulsiveness as measured on the parent and teacher versions of the Swanson, Nolan, and Pelham Checklist (SNAP); DSM-III criteria were met for hyperactivity as measured in the parent version of the SNAP; score of ≥15 points on the parent Abbreviated Conners Rating Scale (Conners, 1973). CAPD was defined as performing below age expectations on at least 3 of 5 central auditory processing measures (CAPD test battery included speech discrimination; SSW; and three subtests of the Willeford, 1977 battery: competing sentence Binaural Separation Test, Filtered Speech Test, Rapidly Alternating Speech Test). There were no learning disabled subjects nor subjects with speech and language problems. Twelve of the 15 children who met the preceding ADD criteria also met the CAPD criteria. The other three children with ADD scored below age-level on two of the five CAPD measures. However, none of the children without ADD met the criteria for CAPD. Furthermore, an improvement was noted on all of the behaviour rating scales and on the three CAPD measures (competing sentences, speech discrimination in noise, RAST) that had differed at baseline. However, there was also an improvement on the Competing Sentence test for the ADD group on placebo . Nonetheless, there was no improvement found in the non-ADD group, which might have otherwise suggested practice effects. Cook et al (1993) cautioned against generalizing these findings to other studies that used different behavioural rating scales and central auditory processing batteries. They also acknowledged that the CAPD tests used in their study may not discriminate between children with CAPD and ADD from those with CAPD only.

Ludlow et al. (1983) utilized an experimental auditory processing battery as well as a vigilance or continuous performance test that consisted of a tone, presented 10 dB above threshold, as the stimulus to be detected in white noise. Four groups of subjects were included in this study, three of which were given an operationally defined label of hyperactivity based on meeting the criteria of DSM-III re:motor activity that exceeded age-appropriate expectations, impulsivity, and poor attention span. These groups were also differentiated on the basis of language or learning disabilities and reading disabilities. Based on the auditory processing results, Ludlow et al. found that children with auditory temporal processing deficits may or may not have concomitant language problems. Furthermore, such auditory processing deficits may only partly contribute, if at all, to language problems. These researchers did attempt to minimize the effect of attention deficits on their results and thus indicated that performance differences on the auditory processing measures were most likely due to processing deficits rather than attention deficits. On the vigilance task, significant difficulties were only found for the hyperactivity group (no learning disability or language impairment) compared to a normal control group. Most of the former groups' errors were due to impulsivity as opposed to inattention.

It has even been suggested that ADHD and CAPD are essentially the same construct (Gascon et al., 1986). However, this conclusion was based on a study of 19 children previously diagnosed with ADD, 15 of whom were also found to have CAPD on the basis of a central auditory processing test battery, including the Competing Sentence Test, the Filtered Speech Test, the Rapidly Alternating Speech Test (RAST), and the Staggered Spondaic Word Test (SSW). In addition, results indicated that 79% of the children improved on the central auditory test battery following stimulant medication administered to control hyperactivity levels. They hypothesized that ADHD causes depressed performance on central auditory tests. Ivey and Jerome (1991), however, cautioned that the nature of Gascon et al.'s (1986) study of children previously identified with ADHD, suggests a selection bias towards a large overlap between ADHD and CAPD. In contrast, they found that although children with central auditory disorder may also have ADHD, there also exists a subgroup of children with CAPD without ADHD. Specifically, in their study of children referred for CAPD testing, Ivey and Jerome (1991) noted that only 43% of the total group of children (N=64) with normal hearing sensitivity who showed central auditory deficits on at least one of four tests (Competing Sentences, Filtered Speech, Words in Competition, and Binaural Resynthesis) fell into an ADHD (with or without hyperactivity) category in accordance with teacher rating scales based on the DSM-III (1980) criteria.

Ivey and Jerome (1991) also assessed the effects of medication on central auditory test results. They compared two groups of children, each group including both those with CAPD only and those with ADHD and CAPD. They hypothesized that: (i) there would be a sub-group of children with CAPD and ADHD, as well as a sub-group of children with CAPD only; (ii) if CAPD results from ADHD then approximately 70% of the children medicated with methylphenidate should show a positive response (Satterfield et al., 1974), namely a clinically significant improvement on the central auditory processing test(s) used in their study. Medication "A" (methylphenidate) was randomly assigned to one group and medication "B" (placebo) to the other. Only the medicated (methylphenidate) group demonstrated improved performance statistically on two of the four CAPD tests upon reassessment (Words in Competition or WIC and Binaural Resynthesis or BR). Compared to the placebo group, a greater number of subjects in the methylphenidate group demonstrated clinically significant improvements only on the WIC test scores. However, chi-square analyses indicated that there were significant differences (Right Ear: $X^2 = 6.25$, $\underline{df} = 1$, $\underline{p} < .05$; Left Ear: $X^2 = 9.00$, $\underline{df} = 1$, $\underline{p} < .01$) between the expected number of clinically improved scores i.e. 70% (Satterfield et al., 1974) by individuals taking methylphenidate and the improvement that was actually observed in the group that was medicated with methylphenidate. Ivey and Jerome (1991) indicated that these findings suggest that the treatment (methylphenidate) that is presumably effective for approximately 70% of children with ADHD (Satterfield et al., 1974) does not significantly alter central auditory processing per se; rather, the degree to which such medication has an effect on central auditory test results depends on the degree to which ADHD interferes with the child's ability to attend to the test. Based on these findings, they suggested that although there is a significant overlap in behavioural expression between ADHD and CAPD, they are each independent disorders.

Behavioural rating scales are often used as part of an assessment battery for children with learning difficulties in order to obtain information from the perspective of several sources. The Conners Rating Scale includes subjective measures by the rater(s) of a child's listening behaviours similar to that on the CHAPPS. The Conners Scale has often been used as part of an assessment battery for children suspected of having ADHD; the CHAPPS, or a similar such scale, has frequently been used for children suspected of having CAPD. The CHAPPS is divided into subsections, some of which address more specifically an individual's auditory attention which relates to difficulties hearing and understanding speech in the presence of background noise and/or competing stimuli/messages. Smoski et al. (1992) reported that a pilot study comparing CHAPPS scores of 20 CAP-disordered children with 20 non CAP-disordered children of similar age and background revealed such dissimilar observed listening performances that there was no overlap between the range of scores for each group. In Jerome and Ivey's (1991) study, the children with ADHD and CAPD had higher degrees of difficulty with attention than with impulsivity and hyperactivity, based on their scores on the Conners scale and a questionnaire based on DSM-III (1980) criteria for ADHD. In a study that examined the validity of the auditory processing construct, MacPherson (1990) divided children with learning disabilities into two groups based on their performance on four tests: Competing Sentences, Filtered Speech, Alternating Speech Perception, and Binaural Resynthesis. Included in her findings was that the group of children who scored below normal limits on at least one of these four tests also demonstrated significantly poorer performance on the Conners Conduct Problem and Hyperactivity Index.

Not surprisingly, central auditory processing test batteries have been criticized in that they are also sensitive to nonauditory factors such as attentional, cognitive, and linguistic deficits/difficulties (Peck et al., 1991). Keith et al. (1989) indicated that the SCAN does not place emphasis on the cognitive and comprehension aspects of audition. However, their findings suggested that the SCAN battery, particularly the FW and AFG subtests, may be sensitive to the presence of attention deficits. The findings of both Keith and Engineer (1991) and Cook et al. (1993), in particular, indicate that interpretations regarding the test results on the SCAN should be made with caution. The extent to which general "attentional" deficits reflect auditory attention difficulties has yet to be determined. However, the extent to which a child may have attentional problems interfering with his/her performance rather than specific auditory processing problems may be interpreted using a qualitative analysis of the results, as described in the SCAN manual (Keith, 1986). For example, unilateral deficits i.e. particular difficulties in accurately identifying words presented to one ear only, might suggest specific auditory processing problems rather than attentional or linguistic-cognitive deficits. However, a differential diagnosis between CAPD only versus ADHD and CAPD in combination may be much more difficult to determine.

Rationale for the Present Study

Children with ADHD may or may not have learning disabilities (Cantwell & Baker, 1991) and children with learning disabilities may or may not have auditory processing disorders (ASHA, 1994). In addition, children may have auditory processing deficits and intact language or children may have language impairments to which auditory processing deficits such as temporal processing difficulties are contributing factors (Ludlow et al., 1983). Moreover, the literature suggests that children with speech/language disorders are at-risk for learning and psychiatric disorders (Baker & Cantwell, 1987), particularly attention deficit disorder (Love and Thompson, 1988).

Since children who have LD and/or ADHD and/or CAPD may present with similar symptomatic behaviours, an assessment battery is needed that includes procedures with documented sensitivity to central auditory nervous system dysfunction in order to differentiate these groups, as well as children with any other disorders, such as psychologic, speech-language, emotional, or neurologic, that may also give rise to similar symptoms (Hall et al., 1993). This type of differential diagnosis should consist of a test battery that is not likely to be influenced by linguistic, cognitive, or attentional disorders (Hall et al., 1993). Consequently, however, considerable difficulty will be encountered in cases in which there is a significant overlap between two or more disorders.

As noted previously, there are controversial findings in the literature regarding the correlations among the various tests/subtests and/or scales that might be administered to assess and discriminate among these children. The controversy that exists to date is possibly due to both the definitional issues and the heterogeneity within each of these groups that are referred to as LD, ADHD, and CAPD (Gascon et al., 1986; Hall et al., 1993; Ivey & Jerome, 1991). Comprehensive assessment procedures in both research and clinical practice may help identify the particular difficulties each child is encountering so that remediation and/or compensatory procedures may be of maximum benefit. However, despite the apparent overlap among ADHD, LD, and CAPD, it is possible that certain subtle distinctions may be found through both a quantitative and qualitative analysis of a variety of tests/scales as well as clinical interviews, observations, and dynamic assessment procedures. The tests and scales chosen for this study include those that address an individual's cognitive and academic status, auditory processing abilities, auditory vigilance, and observable behavioural characteristics across several environments. If these tests/scales are sensitive enough, they may contribute to the task of differentiating between groups of children with LD and/or ADHD.

Expectations for performance of groups of children with ADHD and/or LD on measures assessing auditory processing skills, auditory vigilance, and observable (listening) behaviours are dependent upon one's operational definitions of each of these terms. For this study, it was assumed that the performance of these children would be dependent not only on which group (ADHD,LD) they belonged to but also on the severity of their disorder and the specific difficulties unique to each individual. The heterogeneous nature of these disorders therefore made it difficult to make specific hypotheses regarding the performance across/between groups, with the exception of the normally achieving group. For example, the learning disabilities of the children in the LD and ADHD groups may or may not include auditory processing difficulties. However, if the SCAN and CHAPPS both represent different methods of measuring similar central auditory processing difficulties, one might predict that there would be positive correlations between these measures.

Purpose and Hypotheses

The purpose of this study was twofold: (i) to examine if there are any correlations within a given individual's scores among the SCAN, CHAPPS, ACPT, Conners, WRAT-3 Reading/Arithmetic subtests, WIAT Listening Comprehension subtest, and WISC-III Block Design, Vocabulary, and Digit Span subtests, regardless of group (NA, LD, ADHD); (ii) to see if the groups can be discriminated on the basis of their performance on the tests/scale administered in this study. To summarize, the hypotheses are as follows:

1. There will be significant differences between the normally achieving children and the other two groups of children (LD, ADHD) on all measures of the SCAN test, as well as on the Auditory Continuous Performance Test (ACPT), the Conners Parent Rating Scale and the Children's Auditory Processing Performance Scale (CHAPPS).
2. There will be a significant relationship between the SCAN scores and the CHAPPS scores.
3. Children in the ADHD group (ADHD and/or LD-ADHD) will have higher error scores (related to poorer performance) on the Auditory Continuous Performance Test as compared to the LD and NA groups since this test is a screening measure for ADHD.
4. A group of children may emerge who present with central auditory processing difficulties but do not match the criteria for the LD or the ADHD group. This finding may provide evidence that CAPD is an independent disorder which may or may not present itself co-morbidly with LD and/or ADHD.

METHOD

Subjects

A total of 37 children (20 males, 17 females) were included in this study. Their ages ranged from 83 months (6 years, 11 months) to 131 months (10 years, 11 months) with a mean age of 105 months (8 years, 9 months) and a standard deviation of 15 months (1 year, 3 months). Seven children had initially been seen for an audiological evaluation at the dB Audiology Clinic, a private practice audiology clinic in Toronto, Ontario, as part of an investigation of learning concerns reported by the parent(s) and/or teacher(s). The remaining thirty participants were solicited from several referral sources, including: other Audiology clinics and/or colleagues, pediatricians, private schools, and published newsletters (written by the author and placed in the Learning Disabilities Association newsletter). The subjects were tested at three different sites, as follows: the dB Audiology Clinic (31 children); the Audiology Department at Scarborough Grace Hospital in Scarborough, Ontario (2 children); and a sound treated room in Burlington, Ontario (in order to avoid the travelling time and expenses the parents would have otherwise had to incur in coming to Toronto). Written parental consent was obtained for each child (see Appendix A).

The following criteria were required for inclusion in the study: an estimated IQ score >80, derived from the WISC-III (Wechsler, 1991) Block Design and Vocabulary subtests (Sattler, 1992, Table C-37, p.851); documented evidence of normal peripheral hearing sensitivity bilaterally with hearing levels at octave frequencies 500 to 4000 Hz at 15 dBHL or better and normal tympanograms with middle ear pressures between -200 and +25 daPa. Seven of the thirty-seven subjects had either been assessed for learning difficulties within the past year or were in the process of undergoing a psychoeducational and/or medical evaluation around the same time as this assessment. Additional written consent was therefore obtained from each of these seven children's parent(s) to obtain the necessary scores from the appropriate professional. Two children who had been medically diagnosed with ADHD had been taking Ritalin and were therefore asked to refrain from taking their medication for at least 4 hours prior to participation.

For purposes of this study, the children were identified as learning disabled (LD), attention deficit hyperactivity disorder, with or without a co-morbid learning disability (ADHD), or normally achieving (NA), as defined below.

To be defined as learning disabled, a child had to have a score ≤25 percentile on at least one subtest of the WRAT-3 (Jastak & Jastak, 1994) i.e. Reading, Arithmetic. To be defined as having attention deficit hyperactivity disorder, a child had to have a score ≥2SD above the mean for age and sex on the Conners Parent Questionnaire (Goyette. Conners, & Ulrich, 1978) and behaviour problems as reported by teachers, parents, and/or physicians. To be defined as normally achieving, a child had to have WRAT-3 Reading and Arithmetic scores ≥30 percentile.

Design

The subjects were divided into three groups as follows: normally achieving - NA (n=13); learning disabled - LD (n=10); and attention deficit hyperactivity disorder, with or without a concomitant learning disability - ADHD (n=14). One subject who had a WRAT-3 arithmetic percentile score between the 25th and 30th percentile, was included in the LD group.

Instrumentation

All auditory tests were administered through TDH-39 headphones while the subject was seated in a single-walled IAC booth, with the exception of the four subjects who were tested in a sound treated room in Burlington, Ontario . Equipment used at each of the three testing sites included: Grason Stadler 16 pure tone audiometer (dB Audiology Clinic), Madsen OB-822 audiometer (Scarborough Grace Hospital and Burlington site); Grason Stadler 33 impedance bridge (dB Audiology Clinic and Scarborough Grace Hospital), Madsen Z0901 impedance bridge (Burlington site). A quality stereo cassette player (Sony TXD-R11) was used for administering the central auditory and the vigilance screening tests. The Phonetically Balanced-Kindergarten (PB-K) word list was used to assess word recognition in quiet; however, word recognition was not assessed at the Burlington site as the examiner and subject were seated in the same room.

The psychoeducational test materials consisted of selected subtests from the Wechsler Individual Achievement Test (WIAT; Wechsler, 1992), the Wechsler Intelligence Scale for Children - Third Edition (WISC-III; Wechsler, 1991), and the Wide Range Achievement Test (WRAT-3; Jastak & Jastak, 1994); the SCAN, A Screening Test for Auditory Processing Disorders (Keith, 1986); the Auditory Continuous Performance Test (Keith, 1994), the short form of the Conners Parent Rating Scale (Conners, 1985) and the CHAPPS or Children's Auditory Processing Performance Scale (Smoski et al., 1992).

Tasks

All tests were administered in the same order, as follows: peripheral hearing test;

central auditory screening test (SCAN); auditory vigilance test (ACPT); WIAT Listening Comprehension subtest; WISC-III Block Design, Vocabulary, and Digit Span subtests; and WRAT-3 Reading and Arithmetic subtests. The only exception to this order was for the seven subjects who had already been administered (or were going to be administered) any of these measures within a one year period from the date of this assessment; for six of those cases, the WISC-III subtests were not administered and for the seventh case, the WISC-III and WIAT subtests were not administered. The total testing time for the entire test battery was approximately 2 hours, including breaks. The Conners Parent Questionnaire and the CHAPPS were administered to each child's parent/s; these rating scales were either filled out by the parent(s) in the waiting room while the child was being evaluated or returned to the examiner at a later date. Three of the 37 subjects required multiple sessions to complete the testing due to time constraints.

Audiological Evaluation

The audiological evaluation consisted of pure tone air conduction and bone conduction thresholds, speech reception thresholds (SRT) and word recognition measures in quiet, and impedance audiometry (tympanograms). On the word recognition test, the subject was required to listen to and repeat familiar monosyllabic words presented at 40 dB SL (sensation level). For the reader who is not familiar with this term, it represents an intensity level that is 40 decibels above the softest sound level at which a given individual is able to identify 50% of spondee words (familiar two-syllable words with equal stress on each syllable) i.e. relative to the speech reception threshold.

SCAN: A Screening Test for Auditory Processing Problems

The central auditory test battery consisted of the SCAN (Keith, 1986), which includes the following three subtests:

(i) Filtered Words (FW) - the child listens to and is required to repeat 1000 Hz low-pass filtered monosyllabic words with a filter roll-off of 32 dB/octave. Poor performance on this task suggests that a child may have difficulty understanding words, particularly those that are distorted in some way such as when a teacher has an accent, speaks too quickly, or speaks with his/her back facing the class. As low-pass filtered speech represents an auditory closure task, this subtest may therefore identify children who would benefit from additional receptive language testing.

(ii) Auditory Figure Ground (AFG) - the child listens to and repeats monosyllabic words recorded at +8 dB signal to noise ratio with a multitalker babble background. Poor performance on this test may be indicative of difficulty listening to and comprehending speech in the presence of background noise and/or a delay in development of the auditory system.

(iii) Competing Words (CW) - the child listens to monosyllabic word pairs presented dichotically with simultaneous onset times and is instructed to repeat both words. Two separate lists are included so that on the first list the child is required to repeat the word heard in the right ear first and vice versa on the second list. Depressed scores on this subtest may suggest a maturational delay in development of the auditory system.

The SCAN is a norm referenced test that was standardized on 1034 children between 3 and 11 years of age who attended regular classrooms (Keith, 1986).

Scores on the SCAN were reported as percentile ranks. For the purpose of this study (and as suggested by Keith, 1986) scores on the SCAN test equal to or below the 16th percentile (at least 1 standard deviation below the mean) were considered below average.

Auditory Continuous Performance Test (ACPT)

The Auditory Continuous Performance Test was designed to provide an objective measure of the auditory attention behaviour of children between the ages of six and eleven years (Keith, 1994). It is an auditory vigilance screening measure that proposes to measure two aspects of attention, namely selective attention and sustained attention. The children's task involves listening to familiar monosyllabic words and raising the thumb (or pressing a button) whenever they hear the word "dog." There are six trials of ninety-six prerecorded words that are presented to the children diotically through headphones. The test duration is approximately ten minutes.

Two sets of scores are evaluated on the ACPT. The "total error score," a measure of selective attention, is determined by adding up the number of inattention errors (the word "dog" was presented but the child did not respond) and impulsivity errors (the word "dog" was not presented yet the child responded). Sustained attention is measured by comparing the number of correct responses (hits) on the first trial to those on the last trial. The latter score is referred to as the "vigilance decrement." The manual and test protocol provide criterion values to determine if the child's total error score is most similar to those of the children in the standardization sample who were identified as having ADHD or to those not identified as having ADHD. A child whose total error score is greater than the criterion score by age is assumed to be at-risk for having ADHD. However, the manual also indicates that "the novelty of the ACPT task, the one-to-one attention the child receives in a testing situation, and the fact that the situation is highly structured and you are monitoring each response may enable the child who has ADHD to override the effects of the disorder" (Keith, 1994, p.17). The vigilance decrement score is interpreted by determining the prevalence of such a score in the normal sample. Scores corresponding to prevalence values of 1-5% are considered significant. The ACPT was standardized on 510 children from 6 to 11 years old who had not been diagnosed with ADHD.

The ACPT error scores and vigilance decrement scores were reported as continuous scores since the manual does not provide a means of converting the raw scores to derived scores. The means and standard deviations for the ACPT error scores were calculated based on the total group raw scores (NA, LD, ADHD). The manual only provides criterion error scores which are based on comparisons of the Total Error Score to a standardization sample. Criteria for age-appropriate performance is actually based on performance within 1 standard deviation of the mean total error score by age. Therefore, the total error scores were converted into z-scores for subsequent analyses. For some analyses, however, performance on the ACPT was reported as dichotomous scores (pass/fail). The vigilance decrement scores were reported as continuous scores and for reasons to be explained in a subsequent section, only qualitative observations were made regarding these scores.

Wechsler Individual Achievement Test - Listening Comprehension

The Listening Comprehension subtest of the WIAT was used to measure listening comprehension, such as listening to a word and pointing to one of four pictures associated with the word; listening to short paragraphs and answering oral questions related to the paragraph. For the latter tasks, a single picture is provided as a helpful cue but the answer to the question is not found within the picture itself. Results were reported as percentile ranks.

Wechsler Intelligence Scale for Children

Three subtests of the Wechsler Intelligence Scale for Children - III (Wechsler, 1994) were administered. The Block Design and Vocabulary subtests were used to obtain an estimated IQ score (Sattler, 1992, Table C-37). On the Block Design subtest, the subject is required to assemble a set of blocks to match a picture of a given design. The Vocabulary subtest requires that the subject orally provide the meanings of individual words. The Digit Span subtest was also included as a measure of each subject's short term auditory memory for numbers. The subtest scores were reported as scaled scores and the estimated IQ was reported as a percentile rank.

Wide Range Achievement Test

The Reading and Arithmetic subtests of the Wide Range Achievement Test - 3 (WRAT-3) were used as measures of each child's decoding and computational skills, respectively. On the reading subtest, the subject is required to read individual words. On the arithmetic subtest, the subject is required to perform written computational exercises. The results were reported as percentile ranks.

Conners Parent Rating Scale (Short Form)

The Conners Parent Rating Scale was designed to identify attentional and behavioural difficulties according to the parents' perception. The abbreviated version (48 items) of this scale was used in this study. Six behavioural descriptors are calculated: Conduct Problem. Learning Problem, Psychosomatic, Impulsive-Hyperactive, Anxiety, and Hyperactivity Index. Based on previous literature, this scale has often been used as part of an assessment protocol for children with attention and concentration difficulties. The results were reported in t-scores, with a score ≥70 (i.e. ≥2SD above the mean for age and sex) indicative of age-inappropriate hyperactivity.

Children's Auditory Processing Performance Scale (CHAPPS)

The CHAPPS, a questionnaire-type scale, was developed to systematically collect and quantify data concerning the observed listening performance of children (Smoski et al, 1992). It consists of 36 items that address listening behaviour in a variety of listening conditions and functions including noise, quiet, ideal, multiple inputs, auditory memory/sequencing, and auditory attention span. Smoski et al. (1992) indicated that these conditions/functions were chosen since they were most often reported in the literature regarding children with central auditory processing disorders (CAPD) as well as by teachers and parents when they refer children for a central auditory processing evaluation. There are no normative data for this scale. However, Smoski et al. (1992) reported that a pilot study comparing CHAPPS scores of 20 CAP-disordered children with 20 non CAP-disordered children of similar age and background revealed such dissimilar observed listening performances that there was no overlap between the range of scores for each group.

Each child's parent(s) was required to rate the difficulty level that they perceive their child experiences relative to children of similar age and background. Examples included the amount of difficulty a child has "when paying attention," "when being asked a question." and "when being given simple instructions" under several different listening conditions such as "listening in a room where there is background noise such as a TV set, music, others talking, children playing, etc." and "listening in a quiet room, no distractions, face-to-face, and with good eye contact." The child's difficulty level in recalling spoken information and in listening for extended periods of time is also addressed. The original scale consists of 7 response choices which are quantified and labelled from less difficulty (+1) to cannot function at all (-5). For the present study, there were only three labelled response choices, as follows: less, same, more. The CHAPPS scores were reported as continuous scores since there is no available normative data for this scale. Similar to the original article describing the CHAPPS (Smoski et al, 1992), the average raw score for each subsection was calculated to allow for subsection comparisons. For a more detailed account of this scale and the CHAPPS original scale, see Appendix B.

RESULTS

Table 1 includes the means and standard deviations by group (NA, LD, ADHD) of all the variables used in the study. Due to unavailability of the data, four subjects' scores are missing for the WISC-III Block Design, Vocabulary, Digit Span, and Estimated I.Q. (one subject from the NA group; two subjects from the LD group; one subject from the ADHD group).

Relationships Among Groups

Analysis of variance (ANOVA) was performed to determine if there are significant differences across groups on each of the independent variables (tests/subtests and scales). As indicated on Table 1, there were statistically significant differences among the three groups on the Arithmetic subtest of the WRAT-3 (F=8.46), five of the six Conners subsections, namely Conduct Problem (F=6.18), Learning Problem (F=14.32), Psychosomatic (F=10.98), Impulsive-Hyperactive (F=10.98), and Hyperactivity Index (F=32.63), and the Noise and Quiet subsections of the CHAPPS (F= 4.68; F=3.97).

Insert Table 1 about here

A post hoc Scheffe test was performed to determine which pairs of scores differ significantly from one another. The Scheffe test revealed that the NA group had significantly higher (better) Arithmetic scores compared to the LD group. Furthermore, the ADHD group had significantly higher (worse) scores than the NA and LD groups on the Conners Conduct Problem (p<.05), Learning Problem (p<.01), Impulsive-Hyperactive (p<.01) and Hyperactivity Index (p<.01); the NA and LD groups did not differ on these measures. The ADHD group also had significantly higher (worse) scores on the CHAPPS Noise subsection than the NA group. The Scheffe test did not reveal which pairs of scores differed significantly for the Conners Psychosomatic and the CHAPPS Quiet subscales.

Three of the subjects in the NA group had been identified as exceptional by the schools they were attending despite meeting the criteria for average performance on the WRAT-3 subtests used in this study. A modified analysis of variance (Table 2) was therefore performed across the NA (n=10), LD (n=13), and ADHD (n=14) groups, this time including these three subjects in the LD group rather than the NA group. The results of this modified group placement ANOVA were similar, with the exception of two additional significant differences across groups: CHAPPS Multiple Inputs (F=3.54, p<.05) and Total (F=4.11, p<.05) scores. Post hoc Scheffe analysis revealed significantly higher (worse) scores for the ADHD group compared to the NA group (p<.05) but not compared to the LD group.

Insert Table 2 about here

Of the 24 subjects in the LD or ADHD groups, 18 met the criteria for Learning Disability (Reading and/or Arithmetic). Subjects were further subdivided into Reading disabled only (RD, n=7) versus Arithmetic disabled only (AD, n=6). An ANOVA was performed to determine if there were differences among the RD only, the AD only, and the RD-AD combined (regardless of whether or not there was a concomitant ADHD) groups on any of the measures administered (Table 3). Significant differences were found on the Conners Conduct Problem scale (F=5.48, p<.05) and the ACPT Total Error Score (F=6.26, p<.05). A post hoc Scheffe test revealed that the RD scored significantly higher (more poorly) than the AD on Conduct Problem ($p<.05$) and that the RD-AD scored significantly higher (more poorly) than the RD and the AD on the ACPT ($p<.05$).

Insert Table 3 about here

The ADHD group was further divided into ADHD-LD (RD and/or AD, $n=6$) and ADHD-no LD (based on the LD criteria used in this study, $n=8$). The only significant difference across these groups (Table 4) was on Vocabulary: subjects with ADHD (no LD) performed significantly better than subjects with ADHD-LD ($F=8.71$, $p<.05$). However, these subgroup analyses must be interpreted with caution due to the small subsamples.

Insert Table 4 about here

Relationships Among Tests/Scales

Pearson-product moment correlations were computed to determine the correlations among the tests administered in this study. These correlations are displayed in Tables 5, 6, and 7. Table 5 illustrates the correlations of the SCAN and all the other independent variables included in this study. High scores on the Conners, the CHAPPS, and the ACPT were indicative of greater difficulty while high scores on the SCAN reflected better performance. There were negative correlations between the Composite Standard Score (CSS) and the Competing Words (CW) score of the SCAN and all of the CHAPPS scores, ranging from -.47 to -.16 (meaning that better scores on the CSS or CW correlated with better scores on the CHAPPS). Three of these correlations were significant (p<.01): CW and Quiet, Auditory Memory/Sequencing, and Total. The correlations between the FW and the AFG with the CHAPPS were lower (-.17 to .19) and not significant. Only approximately half of the correlations between either the FW or the AFG and the CHAPPS were negative.

Insert Table 5 about here

Correlations between the SCAN and the Conners ranged from - .36 to .34. None of these correlations were significant. Correlations between the SCAN and the WRAT-3 ranged from -.04 to .45.; the only significant correlations were between the CW of the SCAN and the arithmetic test of the WRAT-3 (p<.01). There were no significant correlations between the SCAN and the WIAT, ranging from .18 to .40.

Significant correlations were found between both the CSS and the CW and the Estimated IQ (p<.001), as well as the Vocabulary (p<.01) and Digit Span (p<.01) subtests but not with the Block Design subtest. The ACPT Total Error Score correlated significantly with the SCAN CSS and CW (p<.01).

Correlations between the CHAPPS and the Conners, the WRAT-3, the WIAT, the WISC-III, and the ACPT can be found in Table 6. The Total CHAPPS score and 4 subsections (Noise, Quiet, Ideal, Auditory Attention Span) correlated significantly with the Conners Learning Problem and Hyperactivity Index. There were also significant correlations for the CHAPPS Quiet and Auditory Attention Span with the Conners Conduct Problem. Low negative correlations were found between the CHAPPS and the WRAT-3 Reading (-.36 to -.15) and Arithmetic (-.32 to -.09) and between the CHAPPS and the WIAT (-.26 to -.02). However, the CHAPPS Ideal correlated significantly with the WISC-III Vocabulary ($p < .01$) and the CHAPPS Auditory Attention Span correlated significantly with the WISC-III Digit Span ($p < .01$). There were no significant correlations between the CHAPPS and the ACPT (.22 to .34).

Insert Table 6 about here

As Table 7 reveals, there were no significant correlations between the WRAT-3 or the WIAT and the Conners (-.36 to .11); the WRAT-3 and the WIAT (.27 to .32); and the WRAT-3 or WIAT and the ACPT (-.40 to -.38). Significant correlations were found between: WRAT-3 Reading and WISC-III Vocabulary; WRAT-3 Arithmetic and estimated WISC IQ; WIAT Listening Comprehension and WISC-III Vocabulary and estimated IQ.

Insert Table 7 about here

"Pass" versus "Failure" on the SCAN and/or ACPT

The individual subject scores and pass/fail status for the SCAN Composite and each subtest are listed in Tables 8 to 10. Altogether, 16 subjects performed below age-appropriate expectations on at least one of the SCAN subtests. The proportion of subjects in each group who "failed" at least one subtest or the composite on the SCAN was as follows: (i) NA = 5/13 (original group, based on operational definition of LD); NA = 3/10 (modified group, based on operational definition of LD and/or recent school board identification as exceptional) (ii) LD = 5/10 (original group); LD = 7/13 (modified group) (iii) ADHD = 6/14. Only one subject performed below age-appropriate expectations on the FW test.

Insert Tables 8-10 about here

Subjects whose performance was within an age-appropriate range on all SCAN scores were compared to those who "failed" (<16%ile on at least one subtest) this test (Table 11). Significant differences were found on WISC-III Block Design (F=7.58, p<.01), Vocabulary (F=11.82, p<.01), and estimated IQ (F=17.82, p<.001). With respect to the SCAN there were also significant differences between these two groups on AFG, CW, and CSS but not on FW. Performance on the ACPT was also significantly better for subjects who performed within age-appropriate norms on SCAN (F=4.40, p<.05).

Insert Table 11 about here

Ten subjects performed below age-appropriate expectations ("failed") based on the ACPT Total Error Score. Seven of these 10 subjects also performed below age-appropriate expectations ("failed") on the SCAN. Subjects who passed the ACPT yet failed the SCAN (n=9) were compared to subjects who failed the ACPT (n=10). As Table 12 reveals, the former group (ACPT pass, SCAN fail) performed significantly better on Listening Comprehension ($F=7.85$, $p<.05$).

Insert Table 12 about here

The vigilance decrement score, a measure of sustained attention, is based on a child's decline in attention over the course of the ACPT administration. This score is determined by computing the difference in the number of correct target responses between the first and the last (6th) trial of 96 words. If the score is quite prevalent (seen in at least 10% of the norm population of children in the same age group), it is considered age-appropriate. However, a score that is prevalent in only 1-5% of the norm population is considered age-inappropriate. The means and standard deviations of the correct target words by trial for each group are displayed in Table 13. Analysis of variance revealed no significant differences across groups. Closer examination of individual scores indicated that only 4 subjects performed below age-appropriate expectations on this measure. However, each subjects' performance did not necessarily follow a pattern of steadily decreasing performance across trials.

Insert Table 13 about here

Several chi-square analyses were performed to determine if there is an association across performance on the SCAN, ACPT, CHAPPS, and Conners Hyperactivity Index. The WRAT-3 subtests (Reading, Arithmetic) and the WIAT Listening Comprehension subtest were also included in the chi-square analyses involving the SCAN. Performance on each of the preceding variables was categorized as Pass or Fail (dichotomous) based on age-appropriate norms and/or operationalized criteria used in this study. The criteria for Pass and Fail for each variable have been included in the respective Tables. Tables were only included for significant associations (Tables 14 to 19).

Insert Tables 14-19 about here

These results indicated that there is an association between performance on the SCAN and the ACPT (re: total error score criteria) (X^2=4.00, df=1, $p<.05$) and the SCAN and the WRAT-3 Arithmetic (X^2=3.66, df=1, $p<.056$). In addition, the results revealed that the Hyperactivity Index is significantly associated with the CHAPPS Noise (X^2=6.57, df=1, $p<.05$), Quiet (X^2=5.311, df=1, $p<.05$), Auditory Attention Span (X^2=7.74, df=1, $p<.01$), and Total (X^2=8.33, df=1, $p<.01$)

GENERAL DISCUSSION AND CONCLUSIONS

The results of this study appear to support the heterogeneous nature of attention deficit hyperactivity disorder, learning disability, and central auditory processing disorder. It was hypothesized that there would be significant differences between the performance of the NA group and the other two groups on all of the variables. However, significant differences were only found on five of the Conners scales and two of the CHAPPS scales. Moreover, there were large variations of scores within each group on each of these and the other variables. If one were able to accurately categorize children within each of these groups into various subtypes, specific patterns of behaviour and performance might be more readily apparent. Yet undoubtedly there might still be some overlapping manifestations of behaviours as each child is a unique individual who will certainly not function exactly according to a predetermined label.

There appears to be evidence from the present study and from previous investigations that there is a relationship between ADHD and CAPD. The significant associations between the ACPT and the SCAN and the greater amount of difficulty demonstrated on the ACPT by children with age-inappropriate performance on the SCAN attests to this relationship. There were also significant correlations between the ACPT and the SCAN Competing Words subtest and Composite Standard Score.

Moreover, the results of this study provide evidence that CAPD and ADHD are separate constructs despite their overlapping symptomatology. If CAPD and ADHD were completely overlapping disorders, it would be expected that all of the children with ADHD would fail the SCAN, the auditory processing measure used in this study, and that all the children who failed the SCAN would also have ADHD. However, this was not the case. Only

6 of the 14 children in the ADHD group failed the SCAN and the children who failed the SCAN were not limited to the ADHD group. Rather, almost half of the total sample (i.e. 16/37) demonstrated difficulty on at least one of the auditory processing measures and these children were spread rather evenly across the groups.

The finding that central auditory processing difficulties were also exhibited by children with average performance (≥30%ile) on measures of reading decoding and computational arithmetic tasks further substantiates the independence of CAPD. Interestingly, two of the five children in the original NA group who failed the SCAN were indeed experiencing learning difficulties at school. Based on the modified groups, however, only three subjects in the NA group performed below age-appropriate expectations on the SCAN. As these three subjects all demonstrated difficulty on the AFG subtest, it is possible that the AFG may have a higher false positive rate than the other SCAN measures. Alternately, these children may indeed demonstrate difficulty listening in background noise yet it is possible that thus far they have been able to compensate for such difficulties. The implications of this latter explanation are that it would be important to acknowledge that children may present with symptomatic behaviours suggestive of CAPD (e.g., difficulty listening in noise, problems following multi-step instructions, frequently asking others to repeat themselves) yet perform within "average" expectations on academic tasks such as word identification (reading decoding) and computational arithmetic. It would be interesting to follow these three subjects over the next few years; perhaps, if they do indeed have mild auditory processing weaknesses at present, such weaknesses may be exacerbated as the listening demands increase at school.

As hypothesized, there was an association between the CHAPPS and the SCAN, the two measures designed for children suspected of having auditory processing difficulties. Specifically, significant correlations were found for the Competing Words subtest and the CHAPPS Total scores. However, the Competing Words subtest was only significantly correlated with 2 subsections of the CHAPPS, Quiet and Auditory Memory/Sequencing. No correlations were found between the SCAN and the Conners. In contrast, when analyses took into account whether a subject's score was considered age-inappropriate ("Pass"/"Fail"), the following associations were observed: (i) performance on the SCAN was associated with performance on the ACPT but not on the CHAPPS; (ii) ratings on the Hyperactivity Index were associated with ratings on the CHAPPS Total as well as Noise, Quiet, and Auditory Attention Span subsections. Moreover, the significant correlations between the SCAN CW and CSS with the ACPT Total Error Score suggest a relationship between these two tests.

The ACPT error scores were not significantly higher in the ADHD group compared to the NA and LD groups, as hypothesized. Two possible explanations for this finding include: (i) as a screening measure of attention deficit hyperactivity disorder, the ACPT may not have very high levels of sensitivity and/or specificity, possibly related to its administrative and/or scoring procedures (to be discussed subsequently); (ii) some of the subjects that met the criteria for ADHD as operationally defined for this study may not have been identified as ADHD if a more comprehensive diagnostic procedure had been implemented, including parent(s) and teacher rating scales and observation of the child in the classroom and/or home environment, if feasible. The inconsistent patterns found on the ACPT with respect to the vigilance scores (sustained attention) suggest that observations of a child's behaviour regarding attention, concentration, impulsivity, etc. may provide important information to supplement the quantitative comparison of the decrement value to the age-appropriate expectations based on standardized norms. The inconsistency that is often characteristic of children with ADHD may confound the actual decrement score, however. For example, several children were observed to "drift in and out" throughout this task. However, if the performance improved during the last trial, the decrement score may have suggested age-appropriate performance. Keith (1994) does include a checklist of behavioural observations on the ACPT test protocol (page 4). Including these observations in a verbal and/or written report may be quite valuable, particularly in cases for which the decrement score might otherwise suggest age-appropriate sustained attention on this task.

It is difficult to explain the significant difference in the estimated I.Q. scores between subjects who passed versus failed the SCAN. The simplest explanation would suggest a relationship between central auditory processing difficulties and I.Q. It is also possible that the language/learning difficulties associated with CAPD may affect childrens' performance on the WISC-III. Detailed examinations of the individual scores revealed that almost half the subjects who passed the SCAN (10/21) had estimated I.Q. scores that were greater than one standard deviation above the mean for age i.e. above the 84th %ile. As these subjects constitute approximately 48% of the total sample, rather than the expected 16% (based on the bell curve), the results for this sample may not be generalizable to the population at large. However, such findings must also be interpreted with caution as the estimated I.Q score is only based on 2 rather than 10 WISC-III subtests (Block Design, Vocabulary).

Although the original CHAPPS scale was modified for this study in an attempt to render it more "user friendly," most of the parents reported that it was difficult to rate their child's behaviour as compared to the child's peers since they do not typically observe their child amongst same-age peers under all of the given listening conditions. Furthermore, many parents had difficulty differentiating between whether a child's difficulty hearing and understanding is due to difficulty processing or difficulty attending to the spoken message. For example, comments included, "It's difficult to know whether he has heard and chosen not to respond or whether he was too distracted to take it in", "If she initially attended and can initially repeat it back, then I don't think time is a factor," "...according to her teacher." Of particular interest was the significant association found between the Conners Hyperactivity Index and all but two (Ideal, Multiple Inputs) of the CHAPPS subsections. The Noise subsection, in particular, should be interpreted with caution as it might be misperceived as an auditory processing measure when in fact, it may be the child's attention that is being rated, regardless of the listening condition. These comments also suggest that it would be preferable to have the child's teacher(s) fill out this form; the parents could either also fill out the CHAPPS and/or another scale that qualifies how much difficulty the child has in a non-school environment when s/he is required to listen to spoken information. The CHAPPS might be more useful in terms of intervention planning, as well as in measuring the effects of intervention, as suggested by its authors (Smoski et al., 1992). It would probably be most effective to use the parents' and teachers' comments on this type of scale as a framework for a more in-depth, qualitative examination of the child's listening/attentional difficulties by way of clinical interviews. When the presenting complaints concern listening difficulty, the CHAPPS or a similar such rating scale might be more appropriate than the Conners questionnaire as it includes ratings of attention as it relates to communication.

Although the SCAN may provide an indication of an individual's auditory processing difficulties, it does not address all aspects of central auditory processing and therefore it may not correlate, for example, with the WRAT-3 Reading and Spelling scores as well as a test that requires auditory discrimination of speech and nonspeech stimuli with acoustic features similar to speech, in quiet and in noise (Breedin, Martin, & Jerger, 1989; Jerger, Martin, & Jerger, 1987). Based on the results of this study, the FW test may not be as sensitive to auditory processing difficulties as the other two subtests of the SCAN. Furthermore, dichotic tests such as the competing words test may be influenced by auditory processing, attention, and possibly short-term memory. A number of investigators have demonstrated abnormal performance on dichotic tests for patients with lesions involving the auditory reception areas in the brain (Hughes, 1983; Kimura, 1961; Musiek, 1983; Olsen, 1983). For example, Musiek administered three dichotic tests (Dichotic Digits, Staggered Spondaic Word, Competing Sentences) to thirty adults subjects with surgically, radiologically, or neurologically diagnosed intracranial lesions (brainstem or hemispheric). Abnormal performance was observed for 80%, 70% and 53% of the subjects on these tests, respectively. Since there is a maturational effect on dichotic tests, Keith (1983) suggests that below average performance may occur because of a developmental delay in the maturation of the auditory nervous system rather than a specific lesion. Interpretation on these tests generally involves comparing the child's right and left ear performance on tests of competing digits, syllables, words, or sentences to the performance expected by children the same age (based on age-related normative data). Performance on dichotic tests may also be depressed in children with ADHD and/or LD; for these children, there may or may not be involvement of the auditory reception areas of the central nervous system. Future research may help to determine modality specificity to help differentiate global attentional problems from processing problems specific to auditory information, as suggested by McFarland and Cacace (1995). For example, "difficulty attending" may occur for auditory and/or visual tasks. Without a comprehensive evaluation, it may not be appropriate to infer the presence of an auditory processing disorder if a given individual's difficulties are not restricted to the auditory modality.

On the Auditory Figure Ground subtest of the SCAN, monosyllabic words are presented at a signal-to-noise ratio (S:N) of +8dB. The actual noise floor of a typical classroom and the complexity of that environmental auditory noise may make it even more difficult for children to listen in school. Children who perform within normal limits on the AFG subtest may still have particular difficulty hearing and understanding in a noisy environment (classroom, restaurant). When the presenting complaint is difficulty listening in the classroom, an alternative approach to auditory figure ground discrimination testing may be to administer word lists at various S:N ratios to determine where the breakdown occurs; observing the child in the classroom and measuring the noise floor may also contribute useful information. Unfortunately, there do not appear to be well-normed figure ground tests of this nature.

Despite attempts to rule out the potential influence of attention, memory ,and language on batteries of central auditory processing tests, it may still be difficult to ensure that the performance of children who perform below age-appropriate expectations on such tests have not been otherwise influenced, particularly for children with attentional difficulties. This is not to say that such tests are useless for this population. Indeed, difficulties on CAPD tests may suggest the necessity to further evaluate concerns regarding a child's behavioural and/or learning status. For some children, poor performance on such tests in combination with qualitative observations of behaviour/performance at home/school that are consistent with auditory processing difficulties may be sufficient to render a diagnosis of CAPD. Lest we forget, tests frequently used by speech-language pathologists and psychologists may also be influenced by other variables other than those they propose to tap. As the group of children who failed the ACPT also demonstrated relatively more difficulty on Listening Comprehension, one might suggest that this test is influenced by attention. Yet other children who reportedly have difficulties with attention and concentration performed relatively well on this listening test. Similarly, the group of children who failed the SCAN also had relatively more difficulty on the Block Design and Vocabulary subtests than those who passed the SCAN. However, this finding does not necessarily mean that auditory processing difficulties in and of themselves cause relatively decreased performance on Block Design and Vocabulary. As a final example, the Digit Span subtest of the WISC-III may also be influenced by several other factors, including attention span, distractibility, learning disabilities/ADHD, and anxiety (Kaufman, 1994).

There may therefore be several possible explanations for poor performance on central auditory processing tests that should be recognized prior to making a differential diagnosis, including: attentional difficulties may hamper the child's ability to process auditory information; there may be a true auditory processing disorder; attentional difficulties may coexist with auditory processing difficulties. Furthermore, Keller's (1992) query as to whether many of the children who experience CAPD are the children who are being described as having ADHD without hyperactivity should be further explored. Performance on an auditory vigilance test may contribute additional information when ADHD is suspected; however, it may be most advantageous to compare a child's performance on auditory and visual continuous performance tests. These results should still be interpreted with caution due to the consistent inconsistency typically observed in children with ADHD.

Due to many funding cutbacks in the school boards, children with auditory processing difficulties may not be otherwise identified if a routine audiological evaluation revealed normal hearing sensitivity, particularly if the presenting complaint is inattention rather than excessive motor activity and/or impulsivity which might be more disruptive or "bothersome" to the child's educators and caregivers; however, "evidence" from an audiologist of poor performance on a given CAPD test battery may alert the child's family and educators that a more in-depth evaluation of the child's learning profile is warranted. In other cases, naming a child's attentional and/or listening difficulties as attention deficit hyperactivity disorder and/or central auditory processing disorder may take the blame off the child and initiate a "what can we do to help this child?" approach. A more qualitative assessment of attention and memory may also help pinpoint the child's difficulties in order to understand how to best intervene (Levine, 1994).

The findings from this study may be limited in terms of their ability to form generalizations to the population at large due to the small total sample size (N=37), and in particular since each identified group (NA, LD, ADHD) consisted of only 10-14 subjects. A larger sample size used to compare the scores of children with "pure" ADHD and "pure" CAPD on a variety of measures that address both auditory attention and other aspects of attention might be more discriminative. However, as noted previously, it is possible that many children with presumably pure ADHD indeed have auditory processing problems. If such problems are specific to difficulties with extraneous noises, they may go undetected since the behaviours (distractibility, concentration problems, hyperactivity) associated with such listening difficulties are similar, if not exactly the same as those associated with other types of attentional problems.

The criteria for group assignment in this study (NA, LD, ADHD) may have affected the comparisons across and between groups. Only two achievement measures (reading, arithmetic) were used to determine whether or not a child is normally achieving. A child may have performed within the average range (≥30%ile) on these two subtests but may have presented with poorer performance on other measures such as spelling or pseudoword reading. Additionally, despite meeting the criteria for the NA group, there had been some concerns from the parent(s) and/or teacher(s) regarding the academic/behavioural status of 8 of the 13 children in this group, 3 of whom had actually been identified as exceptional at school. Nonetheless, the pattern of results was rather similar when these 3 children were placed in the NA group and when they were then placed in the LD group.

The operational definition of ADHD was mostly based on criteria regarding the Hyperactivity Index rating on the Conners Parent Rating Scale. Inclusion of a teacher rating scale is highly recommended in future studies, particularly since a diagnosis of ADHD should include corroborating evidence from multiple sources (parents, teachers, other caregivers, and the child him/herself). It is important to note as well that although widely used in research and clinical practice, the Conners Scales are only rated as having "adequate" reliability and validity (Sattler, 1994) and tend to confound hyperactive behaviour with conduct problems and anxiety. These scales may also not be as sensitive to symptoms of inattention as they are to hyperactivity and impulsivity. Therefore more stringent criteria that includes teacher rating scales as well as other achievement screening tests are recommended for future studies. As there is evidence of significant interrelationships between language disorder and attention deficit disorder (Love et al., 1988), as well as evidence of an association between speech/language disorders and learning disorder (Baker & Cantwell, 1987), screening children for expressive and receptive language problems might also help to provide for more homogeneous groups.

Many children who are referred for central auditory processing testing have reading difficulties. Moreover, children diagnosed with LD and/or ADHD may or may not have auditory processing problems which may or may not be associated with reading problems. Another study might compare the reading ability of children diagnosed with CAPD based on the CHAPPS and a more comprehensive central auditory processing battery, including perceptual measures that assess auditory discrimination and temporal sequencing with children who have ADHD only (and presumably no CAPD).

Although the present study did not specifically address this issue, it appears that parents of children with learning and/or behavioural difficulties are often caught in between the so-called "professionals", being informed of different diagnoses following a variety of different evaluations. In many cases, there has not been a sufficient attempt or even any attempt at all, to collaborate the varied pieces of information. As Keller (1992) indicated, whether a child is diagnosed as having an auditory processing disorder or an attention deficit disorder may depend on whether or not the diagnostician is an audiologist or a psychologist. Unfortunately, children with learning difficulties often present with comorbid difficulties and a differential diagnosis becomes much more confusing. Nonetheless, unless parents are properly informed of the child's strengths and weaknesses and their concerns regarding confusing terminology are addressed, we are doing a disservice for both parent and child alike.

Despite concerns regarding the influence of nonauditory variables on audiologic measures of CAPD, certain patterns of results may be commonly found in children with CAPD, such as a marked left ear deficit (Hall et al., 1993; Stach & Loiselle, 1993). For example, if a child demonstrates age-appropriate performance for the right ear but performs below age expectations for the left ear on a task which requires identifying words presented in background noise, it suggests that cognitive, linguistic and attentional factors may be ruled out (Stach & Loiselle, 1993) since such factors would likely affect performance similarly for both ears. An analysis of the findings on tests purporting to measure central auditory processing abilities, including specific response errors may therefore help to rule out other disorders with similar symptoms such as language/linguistic, cognitive deficits, learning disabilities and attention deficit disorders (Hall et al., 1993). Furthermore, a multidisciplinary approach may help differentiate ADHD from CAPD (either of which may involve a LD as well) from a combination of the two (ADHD with CAPD);or rather, an interdisciplinary approach, in which each team member has at least some knowledge and understanding of the other members' fields may be most effective. In particular, audiologists, speech-language pathologists, psychologists, and educational specialists need to collaborate their efforts and approaches so that their "diagnoses" and recommendations for intervention have both clinical and practical relevance. The terms auditory processing, learning disability, and attention deficit have not as of yet been clearly defined and may currently only operate as umbrella terms. It is not the actual label that should be emphasized here; rather it is specifying the problems so that appropriate management can follow. For example, a child may be diagnosed as having ADHD yet s/he may also have central auditory processing problems that have not been identified. Although stimulant medication such as Ritalin may improve this child's listening abilities by improving his/her attentional or behavioural difficulties associated with ADHD, the medication may not actually "improve" his/her auditory processing problems per se (Ivey & Jerome, 1991). In this situation, therefore, appropriate intervention and/or remediation strategies may be necessary to alleviate the difficulties related to a central auditory processing disorder.

Assessment procedures that have high levels of sensitivity, specificity, and reliability may help differentiate auditory processing problems from attentional problems from other disorders associated with learning difficulty (Musiek & Chermak, 1994). It appears that auditory processing difficulties may or may not contribute to the difficulties experienced by children with LD and/or ADHD and that CAPD, LD and ADHD are separate yet overlapping disorders. Each of these "disorders" may still vary from one individual to the next. Despite the confusion surrounding the definitions of attention deficit hyperactivity disorder, learning disability, and central auditory processing disorder, an interdisciplinary approach, incorporating the expertise from a number of different professionals with both similar and varying perspectives, is necessary if the goal is, as it should be, to maximize a child's learning potential.

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APPENDIX A

Letter of Permission

Dear Parent:

I am a graduate student in the Department of Applied Psychology at the Ontario Institute for Studies in Education. I am conducting a study of children with learning difficulties, particularly related to listening and attention. My work will be supervised by Professor Linda Siegel (Psychologist). The purpose of the study is to understand how these children perform on a variety of tasks that are frequently used to assess children with academic problems.

When a child is having problems at school, s/he is often referred for a hearing test to rule out a hearing loss. As a practising audiologist, I am aware that there are many children who have normal hearing sensitivity yet seem to act as if they have hearing difficulties. These children may have attentional and/or listening problems, particularly in more difficult listening situations. In addition, some of them may hear what is being said but have difficulty processing or making sense of what they hear. It is hoped that by better understanding the specific difficulties that these children are experiencing, the appropriate type of management may be recommended and implemented in the classroom and/or home setting.

I would like permission to include your child in this study. If you agree, your child will be given a hearing test; academic tests (e.g., reading, math, listening comprehension); auditory processing tests; and attentional/listening tests. In addition, I will ask you to complete two questionnaires (rating scales), giving me your view of your child's listening and/or behavioural difficulties. The total amount of time that will be needed to complete these tasks will be approximately 2-3 hours, depending on whether or not your child has had any recent previous assessments. Your child will be given breaks during the testing period as needed. The tasks may be given in one to two sessions (within a time span of approximately 3 weeks), depending both on your preference and your child's needs.

Your participation in this study is entirely voluntary and you may withdraw your child from the study at any time. All of the information obtained from this study will remain confidential. I will share the results with you after the completion of all of the tasks. Some of the results will be shared with the developer of the tests, as part of his own research interests; your child's name, however, will not be released. If you would like (with written permission) the results may also be provided to other psychological and/or audiological professionals.

Please indicate if you would like your child to participate in this study by reading and signing the attached consent form. If you would prefer, prior to signing the form, I will contact you by telephone to address any questions or concerns you might have.

Sincerely,

Elana Miller

Research Consent Form

I, ______________________________, give permission for my child, ______________________________, to participate in the research study being conducted by Elana Miller.

I have read the letter explaining the study and its purpose. I understand that my child will be given the following types of tests: a hearing test; academic tests (e.g., reading, math, listening comprehension); auditory processing tests; and attentional/listening tests. I also realize that I will be asked to complete two questionnaires. I understand that both my participation and that of my child's is entirely voluntary and that I may withdraw my child from the study at any time. I also recognize that test results and any information I share about my child will remain confidential and only released to other psychological and/or audiological professionals with my written consent.

I understand that the results will be explained to me and that a brief written report will be provided at my request.

Signature of Parent: ______________________________

Date: ________________________

APPENDIX B

APPENDIX

Children's Auditory Processing Performance Scale (CHAPPS).

Child's name ____________________ Age (years ______months ______) Date ______________

Name of person
completing questionnaire ______________________________ Relationship: parent - teacher
other - ________

PLEASE READ INSTRUCTIONS CAREFULLY

Answer all questions by comparing this child to other children of similar age and background. Do not answer the questions based only on the difficulty of the listening condition. For example, all 8-year-old children, to a certain extent, may not hear and understand when listening in a noisy room. That is, this would be a difficult listening condition for all children. However, some children may have more difficulty in this listening condition than others You must judge whether or not this child has MORE difficulty than other children . . each listening condition cited. Please make your judgment using the following response choices: (CIRCLE a number for each iter

RESPONSE CHOICES:

LESS DIFFICULTY ------------------------ +1
SAME AMOUNT OF DIFFICULTY --------------- 0
SLIGHTLY MORE DIFFICULTY ---------------- −1
MORE DIFFICULTY ------------------------ −2
CONSIDERABLY MORE DIFFICULTY ----------- −3
SIGNIFICANTLY MORE DIFFICULTY ---------- −4
CANNOT FUNCTION AT ALL ----------------- −5

Listening Condition - NOISE:

If listening in a room where there is background noise such as a TV set, music, others talking, children playing, etc. this child has difficulty hearing and understanding (compared to other children of similar age and background).

1. When paying attention .... +1 0 −1 −2 −3 −4 −5
2. When being asked a question .... +1 0 −1 −2 −3 −4 −5
3. When being given simple instructions .... +1 0 −1 −2 −3 −4 −5
4. When being given complicated, multiple, instructions .... +1 0 −1 −2 −3 −4 −5
5. When not paying attention .... +1 0 −1 −2 −3 −4 −5
6. When involved with other activities, ie., coloring, reading, etc. .... +1 0 −1 −2 −3 −4 −
7. When listening with a group of children .... +1 0 −1 −2 −3 −4 −

Listening Condition - QUIET:

If listening in a quiet room (others may be present, but are being quiet), this child has difficulty hearing and understanding (compared to other children).

8. When paying attention .... +1 0 −1 −2 −3 −4 −5
9. When being asked a question .... +1 0 −1 −2 −3 −4 −5
10. When being given simple instructions .... +1 0 −1 −2 −3 −4 −5
11. When being given complicated, multiple, instructions .... +1 0 −1 −2 −3 −4 −5
12. When not paying attention .... +1 0 −1 −2 −3 −4 −5
13. When involved with other activities, i.e., coloring, reading, etc. .... +1 0 −1 −2 −3 −4 −
14. When listening with a group of children .... +1 0 −1 −2 −3 −4 −5

Listening Condition - IDEAL:

When listening in a quiet room, no distractions, face-to-face, and with good eye contact, this child has difficulty hearing and understanding (compared to other children).

15. When being asked a question .... +1 0 −1 −2 −3 −4 −5
16. When being given simple instructions .... +1 0 −1 −2 −3 −4 −5
17. When being given complicated, multiple, instructions .... +1 0 −1 −2 −3 −4 −5

Listening Condition - MULTIPLE INPUTS:

When, in addition to listening, there is also some other form of input, (i.e., visual, tactile, etc.) this child has difficulty hearing and understanding (compared to other children).

18. When listening and watching the speaker's face .... +1 0 −1 −2 −3 −4 −5
19. When listening and reading material that is also being read out loud by another .... +1 0 −1 −2 −3 −4 −5
20. When listening and watching someone provide an illustration such as a model, drawing, information on the chalkboard, etc. .... +1 0 −1 −2 −3 −4 −5

Listening Condition - <u>AUDITORY MEMORY/SEQUENCING</u>:

If required to recall spoken information, this child has difficulty (compared to other children).

21. Immediately recalling information such as a word, word spelling, numbers, etc. .... +1 0 −1 −2 −3 −4 −5
22. Immediately recalling simple instructions .... +1 0 −1 −2 −3 −4 −5
23. Immediately recalling multiple instructions .... +1 0 −1 −2 −3 −4 −5
24. Not only recalling information, but also the order or sequence of the information .... +1 0 −1 −2 −3 −4 −5
25. When delayed recollection (1 hour or more) of words, word spelling, numbers, etc. is required .... +1 0 −1 −2 −3 −4 −5
26. When delayed recollection (1 hour or more) of simple instructions is required .... +1 0 −1 −2 −3 −4 −5
27. When delayed recollection (1 hour or more) of multiple instructions is required .... +1 0 −1 −2 −3 −4 −5
28. When delayed recollection (24 hours or more) is required .... +1 0 −1 −2 −3 −4 −5

Listening Condition - <u>AUDITORY ATTENTION SPAN</u>:

If extended periods of listening are required, this child has difficulty paying attention, that is, being attentive to what is being said (compared to other children).

29. When the listening time is less than 5 minutes .... +1 0 −1 −2 −3 −4 −5
30. When the listening time is 5–10 minutes .... +1 0 −1 −2 −3 −4 −5
31. When the listening time is over 10 minutes .... +1 0 −1 −2 −3 −4 −5
32. When listening in a quiet room .... +1 0 −1 −2 −3 −4 −5
33. When listening in a noisy room .... +1 0 −1 −2 −3 −4 −5
34. When listening first thing in the morning .... +1 0 −1 −2 −3 −4 −5
35. When listening near the end of the day, before supper time .... +1 0 −1 −2 −3 −4 −5
36. When listening in a room where there are also visual distractions .... +1 0 −1 −2 −3 −4 −5

Children's Auditory Processing Performance Scale (CHAPPS)

Child's Name: ______________________________
Age: Years ____________ Months ____________
Date: ____________________
Person completing questionnaire: ______________________________
Relationship: parent - teacher
Other - ________________

PLEASE READ INSTRUCTIONS CAREFULLY

Answer all the questions by comparing this child to other children of similar age and background. Do not answer the questions based only on the difficulty of the listening condition. For example, all 8-year-old children, to a certain extent, may not hear and understand when listening in a noisy room. That is, this would be a difficult listening condition for all children. However some children may have more difficulty in this listening condition than others. You must judge whether or not this child has MORE difficulty than other children in each listening condition cited. Please make your judgement using the following response choices: (Please make a ✓ for each item.)

RESPONSE CHOICES:

LESS DIFFICULTY
SAME AMOUNT OF DIFFICULTY
MORE DIFFICULTY

Listening Condition - <u>NOISE</u>:

If listening in a room where there is background noise such as a TV set, music, others talking, children playing, etc., this child has difficulty hearing and understanding (compared to other children of similar age and background).

		Amount of Difficulty		
		Less	Same	More
1.	When paying attention	◫	☐	☐
2.	When being asked a question	☐	☐	☐
3.	When being given simple instructions	☐	■	☐
4.	When being given complicated, multiple, instructions	☐	☐	☐
5.	When not paying attention	◫	☐	☐
6.	When involved with other activities, i.e. colouring, reading, etc.	☐	☐	☐
7.	When listening with a group of children	☐	■	☐

Listening Condition - <u>QUIET</u>:

If listening in a quiet room (others may be present, but are being quiet), this child has difficulty hearing and understanding (compared to other children).

		Amount of Difficulty		
		Less	Same	More
8.	When paying attention	☐	☐	☐
9.	When being asked a question	☐	☐	■
10.	When being given simple instructions	☐	☐	☐
11.	When being given complicated, multiple, instructions	☐	☐	☐
12.	When not paying attention	☐	☐	☐
13.	When involved with other activities, i.e. colouring, reading, etc.	☐	☐	☐
14.	When listening with a group of children	☐	☐	☐

Listening Condition - <u>IDEAL</u>:

When listening in a quiet room, no distractions, face-to-face, and with good eye contact, this child has difficulty hearing and understanding (compared to other children).

		Amount of Difficulty: Less	Same	More
15.	When being asked a question	☐	☐	☐
16.	When being given simple instructions	☐	☐	☐
17.	When being given complicated, multiple, instructions	☐	☐	☐

Listening Condition - <u>MULTIPLE INPUTS</u>:

When, in addition to listening, there is also some other form of input, (i.e., visual, tactile, etc.) this child has difficulty hearing and understanding (compared to other children).

		Amount of Difficulty: Less	Same	More
18.	When listening and watching the speaker's face	☐	☐	☐
19.	When listening and reading material that is also being read out loud by another	☒	☐	☐
20.	When listening and watching someone provide an illustration such as a model, drawing, information on the chalkboard, etc.	☐	☐	☐

Listening Condition - <u>AUDITORY MEMORY/SEQUENCING</u>:

If required to recall spoken information, this child has difficulty (compared to other children).

		Amount of Difficulty: Less	Same	More
21.	Immediately recalling information such as a word, word spelling, numbers, etc.	☐	☐	☐
22.	Immediately recalling simple instructions	☐	☐	☐
23.	Immediately recalling multiple instructions	☐	☐	☐
24.	Not only recalling information, but also the <u>order</u> or <u>sequence</u> of the information	☐	☐	☐
25.	When delayed recollection (1 hour or more) of words, word spelling, number, etc. is required	☒	☐	☐
26.	When delayed recollection (1 hour or more) of simple instructions is required	☐	☐	☐
27.	When delayed recollection (1 hour or more) of multiple instructions is required	☐	☐	☐
28.	When delayed recollection (24 hours or more) is required	☐	☐	☐

Listening Condition - <u>AUDITORY ATTENTION SPAN</u>:

If extended periods of listening are required, this child has difficulty paying attention, that is being attentive to what is being said (compared to other children).

		Amount of Difficulty: Less	Same	More
29.	When the listening time is less than 5 minutes	☐	☐	☐
30.	When the listening time is 5-10 minutes	☐	☐	☐
31.	When the listening time is over 10 minutes	☐	☐	☐
32.	When listening in a quiet room	☐	☐	☐
33.	When listening in a noisy room	☐	☐	☐
34.	When listening first thing in the morning	☐	☐	☐
35.	When listening near the end of the day, before supper time	☒	☐	☐
36.	When listening in a room where there are also visual distractions	☐	☐	☐

LIST OF TABLES

Table 1

Group Means and Standard Deviations for Independent Variables: Original Groups

Variable Mean (SD)	NA (n=13)	LD (n=10)	ADHD (n=14)	F
SCAN (percentile)				
Composite Standard Score	39.38 (24.65)	41.10 (22.63)	40.64 (26.82)	.02
Filtered Words	48.08 (20.03)	61.30 (19.35)	56.50 (21.31)	1.27
Auditory Figure Ground	36.08 (18.48)	38.30 (21.59)	41.71 (24.98)	.23
Competing Words	44.69 (26.49)	41.30 (30.38)	37.86 (27.92)	.20
WRAT-3 (percentile)				
Reading	60.08 (23.23)	35.60 (32.22)	42.84 (31.29)	2.24
Arithmetic[a]	58.77 (18.50)	25.10 (15.76)	45.14 (22.44)	8.46**
WIAT (percentile)				
Listening Comprehension	61.46 (24.26)	58.84 (29.82)	61.43 (26.37)	.03
WISC-III				
Block Design	11.83 (3.66)	10.63 (4.72)	11.08 (4.09)	.23
Vocabulary	10.42 (2.19)	11.88 (2.70)	10.54 (3.43)	.73
Digit Span	10.58 (2.97)	11.75 (3.33)	10.54 (2.33)	.54
I.Q. (Estimated) percentile	60.00 (25.63)	58.84 (35.68)	54.61 (29.29)	.11

**$p < .01$

Note:
NA = Normally Achieving
LD = Learning Disabled,
ADHD = Attention Deficit Hyperactivity Disorder

[a]The NA group had significantly higher scores than the LD group only which did not differ significantly from the ADHD group.

Continued next page

Table 1 (Continued)

Group Means and Standard Deviations for Independent Variables: Original Groups

Variable Mean (SD)	NA (n=13)	LD (n=10)	ADHD (n=14)	F
Conners (t-score)				
Conduct Problem[a]	47.46 (7.96)	50.10 (16.66)	64.79 (15.47)	6.18**
Learning Problem[a]	58.85 (11.89)	63.50 (18.93)	86.00 (11.61)	14.32***
Psychosomatic[b]	48.92 (10.27)	46.70 (6.13)	59.36 (16.75)	3.75*
Impulsive - Hyperactive[a]	54.46 (10.37)	50.20 (9.51)	69.00 (10.81)	10.98***
Anxiety	54.31 (8.97)	59.10 (12.81)	63.71 (18.55)	1.47
Hyperactivity Index[a]	53.54 (8.39)	54.20 (12.12)	79.86 (8.36)	32.62***
CHAPPS				
Noise[c]	2.09 (.50)	2.34 (.48)	2.61 (.36)	4.68*
Quiet[b]	2.00 (.46)	2.01 (.54)	2.44 (.37)	3.97*
Ideal	1.85 (.59)	1.67 (.50)	2.02 (.53)	1.27
Multiple Inputs	1.87 (.57)	1.87 (.45)	2.21 (.52)	1.91
Auditory Memory/Sequencing	2.14 (.62)	2.20 (.45)	2.34 (.66)	.40
Auditory Attention Span	2.04 (.37)	2.24 (.70)	2.45 (.35)	2.48
Total	2.01 (.46)	2.13 (.45)	2.40 (.35)	3.01
ACPT				
Total Error Score (z-score)	.13	.65	.53	.54
Total Error Score	13.31 (10.90)	22.10 (13.84)	21.14 (21.06)	1.10
Inattention Errors	9.92 (8.51)	19.00 (12.22)	16.00 (16.29)	1.52
Impulsivity Errors	3.38 (3.28)	3.10 (3.14)	5.14 (5.39)	.89

*$p<.05$
**$p<.01$
***$p<.001$

Note:
NA = Normally Achieving
LD = Learning Disabled
ADHD = Attention Deficit Hyperactivity Disorder

[a]The ADHD group had significantly higher scores than the NA and LD groups on these subscales but the NA and LD groups did not differ significantly from each other.
[b]The Scheffe test did not reveal which pairs of scores differed significantly on these subscales.
[c]The ADHD group had higher scores than only the NA group who did not differ significantly from the LD group.

Table 2

Group Means and Standard Deviations for Independent Variables: Modified Groups

Variable Mean (SD)	NA (n=10)	LD (n=13)	ADHD (n=14)	F
SCAN (percentile)				
Composite Standard Score	43.40 (21.57)	37.62 (25.08)	40.64 (26.82)	.15
Filtered Words	47.50 (22.27)	58.69 (18.26)	56.50 (21.31)	.91
Auditory Figure Ground	39.40 (17.19)	35.23 (21.53)	41.71 (24.98)	.30
Competing Words	49.20 (22.24)	38.62 (31.24)	37.86 (27.92)	.57
WRAT-3 (percentile)				
Reading	62.40 (25.70)	39.46 (29.28)	42.84 (31.29)	1.97
Arithmetic[a]	58.90 (20.79)	32.77 (20.41)	45.14 (22.44)	4.26*
WIAT (percentile)				
Listening Comprehension	70.00 (19.89)	52.92 (28.71)	61.43 (26.37)	1.25
WISC-III				
Block Design	12.40 (3.66)	10.30 (4.32)	11.08 (4.09)	.69
Vocabulary	10.50 (2.42)	11.50 (2.51)	10.54 (3.43)	.40
Digit Span	11.10 (3.00)	11.00 (3.33)	10.54 (2.33)	.13
I.Q. (Estimated) percentile	63.50 (25.84)	55.57 (33.03)	54.61 (29.29)	.29

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

Note:
NA = Normally Achieving
LD = Learning Disabled
ADHD = Attention Deficit Hyperactivity Disorder

[a]The NA group had significantly higher scores than the LD group only which did not differ significantly from the ADHD group.

Continued next page

Table 2 (Continued)

Group Means and Standard Deviations for Independent Variables: Modified Groups

Variable Mean (SD)	NA (n=10)	LD (n=13)	ADHD (n=14)	F
Conners (t-score)				
Conduct Problem[a]	47.30 (8.81)	49.62 (14.63)	64.79 (15.47)	6.15**
Learning Problem[a]	56.90 (12.66)	63.92 (16.64)	86.00 (11.61)	15.07***
Psychosomatic[b]	49.70 (11.41)	46.62 (5.81)	59.36 (16.75)	3.86*
Impulsive - Hyperactive[a]	53.50 (11.64)	51.92 (9.01)	69.00 (10.81)	10.31***
Anxiety	53.70 (9.98)	58.46 (11.35)	63.71 (18.55)	1.46
Hyperactivity Index[a]	52.70 (8.72)	54.69 (11.04)	79.86 (8.36)	32.94***
CHAPPS				
Noise[c]	2.00 (.53)	2.35 (.43)	2.61 (.36)	5.80**
Quiet[b]	1.90 (.48)	2.09 (.49)	2.44 (.37)	4.59*
Ideal	1.67 (.54)	1.85 (.55)	2.02 (.53)	1.27
Multiple Inputs[c]	1.67 (.47)	2.03 (.50)	2.21 (.52)	3.54*
Auditory Memory/Sequencing	1.99 (.57)	2.31 (.49)	2.34 (.66)	1.23
Auditory Attention Span	1.98 (.39)	2.24 (.62)	2.45 (.35)	2.93
Total[c]	1.92 (.45)	2.18 (.43)	2.40 (.35)	4.11*
ACPT				
Total Error Score (z-score)	.07	.57	.53	.52
Total Error Score	14.00 (11.49)	19.54 (13.62)	21.14 (21.06)	.58
Inattention Errors	10.70 (9.37)	16.31 (11.94)	16.00 (16.29)	.62
Impulsivity Errors	3.30 (2.75)	3.23 (3.54)	5.14 (5.39)	.88

*p<.05
**p<.01
***p<.001

Note:
NA = Normally Achieving
LD = Learning Disabled,
ADHD = Attention Deficit Hyperactivity Disorder

[a]The ADHD group had significantly higher scores than the NA and LD groups on these subscales but the NA and LD groups did not differ significantly from each other.
[b]The Scheffe test did not reveal which pairs of scores differed significantly on these subscales.
[c]The ADHD group had higher scores than only the NA group who did not differ significantly from the LD group.

Table 3

Means and Standard Deviations for Reading Disabled, Arithmetic Disabled, and Reading-Arithmetic Disabled

	Group			
Variable Mean (SD)	RD (n=7)	AD (n=6)	RD-AD (n=5)	F
SCAN (percentile)				
Composite Standard Score	44.00 (21.97)	39.67 (29.56)	22.60 (15.71)	1.29
Filtered Words	59.57 (16.91)	54.67 (25.72)	56.80 (20.00)	.09
Auditory Figure Ground	35.14 (22.12)	38.83 (22.48)	40.80 (25.32)	.09
Competing Words	46.43 (27.61)	40.50 (35.57)	15.80 (13.07)	1.89
WIAT (percentile)				
Listening Comprehension	68.86 (13.15)	63.17 (31.23)	35.40 (30.25)	2.77
WISC-III				
Block Design	12.83 (2.64)	9.00 (4.94)	9.00 (3.46)	1.75
Vocabulary	10.50 (3.21)	11.33 (2.80)	8.33 (1.15)	1.16
Digit Span	11.83 (2.48)	11.50 (3.21)	8.00 (.000)	2.38
I.Q. (Estimated) percentile	68.00 (26.37)	45.28 (34.58)	32.33 (18.56)	1.75

*$p<.05$
**$p<.01$
***$p<.001$

Note:
RD = Reading Disabled
AD = Arithmetic Disabled
RD-AD = Reading and Arithmetic Disabled

Continued next page

Table 3 (Continued)

Means and Standard Deviations for Reading Disabled, Arithmetic Disabled, and Reading-Arithmetic Disabled

Variable Mean (SD)	RD (n=7)	AD (n=6)	RD-AD (n=5)	F
Conners (t-score)				
Conduct Problem[a]	66.57 (13.44)	42.83 (4.54)	55.60 (8.06)	5.48*
Learning Problem	76.14 (20.19)	73.33 (25.13)	70.80 (16.29)	.10
Psychosomatic	57.43 (20.43)	46.67 (7.03)	48.20 (6.22)	1.14
Impulsive - Hyperactive	63.86 (13.92)	52.00 (14.18)	54.20 (11.92)	1.35
Anxiety	62.57 (20.72)	53.00 (7.24)	63.60 (3.13)	.86
Hyperactivity Index	74.00 (15.79)	60.83 (18.43)	60.40 (13.74)	1.45
CHAPPS				
Noise	2.53 (.42)	2.48 (.45)	2.49 (.48)	.03
Quiet	2.33 (.39)	2.14 (.71)	2.29 (.57)	.18
Ideal	2.00 (.27)	1.61 (.68)	2.00 (.71)	.95
Multiple Inputs	2.33 (.61)	1.89 (.17)	2.00 (.71)	1.20
Auditory Memory/Sequencing	2.38 (.40)	2.08 (.57)	2.65 (.38)	2.09
Auditory Attention Span	2.45 (.27)	2.19 (.77)	2.40 (.67)	.34
Total	2.38 (.32)	2.14 (.52)	2.38 (.49)	.59
ACPT (z-score)				
Total Error Score[b]	.19 (.90)	-.11 (.86)	2.26 (.80)	6.26*

*$p<.05$
**$p<.01$
***$p<.001$

Note:
RD = Reading Disabled
AD = Arithmetic Disabled
RD-AD = Reading and Arithmetic Disabled

[a]The RD subgroup had a significantly higher score than the AD subgroup.
[b]The RD-AD subgroup had a significantly higher score than the RD and the AD subgroups who did not differ significantly from each other.

Table 4

Means and Standard Deviations for ADHD (No LD) and ADHD-LD

Variable Mean (SD)	ADHD (No LD) (n=6)	ADHD-LD (n=8)	F
SCAN (percentile)			
Composite Standard Score	53.50 (24.53)	31.00 (25.66)	2.73
Filtered Words	62.50 (22.70)	52.00 (20.53)	.82
Auditory Figure Ground	47.33 (27.75)	37.50 (23.70)	.51
Competing Words	49.33 (25.29)	29.25 (28.17)	1.90
WIAT (percentile)			
Listening Comprehension	68.50 (26.23)	56.13 (26.93)	.74
WISC-III			
Block Design	11.83 (4.83)	10.43 (3.60)	.36
Vocabulary	12.67 (3.67)	8.71 (1.98)	6.12*
Digit Span	11.17 (2.64)	10.00 (2.08)	.80
I.Q. (Estimated) percentile	67.32 (32.07)	43.71 (23.63)	2.33

*$p<.05$
**$p<.01$
***$p<.001$

Note:
ADHD = Attention Deficit Hyperactivity Disorder
LD = Learning Disabled

Continued next page

Table 4 (Continued)

Means and Standard Deviations for ADHD (No LD) and ADHD-LD

	Group		
Variable Mean (SD)	ADHD (No LD) (n=6)	ADHD-LD (n=8)	F
Conners (t-score)			
Conduct Problem	67.83 (19.40)	62.50 (12.72)	.39
Learning Problem	85.33 (10.73)	86.50 (12.94)	.03
Psychosomatic	62.50 (14.18)	57.00 (19.03)	.35
Impulsive - Hyperactive	70.17 (9.81)	68.00 (12.29)	.12
Anxiety	68.17 (19.07)	60.38 (18.69)	.59
Hyperactivity Index	79.17 (10.53)	80.38 (7.05)	.07
CHAPPS			
Noise	2.50 (.49)	2.70 (.22)	1.02
Quiet	2.29 (.36)	2.55 (.35)	1.93
Ideal	1.89 (.50)	2.13 (.56)	.66
Multiple Inputs	2.00 (.42)	2.38 (.55)	1.94
Auditory Memory/Sequencing	2.06 (.80)	2.55 (.49)	1.97
Auditory Attention Span	2.40 (.42)	2.48 (.32)	.20
Total	2.25 (.36)	2.51 (.31)	2.25
ACPT (z-score)			
Total Error Score	.32 (.96)	.68 (1.91)	.18

*p<.05
**p<.01
***p<.001

Note:
ADHD = Attention Deficit Hyperactivity Disorder
LD = Learning Disabled

Table 5

Correlations of SCAN with: CHAPPS; Conners; WRAT-3 Reading and Arithmetic; WISC-III Block Design, Vocabulary, and Digit Span; WIAT Listening Comprehension

	SCAN			
Variable	CSS	FW	AFG	CW
CHAPPS				
Noise	-.17	.04	.19	-.30
Quiet	-.40	-.06	-.07	-.44*
Ideal	-.35	-.01	-.15	-.39
Multiple Inputs	-.16	.06	-.10	-.22
Auditory Memory/Sequencing	-.38	-.17	.09	-.46*
Auditory Attention Span	-.26	.12	.06	-.36
Total	-.37	-.02	.03	-.47*
Conners				
Conduct Problem	.11	.34	.09	-.01
Learning Problem	-.24	.26	.03	-.36
Psychosomatic	-.07	.18	-.02	-.14
Impulsive - Hyperactive	.12	.09	.26	.002
Anxiety	-.16	.09	-.08	-.22
Hyperactivity Index	-.06	.21	.15	-.21
WRAT - 3 (percentile)				
Reading	.32	-.04	.33	.28
Arithmetic	.39	-.0006	.13	.45*
WIAT (percentile)				
Listening Comprehension	.40	.22	.18	.38
WISC-III				
Block Design	.42	.28	.28	.40
Vocabulary	.54*	.16	.45*	.49*
Digit Span	.55**	.10	.25	.54*
I.Q. (Estimated) percentile	.64**	.32	.40	.61**
ACPT (z-score)				
Total Error Score	.44*	.12	-.29	-.46*

Note: CSS = Composite Standard Score, FW = Filtered Word Subtest, AFG = Auditory Figure Ground Subtest, CW = Competing Word Subtest

* $p<.01$ ** $p<.001$

Table 6

Correlations of CHAPPS with: Conners; WRAT-3 Reading and Arithmetic; WIAT Listening Comprehension, WISC-III Block Design, Vocabulary and Digit Span;

	CHAPPS						
Variable	Noise	Quiet	Ideal	MI	AM / S	AAS	Total
Conners							
Conduct Problem	.29	-.47*	.35	.34	.18	.42*	.40
Learning Problem	.58**	.63**	.51*	.39	.36	.66**	.63**
Psychosomatic	.13	.07	.14	.13	-.03	.13	.10
Impulsive - Hyperactive	.27	.30	.22	.34	.05	.38	.29
Anxiety	-.04	.11	.15	.06	.01	.08	.06
Hyperactivity Index	.47*	.57**	.42*	.38	.23	.57**	.52*
WRAT - 3 (percentile)							
Reading	-.15	-.26	-.35	-.36	-.29	-.31	-.33
Arithmetic	-.32	-.24	-.18	-.18	-.20	-.19	-.27
WIAT (percentile)							
Listening Comprehension	-.02	-.23	-.26	-.26	-.15	-.19	-.19
WISC-III							
Block Design	-.16	-.18	-.11	-.05	-.15	-.13	-.16
Vocabulary	-.14	-.30	-.47*	-.34	-.16	-.43	-.33
Digit Span	-.35	-.39	-.43	-.17	-.32	-.46*	-.42
I.Q. (Estimated) percentile	-.16	-.23	-.20	-.16	-.19	-.21	-.23
ACPT (z-score)							
Total Error Score	.22	.30	.33	.30	.26	.30	.34

Note: MI = Multiple Inputs, AM / S = Auditory Memory/Sequencing, AAS = Auditory Attention Span.

* $p<.01$ **$p<.001$

Table 7

Correlations of WRAT-3 Reading and Arithmetic and WIAT Listening Comprehension with: Conners; WIAT Listening Comprehension; WISC-III Block Design, Vocabulary, and Digit Span

	WRAT - 3		WIAT
Variable	Reading	Arithmetic	Listening Comprehension
Conners (t-score)			
Conduct Problem	-.19	.11	-.09
Learning Problem	-.12	-.18	-.16
Psychosomatic	.01	-.06	-.02
Impulsive - Hyperactive	.0004	-.29	-.11
Anxiety	-.17	-.17	-.36
Hyperactivity Index	-.13	.06	-.13
WIAT (percentile)			
Listening Comprehension	.27	.32	1.00
WISC-III			
Block Design	.20	.44	.44
Vocabulary	.47*	.25	.60**
Digit Span	.21	.21	.37
I.Q. (Estimated) percentile	.32	.50*	.57**
ACPT (z-score)			
Total Error Score	-.40	-.36	-.38

*$p<.01$
**$p<.001$

Table 8

Individual Subject Scores and Pass/Fail Status on SCAN: Normally Achieving (NA) Group

	SCAN			
	CSS	FW	AFG	CW
Normally Achieving				
Subject 1	79 (+)	84 (+)	63 (+)	75 (+)
Subject 2	37 (+)	50 (+)	50 (+)	37 (+)
Subject 3	53 (+)	50 (+)	16 (-)	75 (+)
Subject 4	30 (+)	25 (+)	37 (+)	37 (+)
Subject 5	8 (-)	63 (+)	16 (-)	9 (-)
Subject 6	70 (+)	63 (+)	63 (+)	63 (+)
Subject 7	37 (+)	50 (+)	16 (-)	63 (+)
Subject 8	50 (+)	37 (+)	37 (+)	63 (+)
Subject 9	30 (+)	25 (+)	37 (+)	37 (+)
Subject 10	45 (+)	75 (+)	25 (+)	37 (+)
Subject 11	4 (-)	37 (+)	9 (-)	5 (-)
Subject 12	3 (-)	16 (-)	50 (+)	5 (-)
Subject 13	66 (+)	50 (+)	50 (+)	75 (+)

Note: CSS = Composite Standard Score, FW = Filtered Word Subtest, AFG = Auditory Figure Ground Subtest, CW = Competing Word Subtest
(-) = Fail (score ≥1SD below the mean for age, i.e., ≤16 %ile)
(+) = Pass (score <1SD below the mean for age, i.e., >16 %ile)

Table 9

Individual Subject Scores and Pass/Fail Status on SCAN: Learning Disabled (LD) Group

	SCAN			
	CSS	FW	AFG	CW
Learning Disabled				
Subject 1	50 (+)	37 (+)	50 (+)	63 (+)
Subject 2	5 (-)	37 (+)	5 (-)	5 (-)
Subject 3	84 (+)	75 (+)	16 (-)	95 (+)
Subject 4	55(+)	63 (+)	37 (+)	63 (+)
Subject 5	14 (-)	91 (+)	25 (+)	5 (-)
Subject 6	27 (+)	84 (+)	50 (+)	16 (-)
Subject 7	37 (+)	63 (+)	75 (+)	16 (-)
Subject 8	37 (+)	63 (+)	37 (+)	37 (+)
Subject 9	47 (+)	37 (+)	25 (+)	63 (+)
Subject 10	55 (+)	63 (+)	63 (+)	50 (+)

Note: CSS = Composite Standard Score, FW = Filtered Word Subtest, AFG = Auditory Figure Ground Subtest, CW = Competing Word Subtest
(-) = Fail (score ≥1 SD below the mean for age, i.e., ≤16 %ile)
(+) = Pass (score <1 SD below the mean for age, i.e., >16 %ile)

Table 10

Individual Subject Scores and Pass/Fail Status on SCAN: Attention Deficit Hyperactivity Disorder (ADHD) Group

	SCAN			
	CSS	FW	AFG	CW
Attention Deficit Hyperactivity Disorder				
Subject 1	18 (+)	37 (+)	9 (-)	25 (+)
Subject 2	3 (-)	25 (+)	16 (-)	5 (-)
Subject 3	42 (+)	50 (+)	63 (+)	37 (+)
Subject 4	30 (+)	50 (+)	16 (-)	25 (+)
Subject 5	25 (+)	63 (+)	5 (-)	37 (+)
Subject 6	37 (+)	84 (+)	37 (+)	25 (+)
Subject 7	23 (+)	91 (+)	37 (+)	9 (-)
Subject 8	55 (+)	37 (+)	63 (+)	50 (+)
Subject 9	50 (+)	63 (+)	75 (+)	37 (+)
Subject 10	79 (+)	91 (+)	25 (+)	84 (+)
Subject 11	86 (+)	63 (+)	63 (+)	91 (+)
Subject 12	82 (+)	63 (+)	75 (+)	75 (+)
Subject 13	32 (+)	37 (+)	63 (+)	25 (+)
Subject 14	7 (-)	37 (+)	37 (+)	5 (-)

Note: CSS = Composite Standard Score, FW = Filtered Word Subtest,
AFG = Auditory Figure Ground Subtest, CW = Competing Word Subtest
(-) = Fail (score ≥1SD below the mean for age, i.e., ≤16 %ile)
(+) = Pass (score <1SD below the mean for age, i.e., >16 %ile)

Table 11

Means and Standard Deviations for SCAN Pass and SCAN Fail Subjects

	Group		
Variable Mean (SD)	SCAN Pass (n=21)	SCAN Fail (n=16)	F
SCAN (percentile)			
Composite Standard Score	53.05 (17.70)	23.63 (21.83)	20.51***
Filtered Words	55.24 (19.13)	54.31 (22.82)	.02
Auditory Figure Ground	49.43 (16.30)	24.88 (19.72)	17.18***
Competing Words	53.52 (19.66)	25.00 (28.36)	13.07
WIAT (percentile)			
Listening Comprehension	63.52 (27.25)	57.13 (24.40)	.55
WISC-III			
Block Design	12.65 (4.04)	9.08 (2.90)	7.58**
Vocabulary	12.00 (4.83)	9.00 (1.68)	11.82**
Digit Span	11.25 (2.24)	10.23 (3.47)	1.06
I.Q. (Estimated) percentile	71.43 (26.97)	36.31 (16.04)	17.82***
Range	9 - 99.9	13 - 66	

*$p<.05$
**$p<.01$
***$p<.001$

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Table 11 (Continued)

Means and Standard Deviations for SCAN Pass and SCAN Fail Subjects

	Group		
Variable Mean (SD)	SCAN Pass (n=21)	SCAN Fail (n=16)	F
Conners (t-score)			
Conduct Problem	56.10 (16.87)	52.94 (13.92)	.37
Learning Problem	68.76 (17.17)	72.50 (20.45)	.37
Psychosomatic	52.00 (9.33)	52.63 (17.63)	.02
Impulsive - Hyperactive	60.38 (14.50)	55.93 (10.23)	1.04
Anxiety	58.00 (12.05)	60.69 (17.40)	.31
Hyperactivity Index	64.14 (16.52)	63.06 (15.29)	.04
CHAPPS			
Noise	2.37 (.50)	2.34 (.48)	.03
Quiet	2.10 (.47)	2.27 (.51)	1.14
Ideal	1.76 (.53)	2.00 (.56)	1.76
Multiple Inputs	1.94 (.40)	2.08 (.67)	.68
Auditory Memory/Sequencing	2.14 (.58)	2.35 (.59)	1.19
Auditory Attention Span	2.21 (.49)	2.30 (.52)	.28
Total	2.13 (.43)	2.27 (.45)	.86
ACPT (z-score)			
Total Error Score	.05 (.99)	.90 (1.47)	4.40*

*p<.05
**p<.01
***p<.001

Table 12

Means and Standard Deviations for ACPT Pass (SCAN Fail) and ACPT Fail

	Group		
Variable Mean (SD)	ACPT Pass (SCAN Fail) (n=9)	ACPT Fail (n=10)	F
SCAN (percentile)			
Composite Standard Score	29.89 (26.81)	22.00 (13.14)	.69
Filtered Words	52.22 (23.85)	59.60 (20.86)	.52
Auditory Figure Ground	26.67 (22.98)	28.20 (16.32)	.03
Competing Words	34.44 (34.86)	18.90 (12.71)	1.74
WIAT (percentile)			
Listening Comprehension	72.67 (18.95)	42.50 (26.80)	7.85*
WISC-III			
Block Design	9.38 (3.07)	10.43 (4.28)	.31
Vocabulary	9.50 (1.93)	9.00 (1.91)	.25
Digit Span	10.63 (4.21)	9.57 (1.90)	.37
I.Q. (Estimated) percentile	41.63 (15.39)	42.14 (29.56)	.002

*$p<.05$
**$p<.01$
***$p<.001$

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Table 12 (Continued)

Means and Standard Deviations for ACPT Pass (SCAN Fail) and ACPT Fail

Variable Mean (SD)	Group ACPT Pass (SCAN Fail) (n=9)	ACPT Fail (n=10)	F
Conners (t-score)			
Conduct Problem	47.56 (11.01)	59.90 (19.94)	2.70
Learning Problem	68.33 (21.44)	77.60 (17.98)	1.05
Psychosomatic	53.33 (19.11)	51.30 (14.21)	.07
Impulsive - Hyperactive	54.50 (9.70)	59.20 (13.73)	.67
Anxiety	55.56 (18.10)	65.30 (14.10)	1.73
Hyperactivity Index			
CHAPPS			
Noise	2.33 (.52)	2.37 (.42)	.03
Quiet	2.14 (.52)	2.30 (.49)	.46
Ideal	1.85 (.53)	2.10 (.55)	1.01
Multiple Inputs	1.96 (.66)	2.17 (.59)	.51
Auditory Memory/Sequencing	2.28 (.58)	2.39 (.55)	.18
Auditory Attention Span	2.17 (.53)	2.41 (.52)	1.04
Total	2.18 (.46)	2.33 (.41)	.60
ACPT (z-score)			
Total Error Score	-.09 (.39)	2.13 (1.10)	32.91

*p<.05
**p<.01
***p<.001

Table 13

Mean Correct Responses by Trial Across Groups

	GROUP		
	NA	LD	ADHD
Mean Number of Correct Responses to "Dog"(SD)			
Presentation Order			
Trial 1	19.54(.88)	18.00(1.70)	19.00(1.36)
Trial 2	18.62(1.26)	16.90(1.91)	17.57(3.23)
Trial 3	18.69(1.70)	16.70(2.75)	17.57(2.93)
Trial 4	18.15(1.63)	16.50(2.27)	17.57(3.08)
Trial 5	18.38(1.76)	16.40(2.95)	17.43(4.47)
Trial 6	16.69(2.69)	16.50(2.46)	16.14(2.89)
Mean Vigilance Decrement	2.85	1.50	2.71

Note:
There are 20 presentations of the word "Dog" for each trial.

Table 14

Chi-square Analysis of Performance (Pass/Fail) on SCAN with Performance (Pass/Fail) on ACPT

		Performance on SCAN		
		Pass	Fail	Totals
Performance on ACPT	Pass	18	9	27
	Fail	3	7	10
		21	16	37

$X^2 = 4.00$
$p < .05$

Note: SCAN Pass = >16%ile on all subtests
SCAN Fail = ≤16%ile on at least 1 subtest
ACPT Pass = Total Error Score <1SD below the mean for age
ACPT Fail = Total Error Score ≥1SD above the mean for age

Table 15

Chi-square Analysis of Performance (Pass/Fail) on SCAN with Performance (Pass/Fail) on WRAT-3 Arithmetic

		Performance on SCAN		
		Pass	Fail	Totals
Performance on WRAT-3 Aritmetic	Pass	3	7	10
	Fail	17	9	26
		20	16	36

$X^2 = 3.66$
$p < .05$

Note: SCAN Pass = >16%ile on all subtests
SCAN Fail = ≤16%ile on at least 1 subtest
Arithmetic Pass = ≥30%ile on WRAT-3 Arithmetic
Arithmetic Fail = ≤25%ile on WRAT-3 Arithmetic

Table 16

Chi-square Analysis of Rating on Conners Hyperactivity Index with CHAPPS Noise

		Rating on Conners Hyperactivity Index		
		Pass (Not Hyperactive)	Fail (Hyperactive)	Totals
Rating on CHAPPS Noise	Pass	11	1	12
	Fail	12	13	25
		23	14	37

$X^2 = 6.57$
$\underline{p}<.05$

Note: Hyperactivity Index Pass = t-score <70
Hyperactivity Index Fail = t-score ≥70
Noise Pass = score ≤2 i.e. less or same difficulty compared to peers
Noise Fail = score >2 i.e. more difficulty compared to peers

Table 17

Chi-square Analysis of Rating on Conners Hyperactivity Index with CHAPPS Quiet

		Rating on Conners Hyperactivity Index		
		Pass (Not Hyperactive)	Fail (Hyperactive)	Totals
Rating on CHAPPS Quiet	Pass	12	2	14
	Fail	11	12	23
		23	14	37

$X^2 = 5.31$
$\underline{p}<.05$

Note: Hyperactivity Index Pass = t-score <70
Hyperactivity Index Fail = t-score ≥70
Quiet Pass = score ≤2 i.e. less or same difficulty compared to peers
Quiet Fail = score >2 i.e. more difficulty compared to peers

Table 18

Chi-square Analysis of Rating on Conners Hyperactivity Index with CHAPPS Auditory Attention Span

		Rating on Conners Hyperactivity Index		
		Pass (Not Hyperactive)	Fail (Hyperactive)	Totals
	Pass	12	1	13
Rating on CHAPPS Auditory Attention Span	Fail	11	13	24
		23	14	37

$X^2 = 7.74$
$p<.01$

Note: Hyperactivity Index Pass = t-score <70
Hyperactivity Index Fail = t-score ≥70
Auditory Attention Span Pass = score ≤2 i.e. less or same difficulty compared to peers
Auditory Attention Span Fail = score >2 i.e. more difficulty compared to peers

Table 19

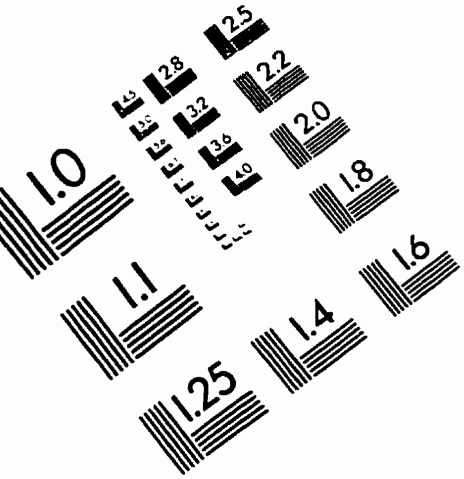
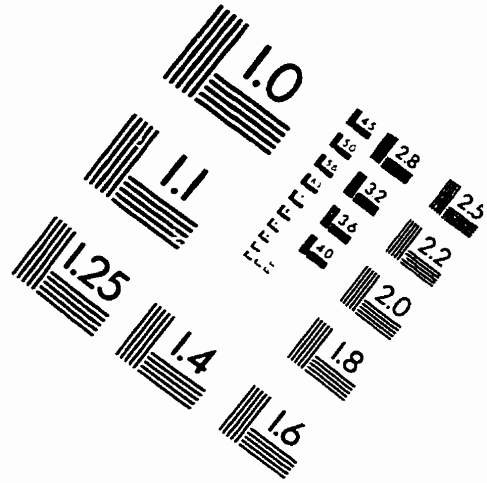
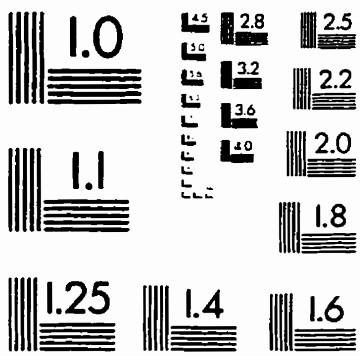
Chi-square Analysis of Rating on Conners Hyperactivity Index with CHAPPS Total

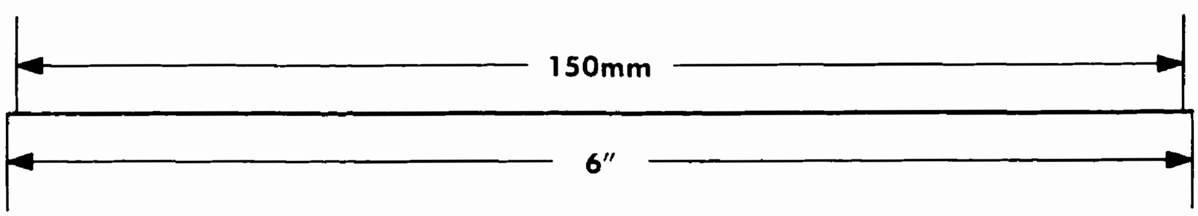
		Rating on Conners Hyperactivity Index		
		Pass (Not Hyperactive)	Fail (Hyperactive)	Totals
	Pass	12	1	13
Rating on CHAPPS Total	Fail	10	13	23
		22	14	36

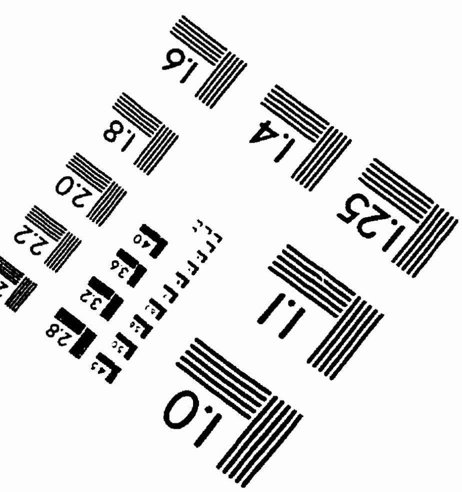
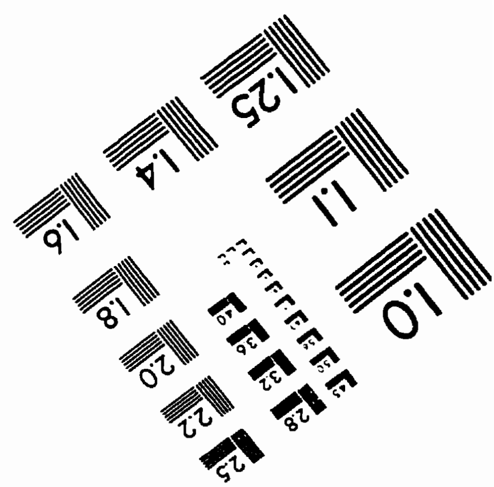
$X^2 = 8.33$
$p<.01$

Note: Hyperactivity Index Pass = t-score <70
Hyperactivity Index Fail = t-score ≥70
CHAPPS Total Pass = score ≤2 i.e. less or same difficulty compared to peers
CHAPPS Total Fail = score >2 i.e. more difficulty compared to peers

IMAGE EVALUATION TEST TARGET (QA-3)



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