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COGNITIVE PERFORMANCE OF CHILDREN WITH AN ARITHMETIC DISABILITY WITH AND WITHOUT ATTENTION-DEFICIT HYPERACTIVITY DISORDER

by

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A thesis submitted in conformity with the requirements for the degree of Master of Arts
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Cognitive Performance of Children

Cognitive Performance Of Children With An Arithmetic Disability With And Without Attention-Deficit Hyperactivity Disorder

Master of Arts, 1998
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Abstract

Using a selection of cognitive, memory, and academic tasks, this study examined the performance of children with a Specific Arithmetic Disability (SAD; no reading disability), investigating whether difficulties were exacerbated by Attention-Deficit/Hyperactivity Disorder (ADHD). Comparisons were made between children with SAD, normal achievement, ADHD, and combined SAD and ADHD. ADHD was found to diminish the already-impaired visual-motor, reading comprehension, and spelling abilities of children with SAD. At younger ages, children with ADHD had more difficulty with phonological processing tasks than those without, possibly because of the memory requirements necessary for these skills. The presence of either or both ADHD and SAD had a negative impact on memory for numbers. Additional difficulties coinciding with the presence of either disability separately were apparent in certain areas. Support was found for the hypothesis that ADHD further impairs the performance of children with an arithmetic disability.
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Cognitive Performance of Children with an Arithmetic Disability with and without Attention-Deficit Hyperactivity Disorder

In order to effectively investigate the features and consequences of a learning disability, it is important to identify specific subtypes (Ozols & Rourke, 1988; Riccio, Gonzalez, & Hynd, 1994; Rourke, 1989; Rourke & Finlayson, 1978; Siegel, 1988; Siegel & Heaven, 1986; Strang & Rourke, 1985). Two subtypes have emerged, reading disability and arithmetic disability (Ingersoll & Goldstein, 1993; Morrison & Siegel, 1991; Shafir & Siegel, 1994; Siegel & Ryan, 1988, 1989) although some researchers identify combined types (e.g., Harnadek & Rourke, 1994; Ozols & Rourke, 1988; Share, Moffitt, & Silva, 1988). Whether or not attention deficit should be included as a category of learning disability is less clear, but it can be examined as an entity separate from reading and arithmetic disabilities. It is the aim of this study to investigate the cognitive aspects of subtypes of learning disability, specifically arithmetic disability (SAD) with and without Attention-Deficit/Hyperactivity Disorder (ADHD).

There are a number of different names for what is referred to as an arithmetic disability in this study: 'developmental output failure,' 'dysgraphia,' 'writing backwardness,' and arithmetic/written work disability (Siegel, 1988a). The nonverbal learning disability described by Rourke (1989) has many of the same characteristics as an arithmetic disability but is a broader classification. The characteristics of arithmetic disability include "difficulties in one or more of the following: computational arithmetic, rote learning (for example memorizing the times tables or number facts), written work, and/or fine motor co-ordination in spite of good oral language and reading skills" (Morrison & Siegel, 1991,
p. 189). It has been estimated that approximately 6 percent of school-age children have an arithmetic disability (Fleischner, 1994). A related conceptualisation of arithmetic disability is that “Children who exhibit this neuropsychological profile [a nonverbal disability] tend to have very predictable and pervasive difficulties in personal, social, and academic development” (Rourke, Del Dotto, Rourke, & Casey, 1990, pp. 361-362).

Rourke and his colleagues consider neuropsychological assets and deficits as the causes of the socioemotional/adaptive and academic assets and deficits. Neuropsychological assets include the areas of auditory perception, simple motor, learning rote material, both attention to and memory of auditory and verbal material, and verbal strengths in phonology, verbal reception, repetition, storage, associations, and volume of output. The accompanying deficits include primary deficits in tactile and visual perception as well as for complex psychomotor actions and novel material; secondary deficits in tactile and visual attention as well as for exploratory behaviour; tertiary deficits in tactile and visual memory, concept formation, and problem solving; and, verbal deficits in oral-motor praxis, prosody, semantics, content, pragmatics, and function. The resultant academic assets are in word decoding, spelling, verbatim memory, and, after extensive practice, later graphomotor skills. The academic deficits are in early graphomotor ability, reading comprehension, mechanical arithmetic, mathematics, and science. Lastly, there are no assets noted in the socioemotional/adapational area, whereas there are deficits in adaptation to novelty, social competence, emotional stability, and activity level (adapted from Rourke et al., 1990, p.363). Thus, an arithmetic disability is only one aspect of a nonverbal learning disability.
The relationship, if any, between specific arithmetic disability and attention deficit has recently become a focus for research. Gross-Tsur, Shalev, Manor, and Amir (1995) conducted a study of 20 children with developmental right-hemisphere syndrome, which they equate with nonverbal learning disability. They state that, “the core symptoms are emotional difficulties and disturbances in interpersonal skill; poor visuospatial ability; academic failure, especially in arithmetic; and left-sided neurological findings” (p.80). It can be seen that these characteristics are indeed similar to those outlined above for nonverbal learning disability and include many factors in addition to an arithmetic disability. The dependent variables for the study by Gross-Tsur et al. differed from those in the current investigation. They did not investigate spelling or reading abilities; the present study does address these areas. One feature common to both studies is the consideration of graphomotor capabilities, in which area “severe” problems were found in 18 of their 20 subjects. Another common feature was the presence of both arithmetic difficulties and ADHD. Although they did not select their subjects for the presence of ADHD, Gross-Tsur and his colleagues found that all 20 subjects met the DSM-III-R (American Psychiatric Association, 1987) criteria for this disorder. No control or comparison groups were used in the Gross-Tsur et al. study.

Prior to that study, Zentall and his colleagues (Zentall, 1990; Zentall, 1993; Zentall & Ferkis, 1993; Zentall & Smith, 1993; Zentall, Smith, Lee, & Wieczorek, 1994) studied the relationship between attention deficit and arithmetic performance, finding that boys with ADHD were slower to complete computations than controls and received lower scores in solving problems due to difficulties with mathematical concepts. The subjects for
these studies were identified as having ADHD, not identified as having an arithmetic 
disability. The current study focuses on arithmetic disability and its correlation with 
performance in areas other than neuropsychological functioning or social adaptation.

For the purposes of the present study, children were considered to have a disability 
in arithmetic or reading on the basis of their achievement scores on the Wide Range 
Achievement Test (WRAT; Jastak & Jastak, 1978) or the Wide Range Achievement Test - 
distinguishing between subtypes of learning disabilities is well-established (e.g., Fletcher, 
1985a; Rourke & Finlayson, 1978; Rourke & Strang, 1978; Siegel & Feldman, 1983; 

The short-term and working memory difficulties of children with an arithmetic 
disability have been documented by a number of investigators (Fletcher, 1985b; Siegel & 
Linder, 1984; Siegel & Ryan, 1984, 1988, 1989). Children with AD have been shown to 
have poorer performance than their normally-achieving peers on memory tasks involving 
nonverbal stimuli (Fletcher, 1985b) and poorer performance on visually-presented than on 
auditorially-presented tasks (Siegel & Linder, 1984). "It would appear from the research 
(Fletcher, 1985b; Siegel & Linder, 1984; Siegel & Ryan, 1988, 1989) that ... deficits in 
short-term and working memory ... [for] those children with arithmetic deficits and normal 
or above-normal reading are more limited to visual, nonverbal, and numerical material" 

One of the academic difficulties experienced by children with arithmetic disabilities 
is with handwriting and other visual-motor tasks (Rourke, 1989). One study
demonstrating visual-motor problems is that of Siegel and Feldman (1983) who found that the Developmental Test of Visual-Motor Integration (VMI; Beery, 1989) discriminated between children with arithmetic disabilities and normally-achieving children. Children with an arithmetic disability have also been shown to frequently have poorer performance on visual-spatial and visual-perceptual tasks (Fletcher, 1985b; Morrison & Siegel, 1991; Rourke & Finlayson, 1978; Rourke, 1989; Share et al., 1988; Siegel & Feldman, 1983; Spellacy & Peter, 1978; Webster, 1979).

Rourke also reported (1989) that children with a nonverbal learning disability have early difficulties with spelling due to later than usual development of "visual-spatial feature analysis skills" (p. 95). In the case of written spelling, the same deficits in grapho-motor, "tactile-perceptual, visual-perceptual, and complex psychomotor skills" (p. 95) which affect their performance on the VMI also have a negative impact on their spelling. The fact that an arithmetic disability can be considered to be a subgroup of a nonverbal learning disability group (Morrison & Siegel, 1991; Rourke, 1989; Rourke & Finlayson, 1978) leads us to expect a similar pattern of performance. As a result of this previous research, two measures of orthographic coding skill were included in this study. It was expected that all groups including an arithmetic disability would be less successful on these tasks than those without it.

The other area of difficulty to be examined in this study was Attention-Deficit/Hyperactivity Disorder (ADHD) which has been described as “the most common neurobehavioral disorder of childhood” (Shaywitz, Fletcher, & Shaywitz, 1994, p. 1). A detailed description of this disorder can be found in Barkley (1990). The Diagnostic and
Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV; American Psychiatric Association, 1994) states that, "the essential feature of Attention-Deficit/Hyperactivity Disorder is 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). All those with any type of diagnosis of ADHD are included in the ADHD groups. A designation of ADHD was made on the basis of the Conners Parent Rating Scale (Goyette, Conners, & Ulrich, 1978) as well as behavioural observations by the researchers, and reports of behaviour from a parent, teacher, or physician.

The relationship between ADHD and learning disabilities has been an area for recent research (e.g., Barkley, 1991; Szatmari, Offord, & Boyle, 1989a), with more extensive investigation of its relationship to reading disability (Ackerman, Anhalt, Holcomb, & Dykman, 1986; August & Garfinkel, 1990; Douglas & Benezra, 1990; Dykman & Ackerman, 1991; Kupietz, 1990; McGee, Williams, Moffitt, & Anderson, 1989; Pennington et al., 1993) than to any other learning disability.

Wood and Felton (1994) examined the possible effects that attentional difficulties might have on reading and concluded that, "Childhood ADD has no measurable impact on the development of single-word reading skill, either in childhood or in adulthood" (p. 55). This finding is similar to that of Siegel and Ryan (1988) although they did find deficits in accuracy and comprehension when children with attention-deficit disorder were confronted with a text-reading task. They considered this to support the notion that prose-reading measures may have additional attentional components.
Comparisons of children with ADHD and children with a reading disability (RD) have shown that the two groups did not differ on measures of automatic processing (Ackerman et al., 1986); the children with ADHD had more impaired executive processes than the children with RD (e.g., Douglas & Benezra, 1990; Pennington et al., 1993; Shelton & Barkley, 1994). Shelton and Barkley linked these difficulties with executive processes with an increased likelihood of language disorders (1994) as have other researchers (e.g., Pribram, 1971; Westby & Cutler, 1994).

Problem-solving abilities and attention to errors have also been examined. “On attention to errors, children with both arithmetic and word-recognition disabilities scored significantly lower than children with only arithmetic disability or NA [normal achieving]. It appears that the metacognitive skill of monitoring errors may be a major source of difficulty in problem solving for children with both arithmetic and word-recognition disabilities” (Shafrir, Siegel, & Chee, 1990, p. 506). In the same study the children with any combination of arithmetic, reading, or ADHD disability scored lower on their ability to make inferences.

Short-term memory has been investigated as well, comparing children with RD and children with ADHD (e.g., August & Garfinkel, 1990; Dykman & Ackerman, 1991; Kupietz, 1990; McGee, Williams, Moffitt, & Anderson, 1989; Siegel & Ryan, 1988, 1989). For example, Douglas and Benezra (1990) found more pervasive verbal memory problems on the part of children with RD than children with ADHD; Siegel and Ryan (1988, 1989) found more pervasive short-term memory problems in children with RD than children with ADHD.
Phonological processing has been receiving more and more support as the primary factor underlying reading disability (e.g., McBride-Chang, 1995; Pennington, 1991; Shankweiler & Liberman, 1989; Siegel, 1986, 1993; Stanovich, 1985, 1988; Stanovich & Siegel, 1994; Wood & Felton, 1994) and children with RD have been compared to children with ADHD on phonological tasks as well. Pennington, Grossier, and Welsh found that children with ADHD only did not have difficulties with phonological processing (1993), however, children with both RD and ADHD did.

The purpose of the current study was to examine the performance of children with an arithmetic disability and investigate whether their difficulties are exacerbated by ADHD. Scores on each task were, therefore, examined to see whether those children with both an arithmetic disability and ADHD would have lower scores than those with only an arithmetic disability.

This study addressed these questions by comparing the performance of subjects with an arithmetic disability, but without ADHD, to that of subjects with both an arithmetic disability and ADHD, as well as to that of normally-achieving subjects who had ADHD, and, finally, to a group of normally-achieving subjects without ADHD. These comparisons were conducted on a selection of cognitive, memory, and academic tasks. Reading measures were included among the academic tasks for a number of reasons. Several investigators have found that ADHD and a reading disability often overlap or co-occur (e.g., August & Garfinkel, 1990; Dykman & Ackerman, 1991; Kupietz, 1990; and Pennington et al., 1993). In addition, reading is one of the key subjects of an academic program and as such, performance in this area is of great practical interest to educators. It
has been noted, in fact, that school programs addressing learning disabilities have frequently focused on reading difficulties to the neglect of arithmetic or other difficulties (Siegel, 1988b). Lastly, the performance on reading tasks of children with ADHD has been shown to differ from that of normally-achieving children (e.g., Branch, Cohen, & Hynd, 1995); from that of children with a reading disability (e.g., Douglas & Benezra, 1990; Siegel & Ryan, 1988); and from that of children with both a reading disability and ADHD (e.g., Dykman & Ackerman, 1991; Pennington, Groisser, & Welsh, 1993). The performance of children with an arithmetic disability on such tasks has been studied (e.g., Rourke, 1993; Share et al., 1988). However, an investigation of the performance of children with both an arithmetic disability and ADHD on reading tasks has not been reported previously.

It was expected that children with both an attention deficit and an arithmetic disability would have even more difficulty on measures negatively affected by an arithmetic disability than would those subjects with only an arithmetic disability. This would be consistent with Webster et al.'s finding that the "comorbid effects of a learning disability further intensify the negative impact of ADHD" (Webster, Hall, Brown, & Bolen, 1996, p.93).

It was also expected that those children with both disorders would perform more poorly on tasks typically impaired by the presence of Attention-Deficit/Hyperactivity Disorder. These include tasks with an attentional component, such as the short-term memory and reading comprehension tasks (Siegel & Ryan, 1988; Shafrir & Siegel, 1994), and those affected by visual-motor co-ordination, such as the VMI.
Method

Subjects

This study consisted of a new analysis of data combined from a number of previously published studies (e.g., Siegel & Ryan, 1988; Siegel & Ryan, 1989; Stanovich & Siegel, 1994) and some unpublished data. Some of the children were from schools in southern Ontario and were tested in their schools. Others came to a psychoeducational assessment clinic to participate in studies of cognitive processes. The children who came to the assessment clinic were from the same schools, classrooms, and neighbourhoods as the children who were tested in the schools. Most of the school sample was achieving at grade-appropriate levels, whereas most of the assessment sample had some type of learning disability. Socioeconomically, the participants were predominantly middle class, and less than 2% were non-white. All were being educated in English and spoke English as their primary language. Children with neurological problems, English as a second language, severe behavioural deficits, and sensory deficits were excluded from the sample.

The total sample included 2167 children, aged 7 to 16. To be included in this study, subjects had to receive an IQ score greater than or equal to 80. IQ scores were derived from the administration of one of three instruments: the Wechsler Intelligence Scale for Children--Revised (WISC-R; Wechsler, 1974); a short form of the WISC-R consisting of the Vocabulary and Block Design subtests (Sattler, 1982); or, the Peabody Picture Vocabulary Test--Revised (PPVT-R; Dunn & Dunn, 1981).

Specific Arithmetic Disability: The subjects were classified into groups on the basis of their scores on either the Wide Range Achievement Test (WRAT) or the Wide Range
Achievement Test--Revised (WRAT-R). For the purposes of these comparisons, two sets of groupings were created. Firstly, subjects were selected from the database on the basis of having an arithmetic disability, without controlling for difficulties in attention. A specific arithmetic disability was defined as receiving a score at or below the 25th percentile on the Arithmetic subtest of the WRAT-R, but a score at or above the 30th percentile on the Reading subtest; thus defining a pure arithmetic disability, not confounded by reading disability. The total number of subjects identified as having a specific arithmetic disability was 403; however, the number of subjects who participated in each task varied.

Secondly, a group of normally-achieving subjects was selected. These subjects, Group NA, also had IQ scores of at least 80 but received scores greater than or equal to the 30th percentile on the Reading and Arithmetic subtests of the WRAT-R. Seven hundred and thirty-four subjects met these criteria.

Next, the subjects in both groups were divided into those with, and those without ADHD, on the basis of the 48 item version of the Conners Parent Rating Scale as well as behavioural observations by the researchers, and parent, teacher, or physician reports of behaviour. To be considered to have ADHD a child had to have received a score that was greater than or equal to 2 SD above the mean for his/her sex and age. To be considered not to have ADHD, a score less than or equal to 1 SD from the mean was required. The subgroups so created were designated "ADHD" and "noADHD" respectively. Subjects were further divided into 5 groups on the basis of age: 6 to 8 years, 9 to 10 years, 11 to 12 years, 13 to 14 years, and 15 to 16 years. The demographic profile of subjects is presented in Table 1.
Measures and Tasks

**WRAT-R.** All subjects were administered the WRAT or WRAT-R. The Arithmetic subtest of the WRAT-R consists of a series of computation tasks of increasing difficulty and is timed; the Reading subtest is a test of word recognition; the Spelling subtest requires respondents to write a word in response to dictation.

**Measures of IQ**

**The Wechsler Intelligence Scale for Children - Revised.** This is an individually-administered test of intelligence consisting of subtests measuring both verbal and nonverbal elements of cognition, and yields a Full Scale IQ based upon the results of the various subtests. Some children received a short form of the WISC-R, consisting of the Block Design and Vocabulary subtests, yielding an IQ estimate (Sattler, 1982).

**The Peabody Picture Vocabulary Test - Revised.** This test is an individually-administered test of receptive vocabulary, based upon which an IQ score is given.

**The VMI Developmental Test of Visual-Motor Integration (VMI).** This test measures some aspects of eye-hand co-ordination involved in written work. It requires the child to copy an increasingly complex series of figures.

**Reading Comprehension**

**Reading comprehension.** The Gilmore Oral Reading Test (Gilmore & Gilmore, 1968) involves reading paragraphs aloud and answering questions on them. Accuracy and comprehension stanine scores can be calculated. The Stanford Reading Comprehension test (Gardner, Rudman, Karlsen, & Merwin, 1982) involves the silent reading of a series of graded paragraphs and answering multiple choice questions.
Pseudoword Reading and Spelling

Pseudowords are pronounceable combinations of letters. They have no meaning, but can be pronounced using the rules for English. A number of tasks using pseudowords were included in this study because pseudowords provide an opportunity to examine decoding skills and knowledge of the rules of reading and spelling separately from previous experience of the children with specific vocabulary.

GFW pseudoword reading. The children were administered the Reading of Symbols subtest of the GFW Sound Symbol Test, which involves the reading of pronounceable nonwords (e.g., him, rayed, neap, toaf, and cedge).

Woodcock Word Attack. The Woodcock Reading Mastery Tests (Woodcock, 1987) Word Attack subtest was administered at a later time to groups of children who had not been administered the GFW pseudoword reading test. It also requires the reading of pronounceable nonwords (e.g., pog, weat, shah, whie, and straced).

Phonological choice task. Subjects were asked to specify which, of a choice of two pseudowords, most sounded like a real word. This task (Siegel, 1986, 1992, 1993; Stanovich & Siegel, 1994) was adapted from the work of Olson, Kliegl, Davidson, and Foltz (1985). The subject viewed pairs of pseudowords (e.g., kake-dake and joak-joap) and indicated which pseudoword sounded like a real word when pronounced. Thus, there is some lexical involvement in the task. However, because the stimulus pairs are both nonwords and the only way to respond correctly is to recode the stimuli phonologically, the task taps phonological recoding skill but does so without the overt pronunciation
required in pseudoword reading. There were 26 trials (chance performance is 13 correct), and the percent correct was used in the analysis that follows.

Goldman, Fristoe, and Woodcock pseudoword spelling. The children were administered the Spelling of Symbols subtest of the Goldman, Fristoe, and Woodcock (1974) Sound Symbol Test (GFW). Each child was asked to write pseudowords (e.g., *tash, chid, and plen*) that were read aloud by the examiner. Any acceptable phonetic equivalent was scored as correct. For example, the sound of *imhaf* could be spelled *imhaf, imhab*, or *imhaff*. Before spelling the word, the child was asked to repeat it to ensure that he or she had heard it correctly. Mispronunciations were corrected.

Orthographic Coding Tasks

WRAT-R Spelling. Children were administered the Spelling subtest of the WRAT or WRAT-R which require respondents to write a word in response to dictation.

Spelling recognition. Children were administered the Spelling subtest of the Peabody Individual Achievement Test (PIAT; Dunn & Markwardt, 1979). The child is required to recognize which of four alternatives represents the correct spelling of a word. Because the alternatives are minimally different (e.g., *time, teim, tihm, and tiem*), performance is facilitated if the subject has an accurate and complete orthographic representation of the stimulus stored in memory.

Language Task

Oral Cloze Task. For this task (Siegel, 1992; Siegel & Ryan, 1988; Stanovich & Siegel, 1994) 20 sentences with one word missing were read aloud, and the child was asked to supply the missing word in each sentence. The class (i.e., noun, verb, preposition,
adjective, or conjunction) of the missing word varied across each sentence. The children were instructed to listen while the experimenter read aloud each sentence and were then asked to supply a word that would fit in that sentence. The experimenter said “blank” in place of the missing word. The following are simpler examples of the format of the sentences: “It blank very cold outside yesterday” and “Blank is at the door? he asked.” The sentence could be repeated several times if the child wished. Few repetitions were requested. The number of sentences that were completed with semantically and syntactically acceptable words was used as a criterion variable in the analyses that follow.

**Short-term and Working Memory**

---

**Short-term memory -- letter span.** This task (Siegel, 1992; Siegel & Linder, 1984; Stanovich & Siegel, 1994) was based upon one used by Shankweiler, Liberman, Mark, Fowler, and Fischer (1979) in which subjects were asked to remember two series of letters. One series of letters rhymed (B, C, D, G, P, T, V) whereas the other did not (e.g., H, K, L, Q, R, S, W). There were seven trials of each type, and the order was intermixed and determined randomly. The stimuli were presented for 3 seconds, and then the cards were removed. The child was required to write down the letters that had been on the card. There were five letters per trial and the maximum scores were 35 for the rhyming and nonrhyming sets.

**Working memory -- words.** This task (Siegel, 1992; Siegel & Ryan, 1989; Stanovich & Siegel, 1994) was adapted from a task used by Daneman and Carpenter (1980). The children were orally presented with sentences that were missing their final words (e.g., *in summer it is very _____, People go to see monkeys in a _____*). The
children were instructed to supply the final word of the sentences and to remember the words that they supplied. After responding to each of the sentences in a set, the child was then required to repeat the words that he or she selected in the same order that the sentences had been presented (scoring without regard to order produced virtually identical results). There were three trials at each of four set sizes (2, 3, 4, and 5); thus the maximum score on the task was 12. Task administration was stopped when the individual failed all the items at one level. To minimize word-finding problems, the sentences were chosen so that the word was virtually predetermined. None of the children experienced any difficulty in supplying the missing word.

WISC-R Digit Span. This task has both short-term memory and working memory components. Subjects were asked to repeat sets of numbers presented orally. The WISC-R Digit Span subtest requires a child to repeat increasing numbers of spoken digits, first forwards, then, with different sets of numbers, backwards. The length of the sets starts at 2 numbers and increases to 9. The aspect of memory utilized in remembering the numbers forwards is primarily short-term memory, whereas remembering the numbers in reverse order requires working memory.

Results

The performance on all tasks was analyzed for two main groups of subjects, each of which had two levels. The groups were Specific Arithmetic Disability (SAD) and Normally Achieving (NA). The two levels for each of these were based upon the presence or absence of Attention-Deficit/Hyperactivity Disorder (ADHD).
The levels of learning disability being considered were, therefore, Specific Arithmetic Disability/Attention-Deficit Hyperactivity Disorder (SAD/ADHD), Specific Arithmetic Disability/no Attention-Deficit Hyperactivity Disorder (SAD/noADHD), Normally Achieving/Attention-Deficit Hyperactivity Disorder (NA/ADHD), and Normally Achieving/no Attention-Deficit Hyperactivity Disorder (NA/noADHD).

Whenever age-adjusted scores, such as percentiles, standard scores, or stanines were available, levels of learning disability were compared without consideration of age. The data used for such analyses are presented in Tables 2 and 3.

Unless otherwise noted, One way ANOVAs were used to detect significant differences between the performances of the different groups and tests to locate the source of group differences were completed using the Tukey-HSD and are reported at the .05 level of significance.

The VMI Developmental Test of Visual-Motor Integration. A comparison, with ages combined (see Table 2), yielded significant group effects, $F(3,526)=12.45, p<.00005$, with the NA/noADHD group performing better than any other group. Data with ages separated are presented in Table 4. An ANOVA comparing the same disability groups, at five age levels, also yielded significant effects of group, $F(3,526)=10.84, p<.0005$, and age, $F(4,525)=2.41, p<.05$. Again the NA/noADHD group received higher scores than any other group. Due to the significant age effects, separate analyses were also conducted at each age level.

At ages 6 to 8, $F(3,155)=4.30, p<.006$, the NA/noADHD group performed better than either of the ADHD groups. The same pattern of effects was found at ages 13 to 14,
At ages 11 and 12 the group effects, $F(3,105)=3.38$, $p<.02$, consisted of the NA/noADHD group performing better than either SAD group. There were no significant differences at ages 9 to 10, $F(3,124)=1.98$, $p<.12$, or 15 to 16, $F(3,47)=.70$, $p<.56$.

**Reading Tasks**

**WRAT Reading.** The data from the groups for the Reading subtest of the WRAT-R are presented in Table 5. An ANOVA comparing the SAD and NA groups yielded no effects of group or age. This expected lack of effect confirms the selection criterion specifying that members of the SAD groups not also have a learning disability in reading.

**Gilmore Oral Reading Test.** Stanines, presented in Table 3, were used in the following analyses, so age levels were combined. Analysis yielded no significant effects, $F(3,162)=1.72$, $p<.17$.

**Stanford Reading Comprehension.** Percentile scores, presented in Table 3, were used in the following analyses. A One-way ANOVA yielded significant effects of group, $F(3,85)=3.60$, $p<.02$, with the NA/noADHD group performing better than the SAD/ADHD group. Additional analysis revealed a significant difference between the SAD/noADHD and SAD/ADHD groups, $t(37)=-2.01$, $p=.052$, with the SAD/noADHD group performing better.

**Pseudoword Reading and Spelling**

**Pseudoword reading.** The children were administered the Reading of Symbols subtest of the GFW Sound Symbol Test and the Word Attack subtest of the Woodcock Reading Mastery Tests, both of which involve the reading of pronounceable nonwords and
yield percentile scores (see Table 3). Significant effects of group were found: GFW, $F(3,59)=3.45$, $p<.02$; Word Attack, $F(3,377)=7.42$, $p<.0001$. As with the spelling, the NA/noADHD group performed significantly better than the SAD/ADHD group. On the Word Attack, the SAD/ADHD group also performed more poorly than the SAD/noADHD group and the NA/ADHD group performed more poorly than the NA/noADHD group.¹

**Phonological choice task.** Data from this task are presented in Table 6. There were insufficient subjects to conduct analyses using all cells. A One-way ANOVA at ages 9 and 10 of the SAD/ADHD, NA/ADHD, and NA/noADHD groups yielded no significant effects. A t-test comparing ages 11 to 12 of the SAD/ADHD and SAD/noADHD groups also yielded no effects.

**Goldman, Fristoe, and Woodcock pseudoword spelling.** Percentile scores, presented in Table 2, were used for the following analyses. A comparison yielded significant group effects, $F(3,60)=2.90$, $p<.04$; the NA/noADHD group performed better than the SAD/ADHD group.

**Orthographic Coding Skill**

**WRAT Spelling.** A comparison of the groups on the Spelling subtest of the WRAT-R, with combined ages (data in Table 2), yielded significant effects of group, $F(3,536)=18.85$, $p<.00005$, with both NA groups performing better than both SAD groups.

Data as a function of age level are presented in Table 7. An ANOVA comparing the same groups, at five age levels, again yielded significant effects of group.

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¹ Additional data, at separate age levels, can be found in the Appendix.
F(3,536)=6.175, p<.0005, with the same performance pattern. However, the ANOVA also yielded a significant group-by-age interaction, F(12,527)=2.35, p<.006, so it was necessary to do separate analyses at each age level.

Oneway ANOVAs yielded significant effects of group at the first three age levels: 6-8 years, F(3,157)=9.22, p<.00005; 9-10, F(3,125)=4.86, p<.003; 11-12, F(3,105)=4.84, p<.003. At all three of these age levels, the NA/noADHD group performed better than the SAD/noADHD group. At the first age level the NA/noADHD group also performed better than any other group; at the second age level the NA/ADHD group also performed better than the SAD/noADHD group; and at the third age level the NA/noADHD group also performed better than the SAD/ADHD group. There were no significant effects at the upper two age levels.

Spelling recognition. Subjects completed the Spelling subtest of the Peabody Individual Achievement Test (PIAT; Dunn & Markwardt, 1979) and percentile scores were used in the following analyses (data presented in Table 2). A comparison yielded significant group effects, F(3,95)=4.37, p<.006: the NA/ADHD group scored significantly higher than the SAD/ADHD group.

Language Task

Oral Cloze Task. The data from this task are presented in Table 8. As can be seen, only certain groups had sufficient numbers to permit analyses. A Oneway ANOVA at ages 9 to 10, comparing the SAD/ADHD, NA/ADHD, and NA/noADHD groups yielded significant effects of group, F(2,46)=3.50, p<.04, with those without any disability scoring
higher than those with both. The NA/ADHD group was not significantly different from either of the other groups.

At both ages 11 to 12 and 15 to 16, Oneway ANOVAs comparing the SAD/ADHD, SAD/noADHD, and NA/noADHD groups yielded no significant effects.

**Short-term Memory**

**Short-term memory -- letter span.** The means on the short-term memory tasks involving rhyming and non-rhyming letters are presented in Tables 9 and 10. A MANOVA yielded significant effects of age, $F(4,396)=36.33, p<.0005$, with older students receiving higher scores. It also yielded a significant group by age interaction, $F(12,396)=1.79, p<.05$. Separate analyses were then conducted at each age level for the two tasks separately. Significant effects were found on both tasks at the first two age levels, with the same pattern of effects for both tasks. At ages 6 to 8, the NA/noADHD group performed better than the NA/ADHD group: Rhyming Task: $F(3,111)=3.36, p<.02$; Non-rhyming Task: $F(3,111)=4.29, p<.007$. At ages 9 to 10, both NA groups performed better than the SAD/ADHD group: Rhyming Task: $F(3,93)=4.83, p<.004$; Non-rhyming Task: $F(3,93)=6.26, p<.0006$.

**Working memory -- words.** The data from this task are presented in Table 11. There were insufficient subjects for analysis of some cells. A Oneway ANOVA was conducted at ages 9 to 10 comparing the SAD/ADHD, NA/ADHD, and NA/noADHD groups. No significant effects were found. At ages 11 to 12, a t-test comparing the SAD/ADHD and SAD/noADHD groups also yielded no significant effects.
**WISC-R Digit Span subtest.** Because standard scores were used for these analyses, all age groups were combined.\(^2\) The data are presented in Table 2. A comparison yielded significant effects of group, \(F(3,520)=12.53, p<.00005\), with the NA/noADHD group performing significantly better than any other group.

**Discussion**

The results of this study provided some support for the hypothesis that the performance of children with both an arithmetic disability and Attention-Deficit/Hyperactivity Disorder perform more poorly than children with either of those disabilities alone on a variety of academic, cognitive, and memory tasks.

Support was found in the performance on the VMI Developmental Test of Visual-Motor Integration. "As many as 52% of ADHD children are characterized as having poor motor coordination, especially on tasks requiring fine motor skills" (Barkley, 1990, p. 729). As well, Siegel and Feldman (1983) identified difficulties with eye-hand coordination, as measured by the VMI, as characteristic of children with an arithmetic disability and Rourke and his colleagues (1990) stated that grapho-motor difficulties are characteristic of those with NLD, at least at the earlier ages. In the current study, the combined learning disability group (SAD/ADHD) performed more poorly than did other groups.

No group effects were found in the analyses on the single-word reading task of the WRAT. In contrast, significant group differences were found on the measures involving the reading aloud of pseudowords. On the Woodcock Word Attack test, those subjects

\(^2\) Additional data, at separate age levels, can be found in the Appendix.
with ADHD performed more poorly than their counterparts without (SAD/ADHD < SAD/noADHD and < NA/noADHD; NA/ADHD < NA/noADHD). On the GFW, children with both difficulties performed more poorly than children with neither problem. Perhaps the novel nature of the tasks, as compared to reading real (and often familiar) words, was the aspect which increased the difficulty of these tasks for children with ADHD. Children reading real words can use their knowledge of sight words as well as phonological knowledge in order to read. With pseudowords it is necessary to look carefully at each letter in the pattern. One can neither rely upon previous knowledge of the word nor leap to a guess without attending to all the letters. Without such attention to detail, a child may read a real word in place of the pseudoword (e.g., crib for crid). These results are not consistent with Pennington et al.'s (1993) finding that children with ADHD do not have difficulty with phonological processing. They also contrast with Rourke's (e.g., 1990) inclusion of phonology as an area of strength for children with a nonverbal learning disability. When, however, subjects did not have to read the pseudowords aloud, as on the phonological choice task, group differences were absent. It may be that the weakness in oral-motor praxis, identified by Rourke and his colleagues (e.g., Rourke, 1990), interfered with subjects' use of their knowledge of phonology when the task included reading the pseudowords aloud, which the phonological choice task did not.

Siegel (1993) identified phonological processing, as measured by the reading of pseudowords, as significantly correlated to reading comprehension. There was evidence of deficits in reading comprehension for those children with both ADHD and AD in comparison to children with neither. This is consistent with Rourke's identification of
reading comprehension as one of the areas of academic deficit for children with a nonverbal learning disability (Rourke, 1990). It is also consistent with previous studies which found that children with ADHD had difficulty with a reading comprehension task (e.g., Barkley, 1990; Siegel & Ryan, 1988; Webster, Hall, Brown, & Bolen, 1996). A difference was found between children with both AD and ADHD and children with only AD, with the latter performing better. This finding lends support to the hypothesis that deficits associated with each disability may be cumulative.

The hypothesis that children with an arithmetic disability also have impaired spelling, and that this impairment is intensified when ADHD is also present, was supported when the task required the spelling of pseudowords. Again, the attention to detail necessary in representing "words" never read may have contributed to these effects. The results for the WRAT Spelling test suggest that at the youngest age level, when spelling skills are less well-developed, either disability is sufficient to impair spelling performance. In general, however, it was the presence of AD which correlated with lower spelling scores until age 12. As previously noted, Rourke (1989) attributed early spelling difficulties to a delay in children's ability to analyse the visual-spatial features of words.

The WISC-R Digit Span is a short-term and working memory task using numbers. Subjects with SAD, ADHD, or both performed more poorly than the comparison group (NA/noADHD). The short-term and working memory difficulties of children with an AD and of children with ADHD have been described by others (e.g., August & Garfinkel, 1990; Barkley, 1997b; Dykman & Ackerman, 1991; Siegel & Ryan, 1984, 1988, 1989). This study has provided additional evidence of those difficulties and added the knowledge
that children with both disabilities also have deficits in their ability to work with orally-presented numbers.

Only at the youngest ages were children in the comparison group (NA/noADHD) better at remembering visually-presented letters. The same pattern of performance was found with both rhyming and non-rhyming letters. At ages 6 to 8 years ADHD alone impaired performance, whereas AD did not; at ages 9 to 10 years, however, both normally-achieving groups performed significantly better than the group with both disabilities and there was no significant difference between the two NA groups. In his work dividing the assets and weaknesses associated with NLD into levels, Rourke has included deficits in visual memory at the third level (1989). For these tasks, it may be that the extent of difficulty was insufficient for effect until exacerbated by the visual attention deficits of ADHD. In addition, considering that the subjects were required to write the remembered letters, at the younger two age levels the difficulties with visual-motor tasks associated with both these disabilities may also have contributed to impaired performance.

On the Oral Cloze language measure, only the group with the combined disabilities (SAD/ADHD) was significantly weaker than children with no disability, and only at the youngest age analyzed (9-10 years). Neither an arithmetic disability nor ADHD by itself significantly impaired performance. Past research (Siegel, 1992; Siegel & Ryan, 1988) has demonstrated that the language difficulties associated with a reading disability significantly impair performance on this task, but that neither an AD nor ADHD do. This task requires detached monitoring of incoming information. It may be that it is only the combination of
attentional difficulties and the attention to syntax required by the oral cloze procedure that results in lower performance on this task.

A strength of this study was the identification of a group with a specific learning disability in arithmetic. The importance of identifying specific subtypes of learning disability to reaching accurate conclusions has been supported frequently (e.g., Fletcher, 1985a, 1985b; Morrison & Siegel, 1991; Rourke & Finlayson, 1978; Siegel & Linder, 1984; Siegel & Ryan, 1984, 1988, 1989; Shafir & Siegel, 1994).

Research regarding ADHD has also supported the need for subtypes to be defined (e.g., Power & DuPaul, 1996; Montague, McKinney, Hocutt, & Harris, 1992; Shaywitz, et al., 1994; Szatmari, et al., 1989), as has again been conducted in the context of the DSM-IV. Research has indicated that there may be differences between the impact on academic areas and learning disabilities of the different subtypes (e.g., Barkley, 1997b; Montague et al., 1992; Power & DuPaul, 1996; Riccio et al., 1994) and the lack of such subgroups is a weakness in this study. Research using groups defined by both a specific arithmetic disability and subtype(s) of ADHD identified in the DSM-IV (predominantly hyperactive-impulsive, predominantly inattentive, and combined types) would address this need for definitional clarity.

The primary limitation of this study was the high degree of variability in the number and identity of subjects participating in each task. Once the division into groups had occurred, there were sometimes too few subjects to make comparisons for particular groups or ages (e.g., Working Memory -- Words).

This study represents an initial investigation of the effects of simultaneously-occurring arithmetic disability and Attention-Deficit/Hyperactivity Disorder. It has
confirmed previous findings that visual-motor integration is problematic for persons with either of these disabilities, and has extended knowledge by confirming the hypothesis that persons with both disabilities have further impairments such as on oral cloze tasks, spelling pseudowords, and reading comprehension of passages that have been read silently. It disputes earlier research indicating that neither of these disabilities is related to difficulties with phonological processing because of difficulty found with reading pseudowords aloud. Further investigation of the area will be necessary to conclude which findings are more representative of the general population of children with these disabilities.
References


Benton (Eds.), *Dyslexia: An appraisal of current knowledge* (pp. 313-348). New York: Oxford University Press.


Siegel, L. S. (1988b). Definitional and theoretical issues and research on learning


and arithmetic learning disabilities. Clinical Pediatrics, 22, 241-244.

In S. Ceci (Ed.), Handbook of cognitive, social, and neuropsychological aspects of
learning disabilities, 1 (pp. 95-121). Hillsdale, NJ: Erlbaum.

reading and arithmetic learning disabilities. Developmental Psychology, 20, 200-207.

Remedial and Special Education, 5, 25-33.

phonological, and short-term memory skills in normally achieving and learning disabled

normally achieving and subtypes of learning disabled children. Child Development, 60,
973-980.

Spellacy, F., & Peter, B. (1978). Dyscalculia and elements of the developmental


## Tables

**Table 1**

Specific Arithmetic Disability with (SAD/ADHD) and without (SAD/noADHD) Attention-Deficit/Hyperactivity Disorder, and Normally Achieving with (NA/ADHD) and without (NA/noADHD) Attention-Deficit/Hyperactivity Disorder, by age.

<table>
<thead>
<tr>
<th>Age, in years</th>
<th>Specific Arithmetic Disability</th>
<th>Normally Achieving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SAD/ADHD</td>
<td>SAD/noADHD</td>
</tr>
<tr>
<td>6-8</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>9-10</td>
<td>29</td>
<td>12</td>
</tr>
<tr>
<td>11-12</td>
<td>46</td>
<td>28</td>
</tr>
<tr>
<td>13-14</td>
<td>26</td>
<td>22</td>
</tr>
<tr>
<td>15-16</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Total n</td>
<td>128</td>
<td>97</td>
</tr>
</tbody>
</table>
Table 2

Age-adjusted performance on tasks as a function of age and learning disability, Specific Arithmetic Disability and Normally Achieving. Tasks primarily related to Arithmetic Disability.

<table>
<thead>
<tr>
<th>Task</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>WRAT Arithmetic*</td>
<td>12.91</td>
<td>7.53</td>
<td>130</td>
<td>12.55</td>
</tr>
<tr>
<td>Beery VMI*</td>
<td>27.18</td>
<td>23.85</td>
<td>126</td>
<td>35.49</td>
</tr>
<tr>
<td>Stanford Reading Comp.*</td>
<td>25.11</td>
<td>19.16</td>
<td>18</td>
<td>39.33</td>
</tr>
<tr>
<td>GFW Spelling*</td>
<td>25.95</td>
<td>18.04</td>
<td>19</td>
<td>35.67</td>
</tr>
<tr>
<td>WRAT Spelling*</td>
<td>38.73</td>
<td>21.56</td>
<td>128</td>
<td>40.07</td>
</tr>
<tr>
<td>PIAT Spelling Recognition*</td>
<td>32.46</td>
<td>23.18</td>
<td>39</td>
<td>43.61</td>
</tr>
<tr>
<td>WISC-R Digit Span**</td>
<td>8.97</td>
<td>2.49</td>
<td>122</td>
<td>9.43</td>
</tr>
</tbody>
</table>

Note. *=Percentile; **=Standard score, mean of 10; ***=Stanine. Means in the same row that do not share subscripts differ at p<.05 in the Tukey Honestly Significant Difference comparison with the exception of <z, difference determined by t-test.
Table 3

Age-adjusted performance on tasks as a function of age and learning disability: Specific Arithmetic Disability and Normally Achieving: Reading Tasks.

<table>
<thead>
<tr>
<th>Task</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>WRAT</td>
<td>57.60</td>
<td>18.43</td>
<td>130</td>
<td>60.76</td>
</tr>
<tr>
<td>Reading*</td>
<td></td>
<td></td>
<td></td>
<td>67.77</td>
</tr>
<tr>
<td>Gilmore Oral Reading***</td>
<td>5.16</td>
<td>1.82</td>
<td>58</td>
<td>5.65</td>
</tr>
<tr>
<td>Reading</td>
<td>25.11</td>
<td>19.16</td>
<td>18</td>
<td>39.33</td>
</tr>
<tr>
<td>Stanford Reading Comp.*</td>
<td></td>
<td></td>
<td></td>
<td>51.79</td>
</tr>
<tr>
<td>GFW Reading*</td>
<td>35.44</td>
<td>22.33</td>
<td>18</td>
<td>41.44</td>
</tr>
<tr>
<td>Woodcock</td>
<td>19.89</td>
<td>56.09</td>
<td>68</td>
<td>50.19</td>
</tr>
<tr>
<td>Word Attack*</td>
<td>14.64</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. *=Percentile; **=Standard score, mean of 10; ***=Stanine. Means in the same row that do not share subscripts differ at p<.05 in the Tukey Honestly Significant Difference comparison.
Table 4

Mean percentile scores on the Beery VMI as a function of age and learning disability: Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Group</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>Age (in years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 to 8</td>
<td>24.36&lt;sub&gt;b&lt;/sub&gt;</td>
<td>12.57</td>
<td>14</td>
<td>36.13&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>9 to 10</td>
<td>25.86</td>
<td>22.32</td>
<td>29</td>
<td>36.03</td>
</tr>
<tr>
<td>11 to 12</td>
<td>30.20&lt;sub&gt;b&lt;/sub&gt;</td>
<td>25.86</td>
<td>25</td>
<td>42.13&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>13 to 14</td>
<td>17.32&lt;sub&gt;a&lt;/sub&gt;</td>
<td>20.46</td>
<td>25</td>
<td>29.48</td>
</tr>
<tr>
<td>15 to 16</td>
<td>33.75</td>
<td>33.49</td>
<td>12</td>
<td>34.41</td>
</tr>
</tbody>
</table>

Note. Means in the same row that do not share subscripts differ at p<.05 in the Tukey Honestly Significant Difference comparison.
Table 5

Mean percentile scores on the WRAT Reading subtest as a function of age and learning disability.

Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Age (in years)</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>6 to 8</td>
<td>53.79</td>
<td>13.64</td>
<td>14</td>
<td>54.53</td>
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<tr>
<td>9 to 10</td>
<td>57.17</td>
<td>18.51</td>
<td>29</td>
<td>55.25</td>
</tr>
<tr>
<td>11 to 12</td>
<td>54.09</td>
<td>17.47</td>
<td>46</td>
<td>55.61</td>
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<tr>
<td>13 to 14</td>
<td>67.77</td>
<td>19.09</td>
<td>23</td>
<td>67.00</td>
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<tr>
<td>15 to 16</td>
<td>54.00</td>
<td>18.65</td>
<td>13</td>
<td>68.00</td>
</tr>
</tbody>
</table>
Table 6

Mean percent correct on the Phonological Choice Task as a function of age and learning disability.

<table>
<thead>
<tr>
<th>Group</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in years)</td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>9 to 10</td>
<td>77.69</td>
<td>10.54</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80.07</td>
<td>12.97</td>
<td>11</td>
<td>83.76</td>
</tr>
</tbody>
</table>

Note: Missing values are due to insufficient n.
Table 7

Mean percentile scores on the WRAT-R Spelling subtest as a function of age and learning disability. Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Group</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in years)</td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>6 to 8</td>
<td>43.00&lt;sub&gt;b&lt;/sub&gt;</td>
<td>21.45</td>
<td>14</td>
<td>39.73&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>9 to 10</td>
<td>37.66</td>
<td>17.74</td>
<td>29</td>
<td>36.42&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>11 to 12</td>
<td>33.48&lt;sub&gt;b&lt;/sub&gt;</td>
<td>21.25</td>
<td>46</td>
<td>31.29&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>13 to 14</td>
<td>43.27</td>
<td>25.85</td>
<td>26</td>
<td>46.95</td>
</tr>
<tr>
<td>15 to 16</td>
<td>46.00</td>
<td>19.17</td>
<td>13</td>
<td>47.25</td>
</tr>
</tbody>
</table>

Note. Means in the same row that do not share subscripts differ at p<.05 in the Tukey Honestly Significant Difference comparison.
Table 8

Mean number correct on Oral Cloze as a function of age and learning disability. Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Group</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Age (in years)</td>
<td>n</td>
<td>n</td>
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<td>n</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>------------</td>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>6 to 8</td>
<td>12.12 (5.21)</td>
<td>12.15 (3.87)</td>
<td>12.15 (3.87)</td>
<td>12.15 (3.87)</td>
</tr>
<tr>
<td>9 to 10</td>
<td>13.92 (3.78)</td>
<td>15.84 (2.01)</td>
<td>16.41 (2.62)</td>
<td>16.41 (2.62)</td>
</tr>
<tr>
<td>11 to 12</td>
<td>16.43 (2.90)</td>
<td>17.90 (1.85)</td>
<td>16.55 (2.38)</td>
<td>16.55 (2.38)</td>
</tr>
<tr>
<td>13 to 14</td>
<td>18.25 (0.97)</td>
<td>16.67 (1.87)</td>
<td>16.67 (1.87)</td>
<td>16.67 (1.87)</td>
</tr>
<tr>
<td>15 to 16</td>
<td>17.67 (2.00)</td>
<td>17.56 (2.19)</td>
<td>18.00 (1.15)</td>
<td>18.00 (1.15)</td>
</tr>
</tbody>
</table>

Note. Missing values are due to insufficient n. Means in the same row that do not share subscripts differ at \( p < .05 \) in the Tukey Honestly Significant Difference comparison.
Table 9

Mean number correct on the Short-term Memory for Rhyming Letters task as a function of age and learning disability, Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Group</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in years)</td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>6 to 8</td>
<td>14.89</td>
<td>4.46</td>
<td>9</td>
<td>12.50</td>
</tr>
<tr>
<td>9 to 10</td>
<td>17.63b</td>
<td>4.41</td>
<td>24</td>
<td>21.25</td>
</tr>
<tr>
<td>11 to 12</td>
<td>22.58</td>
<td>5.70</td>
<td>40</td>
<td>23.37</td>
</tr>
<tr>
<td>13 to 14</td>
<td>26.54</td>
<td>4.68</td>
<td>24</td>
<td>28.11</td>
</tr>
<tr>
<td>15 to 16</td>
<td>29.46</td>
<td>2.99</td>
<td>13</td>
<td>29.06</td>
</tr>
</tbody>
</table>

Note. Means in the same row that do not share subscripts differ at p<.05 in the Tukey Honestly Significant Difference comparison.
Table 10

Mean number correct on the Short-Memory for Non-rhyming Letters as a function of age and learning disability. Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Group</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in years)</td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>6 to 8</td>
<td>20.33</td>
<td>8.49</td>
<td>9</td>
<td>17.00</td>
</tr>
<tr>
<td>9 to 10</td>
<td>22.17</td>
<td>6.56</td>
<td>24</td>
<td>24.88</td>
</tr>
<tr>
<td>11 to 12</td>
<td>27.48</td>
<td>5.49</td>
<td>40</td>
<td>29.26</td>
</tr>
<tr>
<td>13 to 14</td>
<td>30.33</td>
<td>4.83</td>
<td>24</td>
<td>31.17</td>
</tr>
<tr>
<td>15 to 16</td>
<td>31.92</td>
<td>2.63</td>
<td>13</td>
<td>21.89</td>
</tr>
</tbody>
</table>

Note. Means in the same row that do not share subscripts differ at p<.05 in the Tukey Honestly Significant Difference comparison.
Table 11

Mean number correct on Working Memory -- Words as a function of age and learning disability.

Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Age (in years)</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>9 to 10</td>
<td>3.50</td>
<td>1.93</td>
<td>12</td>
<td>4.43</td>
</tr>
<tr>
<td>11 to 12</td>
<td>5.57</td>
<td>2.13</td>
<td>14</td>
<td>5.30</td>
</tr>
</tbody>
</table>

Note. Missing values are due to insufficient n.
Appendix

Additional Results

Table A1

Mean percentile scores on the Woodcock Work Attack as a function of age and learning disability.

Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Group</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 to 8</td>
<td>41.57</td>
<td>14.25</td>
<td>7</td>
<td>56.00</td>
</tr>
<tr>
<td>9 to 10</td>
<td>41.50</td>
<td>22.04</td>
<td>22</td>
<td>54.67</td>
</tr>
<tr>
<td>11 to 12</td>
<td>41.57</td>
<td>20.26</td>
<td>30</td>
<td>50.21</td>
</tr>
<tr>
<td>13 to 14</td>
<td>53.62</td>
<td>18.21</td>
<td>21</td>
<td>61.61</td>
</tr>
<tr>
<td>15 to 16</td>
<td>44.17</td>
<td>18.52</td>
<td>12</td>
<td>55.90</td>
</tr>
</tbody>
</table>

Note: An ANOVA yielded significant effects of group, F(3,380)=5.00, p<.0002 with the SAD/ADHD group scoring lower than the SAD/noADHD and NA/noADHD groups and the NA/ADHD group scoring lower than the NA/noADHD group.
Table A2

Mean scaled score on the WISC-R Digit Span subtest as a function of age and learning disability.

Specific Arithmetic Disability and Normally Achieving.

<table>
<thead>
<tr>
<th>Age (in years)</th>
<th>SAD/ADHD</th>
<th>SAD/noADHD</th>
<th>NA/ADHD</th>
<th>NA/noADHD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>6 to 8</td>
<td>8.50</td>
<td>1.70</td>
<td>14</td>
<td>9.29</td>
</tr>
<tr>
<td>9 to 10</td>
<td>8.36</td>
<td>2.48</td>
<td>25</td>
<td>9.33</td>
</tr>
<tr>
<td>11 to 12</td>
<td>9.50</td>
<td>2.64</td>
<td>24</td>
<td>9.56</td>
</tr>
<tr>
<td>13 to 14</td>
<td>8.69</td>
<td>2.56</td>
<td>26</td>
<td>10.00</td>
</tr>
<tr>
<td>15 to 16</td>
<td>9.15</td>
<td>2.79</td>
<td>13</td>
<td>9.65</td>
</tr>
</tbody>
</table>

Note. An ANOVA yielded significant group effects, $F(3,520)=13.138$, $p<.0001$. A Tukey Honestly Significant Difference comparison revealed that the NA/noADHD group performed better than any other group, $p<.05$. 