CHARACTERISTIC MEMORY FUNCTIONS IN SUBTYPES OF ARITHMETIC DISABLED CHILDREN

DISSERTATION

Presented to the Graduate Council of the University of North Texas in Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

By

Helene Deborah-Lynne Pennett, B.Ed., M.Ed., M.S.

Denton, Texas

August, 1994
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Pennett, Helene Deborah-Lynne, **Characteristic Memory Functions in Subtypes of Arithmetic Disabled Children.**

Doctor of Philosophy (Psychology), August, 1994, 128 pp., 16 tables, bibliography, 112 titles.

The role of memory as measured by the Wide Range Assessment of Memory and Learning (WRAML) was studied in an outpatient clinic sample of 62 arithmetic disabled children. All subjects had a Full Scale IQ ≥ 90 (Mean = 107.02). Using a 15 point ability-achievement discrepancy in conjunction with an achievement score below 90, the subjects were subtyped into the following disability groups: arithmetic only (A, N = 22), arithmetic and spelling (AS, N = 19) and arithmetic, reading and spelling (ARS, N = 21). The children, aged 9 through 13, were administered the WRAML, the Wide Range Achievement Test - Revised (WRAT-R) and the mathematics subtests of the Woodcock-Johnson Psychoeducational Battery - Revised: Tests of Achievement (WJR). The expected difference in scores on the Visual Memory Index did not materialize for the three subtypes. The ARS subtype earned lower scores on the Verbal Memory Index when compared to their own performance on visual memory, as well as when compared to the other two subtypes. In the three four-trial learning tasks included in the WRAML, no difference was found among the subtypes for
visually or verbally presented material. The ARS subtype did, however, performed worse on the task requiring simultaneous visual and verbal learning. Only one of the hypothesized memory-achievement correlations was significant, suggesting the lack of a specific relationship between memory and achievement for this age group of arithmetic disabled children. The meaningfulness of stimuli, whether presented verbally or visually, appears to impact memory in all three subtypes of arithmetic disabled children. Although often considered a heterogeneous group, the ARS subtype demonstrated several distinct weaknesses. On the other hand, the A subtype, generally considered to have deficits in visual processing, did not demonstrate significant weaknesses in visual memory suggesting a dissociation between memory and other processing functions and, furthermore, that visual memory may not be a prominent deficit of arithmetic disabilities.
ACKNOWLEDGEMENTS

I would like to acknowledge Texas Scottish Rite Hospital for Children, Dallas, Texas for the use of subject data. I would also like to acknowledge Richard Browne, Ph.D., Administrative Director of Research at the hospital for his invaluable assistance with statistical analyses.

I would like to acknowledge Cheryl H. Silver, Ph.D., Assistant Professor, University of Texas Southwestern Medical Center for her support and assistance throughout my dissertation process.

I would like to acknowledge Sander Martin, Ph.D. of the University of North Texas Department of Psychology for his support throughout my doctoral program and for chairing my dissertation committee.

Finally, I would like to acknowledge my children, Jeffrey, Janalyn, and Justin Alcantara for cooperating with my different schedules and sacrificing time with me so that I could complete my degree.
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CHAPTER I

INTRODUCTION TO THE STUDY

As little as twenty-five years ago, children who displayed learning disabilities were unable to receive special education services because their group of disabilities did not fit into any of the categories of handicapping conditions (Moats & Lyon, 1993). However, in 1975, the Education for All Handicapped Children Act (PL94-142) incorporated learning disabilities as a handicapping condition. The definition is as follows:

The term 'specific learning disability' means a disorder in one or more basic psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, speak, read, write, spell, or do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. Such terms do not include children who have learning disabilities which are primarily the result of visual, hearing, or motor handicaps, of mental retardation, of emotional disturbance, or
of environmental, cultural or economic disadvantage.

(United States Office of Education, 1977, p. 65083)

The act deferred to individual states the task of operationalizing the definition of learning disabilities for the purpose of identifying learning disabled children and ultimately, to develop and use effective interventions in the schools (Mercer, Hughes, & Mercer, 1985; Mercer, King-Sears & Mercer, 1990; Moats & Lyon, 1993). Operational definitions, therefore, vary from state to state. Consequently, research based on school-diagnosed learning disabled children may differ from state to state, not allowing for replication studies when another state’s criteria are utilized (Council for Learning Disabilities Research Committee, 1993). Given the diversity of state definitions, researchers may choose not to rely on school diagnoses. If this is the case, then some operational definition must be heuristically generated. However, even though researchers have repeatedly asked for a consistent definition of learning disabilities, little progress has been made (Council for Learning Disabilities Research Committee, 1993). As a starting point for research definitions, the predominant criterion has been the discrepancy between aptitude and achievement (Moats & Lyon, 1993).

Even though the disorder was treated as homogeneous by researchers for many years, the parameters of the definition
appear to imply that a heterogeneous group of children is under consideration (Lyon & Moats, 1993). Classification of distinct groups of learning disabled individuals has become a major endeavor for researchers and practitioners. If children are to receive special assistance for their specific type of learning problem, then researcher must help define various classifications, preferably using simple, but valid procedures. The essential variables for classification include cognitive, academic, and even social skills. Indistinct classifications and within group heterogeneity confound study results based on traditional group contrast (learning disabled vs. normal controls) because they are an anachronism in the face of increasing support of research based on the knowledge of learning disability subtypes (Fletcher & Morris, 1986).

One small section of the definition of learning disabilities includes reference to an "...imperfect ability to ... do mathematical calculations." With the vast majority of research pursuing reading disabilities to the relative neglect of developmental dyscalculia or arithmetic disabilities (Badian, 1983), a child with an arithmetic disability may be neglected in both school-based and research-based assessment, and remediation efforts (Kirk & Chalfont, 1984). This neglect is despite the obvious functional significance of mathematical reasoning and calculation skills for activities of daily living, as well
as their importance in the ever increasingly complex workplace (Putnam, Lampert, & Peterson, 1990).

Although the definition of learning disabilities is frequently limited to academic areas, and research in learning disabilities is often closely associated with tasks that are specifically and pragmatically designed for the classroom, the general cognitive development of children is an essential framework for the learning process. One major area of cognitive development in children is memory (Hall, Tinzmann, & Humphreys, 1987; Kirk & Chalfont, 1984). The results of learning experiences must be retained and accumulated, so that children can use the knowledge from past experience, benefit from the present, and anticipate the future (Kirk & Chalfont, 1984). Memory disorders impede the learning process and cause difficulty in both childhood and adulthood, with particular hardship during the early acquisition phase in school-aged years (Piaget & Inhelder, 1973). If this is the situation with normally achieving children, it is more the case for the learning disabled child. Therefore, there is a growing interest in studying the differences in general cognitive/memory tasks that may be characteristic of the learning disabled population. Some researchers speculate that deficits in memory processes may be responsible for many of the difficulties exhibited by learning disabled children (Mastropieri & Scruggs, 1990). Furthermore, Brainerd, Kingma, and Howe (1986) postulate two
important implications inherent in the study of cognition: (1) denial of the traditional view that a learning disabled child's impairment is highly specific to a single academic area; and (2) the possibility that deficits in memory may be responsible for previously recognized research-documented deficits in a whole variety of tasks supposedly related to other areas of cognition. Remembering is essential to learning and there is a current emphasis on memory as an important component of mathematical learning (Byers & Erlwanger, 1985). For example, Bley and Thornton (1989) have asserted that several memory deficits can impact the learning of arithmetic.

Although there has been some research in the area of arithmetic disabilities in children, the research regarding the cognitive component of memory and how it relates to arithmetic learning disabilities is not substantial (Batchelor, Gray, & Dean, 1990). There are several reasons for this paucity of research. Until recently, a well standardized instrument to assess children's memory has not been available, however, several memory tests have been introduced within the last two years: the Wide Range Assessment of Memory and Learning (WRAML; Sheslow & Adams, 1990), the California Verbal Learning Test for Children (CVLT-C; Delis, Kramer, Kaplan, and Ober, 1993), and the Test of Memory and Learning (TOMAL; Reynolds and Bigler, 1993). Secondly, it has only been recently that subtypes of
learning disabilities have gained importance and, in particular, subtypes of arithmetic learning disabled children have been studied (Rourke, 1989). Finally, arithmetic disabilities may not have been regarded by society as particularly critical, and may even have been somewhat acceptable (Cohn, 1968). It is clear, however, that with the existence of standardized tests of children’s memory, the specificity of subtypes of learning disabilities, and the current reform efforts in the importance of arithmetic knowledge (Batchelor et al., 1990), opportunities exist to foster research.

Arithmetic Learning Disabilities

Research specificity has been a central need in the area of learning disabilities for quite some time, since previously, it has often been studied as a homogeneous entity (Badian, 1983). Yet, although researchers within the field of learning disabilities have found that subtype research can be extremely fruitful, some studies continue to use heterogeneous groups of learning disabled children (Badian, 1983). Clearly, future paths lead in the direction of subtyping, but even where subtypes are carefully considered, the studies, like most research in the field of learning disabilities, have generally dealt with reading disability subtypes. Even a cursory review of the historical research literature would suggest that the term learning disability is often synonymous with reading
disability (Badian, 1983, Selz & Wilson, 1989). There continues to be a basic scarcity of research with arithmetic subtypes (Badian, 1983).

While weaknesses in arithmetic skills may actually be more socially acceptable than reading, writing, or spelling disorders (Cohn, 1968), the subtle social impact of arithmetic difficulties continues to plague children in school. Unfortunately, even if this trend toward social acceptability is continuing, many are beginning to see the necessity for American school children to obtain better arithmetic skills in order to compete in world markets (Putnam et al., 1990; Smith and Rivera, 1991). Given the importance of verbal communication (whether written, oral, or electronic), the ability to read and write may be seen as foremost, but without precluding the importance of arithmetic skill (Badian, 1983; Smith & Rivera, 1991). Indeed, there is evidence to show that junior high school students often use mathematics performance as a major criterion to determine how "smart" they are (Levine, Lindsay, & Reed, 1992). In addition, Rourke, Young, and Leenaars (1989) have demonstrated that some children with arithmetic deficits also experience significant deficits in social perception, social judgment, and social skill acquisition, including such particulars as age-appropriate sensitivity to humor, problems with speech prosody (rhythmic
structure of sound in speech), and a marked tendency toward social withdrawal.

Historically, reading and spelling have been the focus of special education (Batchelor et al., 1990) and 5% of all children in public schools were identified as learning disabled (United States Department of Education, 1989), but children with arithmetic learning disabilities are underidentified and underserved (Cohn, 1961; Selz & Wilson, 1989). However, the pervasiveness of arithmetic learning disabilities has been explored and the number of children with arithmetic learning disabilities is significant. In a major methodical study, Kosic (1974) found that 24 of 375 children in a fifth grade were dyscalculic, inferring that 6% of children can be expected to show symptoms of developmental dyscalculia. Other studies have also found that approximately 6% of children have trouble with arithmetic (Badian & Ghublikian, 1982). In addition, according to Carpenter (1985), about one third of the instructional time in special education classes is spent on mathematics and yet, Cawley, Fitzmaurice, Shaw, Kahn, and Bathes (1979) found evidence suggesting that teachers of learning disabled students consider their training in mathematics to be inadequate. There is, then, a pressing need to address arithmetic disabilities, with the central hope that, by defining subgroups, more effective specific
educational interventions can be developed (Lyon, Newby, Recht, & Caldwell, 1991).

Researchers have argued that subtypes should be defined in terms of actual patterns of deficient learning and then other areas of cognitive functioning should be studied (Hynd, Connor, & Nieves, 1988; Satz & Morris, 1981; Taylor, Fletcher, & Satz, 1982). As early as 1963, Kinsbourne and Warrington published a study delineating subtypes of reading disabled children. This study was the beginning of research employing clinical measures to differentiate the unique behavioral manifestations of each subtype. From this earlier study and others like it, many empirical studies delineating subtypes followed (Hynd et al., 1988), although the vast majority of these studies focused on reading rather than arithmetic disabilities.

Even though research with subtypes is becoming more common, many of the studies have not controlled for important moderator variables such as age and IQ. Several researchers (Hynd et al., 1988; Reynolds & Gutkin, 1979) suggest that, when aptitude-achievement discrepancy criteria are used to define learning disabilities in children, these moderator variables may be highly significant correlates or predictors of neuropsychological and cognitive abilities.

Some of the best controlled research in arithmetic disabilities has come from Byron Rourke's team of clinical researchers (Rourke, 1989; Rourke & Finlayson, 1978; Rourke
& Strang, 1978; Strang & Rourke, 1983). They have been particularly interested in whether children who exhibit very specific academic performance patterns also demonstrate identifiable, replicable patterns of neuropsychological abilities. In particular, Rourke (1978) has shown that groups of children with similar scores in arithmetic can be sharply differentiated when non-arithmetic academic variations are considered. Children who have difficulty in reading and spelling as well as arithmetic are clearly different from those who have difficulty only in arithmetic (Rourke, 1989; Strang & Rourke, 1985). Often research with learning disabled children uses a control group of normally achieving children, but additional differences in performance may also be a function of membership in a clinical group (Pennington, 1991). However, Rourke (1989; Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983) compared groups of children with arithmetic deficits to children with deficits in arithmetic and reading, matched for age, Full Scale IQ and level of arithmetic achievement to better delineate characteristics of subtypes of the arithmetic disabled child. The research of Rourke and his associates is described below.

In one of the first major studies, Rourke and Finlayson (1978) investigated three groups of arithmetic disabled children. The subjects were 9 through 14 years of age with Full Scale IQ's ranging from 86-114. Unfortunately,
information on gender, ethnicity, and socioeconomic status was not reported. Group 1 was low in reading, arithmetic and spelling. Group 2 was low in reading and spelling and although achieving below grade level in arithmetic, the arithmetic performance of this group was better than the reading and spelling performance. Group 3 was low in arithmetic, but reading and spelling were within normal limits. A variety of ability tests were used in order to contrast subtype performance: the Wide Range Achievement Test (WRAT; Jastak & Jastak, 1965), the Wechsler Intelligence Scale for Children (WISC; Wechsler, 1949), the Peabody Picture Vocabulary Test (PPVT; Dunn, 1949), the Halstead-Wepman Aphasia Screening Test and the Vocabulary Recognition Task. Groups 1 and 2 were found to be similar on all measures. However, those deficient only in arithmetic (Group 3) had significantly higher Verbal IQ scores than Performance IQ scores, and performed better on all verbal measures than Group 2. As expected, the Performance IQ of Group 2 was also significantly higher than that of Group 3. Of particular interest, however, was that although Groups 2 and 3 had a similar level of performance on the WRAT Arithmetic Test, it was the pattern of academic performance that was tantamount in discriminating the groups. It is logical to ascertain that had Groups 2 and 3 been combined in a single group as arithmetic disabled, the
patterns of differences found in ability measures would have been masked (Rourke, 1992).

A second study with the same subjects (Rourke & Strang, 1978) utilizing only motor, psychomotor, or tactile-perceptual measures found that the three groups did not differ significantly on simple motor measures. When complex psychomotor measures were analyzed, however, it was found that Group 3 significantly poorer scores. In addition, at a later date when norms were developed for these tests, Rourke (1989) found that the performance of Group 3 on the complex psychomotor measures was below, while the scores of Group 1 and 2 were within normal limits.

Using only Groups 2 and 3 in a third study, Strang and Rourke (1983) found that children in Group 3 made significantly more errors on the Halstead Category Test, a nonverbal problem-solving measure. In addition, Group 3 children performed especially poorly on those subtests that required a high order of visual-spatial analysis.

Accordingly, there is considerable evidence to support the contention that arithmetic disabled children can be characterized by visual-spatial and sensorimotor deficits (Rourke, 1989). Rourke and his colleagues used the same children for each of these three studies and gender was reported in the third study, although ethnicity and socioeconomic status remained unreported. In selecting subjects a seemingly atypical variable was used to determine
achievement disability. The majority of studies use either a standard score discrepancy or a percentile minimum. These subjects, however, were chosen based on grade score on the WRAT which may have produced a distinctive sample.

A fourth and fifth study using children aged 7 and 8 years found similar patterns of verbal, auditory-perceptual, and visual-spatial abilities in all three groups, compared with their older counterparts (Ozols & Rourke, 1988). Differences were not as clear-cut in the areas of motor, psychomotor, and tactile-perceptual skills as in the older children and, because of the developmental stage of the children, higher order reasoning and problem-solving abilities were not investigated (Ozols & Rourke, 1991).

While conducting research with arithmetic disabled children, Fletcher (1985) further supported differentiation of learning disabled children on the basis of patterns of achievement. His groups consisted of 87 children 7 to 12 years of age, divided into a control (C) group, a reading-spelling disabled (RS) group, a reading-spelling-arithmetic (RSA) disabled group, a spelling-arithmetic (SA) disabled group, and an arithmetic (A) disabled group. He used selective reminding tasks to examine verbal and nonverbal memory. He found that while the A and SA groups performed poorly on nonverbal tasks, the RS group did well on nonverbal tasks but worse on verbal tasks. The RSA group did poorly on both verbal and nonverbal selective reminding
tasks. Furthermore, to accentuate the significance of these findings since memory is often found to be correlated with IQ, Fletcher found that IQ was not a significant covariate. At the same time, however, there was a significant difference between these subgroups on Verbal IQ and Full Scale IQ and consideration could be given to the effect of these two variables.

Also using WRAT-defined subgroups, Siegel and Linder (1984) compared children defined as reading, spelling and arithmetic disabled (RSA), arithmetic disabled (A), and controls on measures that demanded the use of phonemic coding in short-term memory. The research task included three different input-output procedures using groups of 5 or 6 letters, half with rhyming letters and half with nonrhyming letters. Administration and response were, respectively, as follows: visual-written, visual-oral and auditory-written. Generally, they found that younger RSA children had difficulty regardless of the modality or the memory conditions, but the A children only had difficulty with items presented in the visual modality and were similar to controls in the auditory modality. Criteria for selection for this may be somewhat skewed considering the Peabody Picture Vocabulary Test (PPVT) was used to measure IQ and the minimum IQ was 80. The PPVT used as an IQ measure is inherently limited to a unitary measure of half of the usual visual/verbal IQ dichotomy. Using 80 as a
minimum IQ would seem to increase the possibility of
including children that are not within the normal range of
IQ, given that 80 is more than one standard deviation below
the mean of 100.

In another study, Siegel and Ryan (1988) conducted
research on short-term memory skills using 138 normally
achieving, 65 reading-disabled, 63 arithmetic disabled, and
15 hyperactive children aged 7 to 14 years. They used the
same group of rhyming and nonrhyming letters as in the
Siegel and Linder (1984) study described above. However,
the subjects only had the items presented visually, and had
to respond in writing. There was also a sentence repetition
task. The arithmetic disabled group had below average
memory skills at all ages. Selection techniques for this
study were similar to the Siegel and Linder (1984) and the
same questions surface. In addition, the three studies
above, Fletcher (1985), Siegel and Linder (1984) and Siegel
and Ryan (1988) used memory measures that were not normed or
standardized on a large sample.

Children with arithmetic disabilities do not form a
homogeneous group. In general, two significant patterns of
arithmetic disability have been delineated. The patterns
are based on the presence or absence of disabilities in the
areas of reading and spelling in addition to arithmetic.
Children with pure arithmetic disabilities perform more
poorly on tasks requiring visual processing, usually
considered to be a function of the right cerebral hemisphere function, while children who also experience difficulty with reading and spelling perform more poorly on tasks requiring verbal processing, usually considered to be a left hemispheric function (Rourke, 1993). Since there is substantial evidence for achievement-pattern defined subtypes as meaningful predictors of neuropsychological deficit (Doehring, Trites, Patel, & Fiedorowicz, 1981; Fletcher, 1985; Rourke, 1978), it would appear that research based on these groups could further delineate specific strengths and weaknesses of arithmetic disabled children (Fletcher & Morris, 1986).

Memory

Memory is "the faculty by which sense impressions and information are retained consciously or unconsciously in the mind and subsequently recalled...the total store of mentally retained impressions and knowledge..." (Webster's Dictionary, 1989). In more psychological terms, memory is the encoding, processing, and retrieval of information (Swanson & Cooney, 1991). Although it appears that memory can be simply defined, it is a very complex cognitive ability. Memory is a multimodal process which requires complex assessment (Boyd, 1988). However, memory is often lumped into a single category, without considering distinctions (e.g., long-term vs. short-term, verbal vs.
Many models of memory have been proposed; however, one of the most influential contemporary models of memory is that proposed by Atkinson and Shiffrin (1968). The Atkinson and Shiffrin model (1968) is a multistore model which includes: the sensory register where information first enters and rapidly decays; the short term store, which is working memory and deals with information in auditory, verbal, or linguistic forms; and the long-term store, which has unlimited capacity. Furthermore, the model includes control processes wherein individuals have the capacity to use mechanisms of their choice to control the movement of information both within and between the three major structural components noted above.

Pennington (1991) further divides long-term memory into procedural and declarative memory. Procedural memory includes memory for skills not retrievable as individual facts or abilities. Declarative memory, however, is composed of memories that can be retrieved as specific facts and events and expressed verbally, visually, or by some other means. Declarative memory can further be divided into two categories: semantic memory, the knowledge of meanings and facts; and episodic memory, the knowledge of specific personal events (Pennington, 1991).
While Atkinson and Shiffrin (1968) presented a knowledge based model of memory, Craik and Lockhart (1972) delineated the widely influential depth of processing model (Lockhart & Craik, 1990). Craik and Lockhart (1972) proposed that what is remembered by an individual is a function of how elaborate the analysis of the information is. Information can be stored after initial processing. Retention is a function of the depth of the analysis of the material. Information, whether verbal, visual, olfactory, etc., and depending upon association with past experiences, is processed through levels. That is, meaningful material will be processed more quickly than less meaningful material and will be better retained.

Memory assessment has increasingly been considered an integral part of a comprehensive neuropsychological examination and is one of the most important developmental tasks of school-age children. Remarkably, then, as recently as 1988 there was no single text on childhood memory in the clinical neuropsychological literature (Boyd, 1988). An enormous body of literature demonstrates that the study of memory has been important in the study of cognitive processes in adults. Yet, a little more than a decade ago, no less prominent researcher than Russell (1981) indicated that, although there was a proliferation of literature confirming the need for standardized testing of memory, there was no corresponding test development concerning
adults. If this was, until recently, the situation regarding the assessment of adult memory, it was even more true with regard to the assessment of children’s memory, where the first standardized measures have very recently appeared (WRAML, 1990; CVLT-C, in press; TOMAL, 1993).

In a more general sense, memory tasks have been included in many other assessment instruments, particularly standardized intelligence tests. Because memory abilities demonstrate a reliable developmental course over the age span (Anastasi, 1982), memory-based subtests have routinely been included in intelligence batteries such as the Wechsler Intelligence Scale for Children – Revised (WISC-R; Wechsler, 1974), which measures short-term, immediate memory with the Digit Span and Arithmetic subtests, while the Information subtest can be considered to measure long-term verbal recall. The Kaufman Assessment Battery for Children (KABC; Kaufman & Kaufman, 1983) also includes several tests that tap memory abilities, including: the Hand Movements subtest, which requires a child to remember a sequence of demonstrated hand movements; the Number Recall subtest, which requires repetition of number sequences; the Word Order subtest, which requires the child to remember the order of verbally named objects when the objects are later presented visually; and, finally, the Spatial Memory subtest, which requires the child to remember grid locations. However, although the two tests listed above
clearly assess children's memory in multiple subtests, a memory score is not a part of the results of the test. While the McCarthy Scales of Children's Abilities do include a separate computation for memory, the upper age range of this test is 8 years, 6 months (McCarthy, 1972). Of the major intelligence tests used for children, the only one that includes a memory score across the age range of school children is the Stanford-Binet Intelligence Scale: Fourth Edition (SB-FE; Thorndike, Hagen, & Sattler, 1986). In fact, memory is one of the three cognitive factors used in the test's model of cognitive abilities. However, there have been several psychometric challenges to the integrity of the SB-FE factorial model that have already appeared in the literature, possibly questioning the general utility of the scales (Laurent, Swerdlik, & Ryburn, 1992).

However, while memory is a component of the most widely used intelligence tests for children, its place in neuropsychological batteries is much more tenuous. In the Halstead-Reitan Neuropsychological Battery for Older Children (H-R; Reitan & Wolfson, 1992), the Category Test and the Tactual Performance Test (TPT) require the use of incidental memory for previously learned decision principles and previously learned block placements, respectively (Reitan & Davison, 1974). However, no actual score on the Category Test is so delineated, although scoring on the TPT does include some reference to memory. And while the Luria-
Nebraska Neuropsychological Battery - Children’s Revision (LN-CR; Golden, 1981) includes a Memory Scale, the scale only contains eight items.

The WRAML was developed to fill a void in well-standardized psychometric assessment of memory in children (Sheslow & Adams, 1990). The authors’ goals in developing the test included sensitivity to developmental changes in memory and learning functions, consistency with current theoretical models of memory, consistency with current neuropsychological findings on memory, inclusion of educationally relevant tasks, facile administration within the usual confines of standardized testing situations, and provision of an interesting experience for children in the context of assessing memory functions. Regardless of the above high-minded goals, subtest selection criteria inevitably included the requirement that tasks reflect everyday functioning. Specifically the subtests were constructed:

1. To allow assessment of modality specific competencies (i.e., visual vs. verbal deficits).
2. To vary along the episodic-semantic continuum so that subtests require the memory of discrete, non-meaningful bits of information, while others are tasks of a meaningful nature.
3. So that some learning could be assessed through a multiple trials procedure to allow the evaluation of a child’s memory strategies.

4. To allow the assessment of varied criterion performances (immediate vs. delayed recall vs. recognition).

5. To allow for the evaluation of memory function across childhood and adolescence. (Sheslow & Adams, 1990, pp. 6-7)

Essentially, the WRAML was developed to provide clinicians with a tool to measure memory function in school-age children in a meaningful, multidimensional integrated fashion. (See Appendix I for a table delineating the structure of the WRAML subtests and indices.)

Since the WRAML is a relatively new instrument, there is little research currently available. However, Sheslow and Adams (1990) noted that, given the large number of memory skills tapped by the WRAML, it might be a particularly useful tool in elucidating the role of memory deficits in learning disabled children, especially the assessment of memory for novel information. There are three major divisions within the WRAML: (1) memory vs. learning, although the authors caution that the use of these terms is to demonstrate different aspects of memory processes, per se; (2) visual vs. verbal modalities, with progression from meaningless to more meaningful material; and (3) short-term
(within seconds of presentation) vs. delayed recall (varying from 20 to 30 minutes).

In comparing the WRAML with the WISC-R, the authors found that the Verbal Memory Index was significantly related to Verbal IQ and Full Scale IQ, whereas the Visual Learning Index was significantly related to Performance IQ and Full Scale IQ. The correlational data support the contention that the WRAML is positively related to general cognitive ability at a moderate level ($r = .558$) (Sheslow & Adams, 1990). The WRAML and WRAT-R were compared with two age ranges, 6 to 8 years and 16 to 17 years. The authors found that the General Memory Index (GMI) was significantly correlated with reading, arithmetic, and spelling in the 6 to 8 year age group. Also, in this younger group, the three areas of achievement were significantly related to the Visual Memory and Learning Indices, but not the Verbal Memory Index. In contrast, the GMI and Learning Indexes were significantly correlated with arithmetic achievement only in the 16 to 17 year old age group, while only Verbal Memory correlated with all three areas of achievement. These data may suggest that various aspects of memory are differentially related to academic achievement at distinct ages (Sheslow & Adams, 1990).

Therefore, although memory has been considered essential in the neuropsychological assessment of children and a major part of cognitive development, when it comes to
a well standardized, clinically used, reliable method of assessing memory, little has been established. With the advent of clinical, norm-referenced tests of memory, it would appear that research with these tests could aid the researcher, the clinician, and the teacher.

Memory and Learning Disabilities

Learning disabled individuals appear to be clearly deficient in memory skills and tend to have problems in a number of academic areas (Stanovich, 1986; Torgesen, Rashotte, & Greenstein, 1988). Newman and Hagan (1981) found that children with learning disabilities were delayed or deficient in free and serial recall memory tasks. In a brief review of research on memory, Swanson and Cooney (1991) concluded that children with learning disabilities have memory similar to younger children.

In a major study on long term memory, Brainerd, Kingma, and Howe (1986) compared learning disabled vs. nondisabled children in the second and sixth grades. Brainerd et al. (1986) found that storage ability improved with age and developed similarly in both disabled and nondisabled subjects. At the same time, however, while storage ability improved, the second grade learning disabled group had a smaller storage ability at the outset. More importantly, perhaps, they also found that while retrieval ability increased over the two age groups for nondisabled subjects, this was not the case for the learning disabled subjects.
In addition, they theorized that while the younger group of children had difficulties with poststorage retrieval, older children not only had poststorage retrieval difficulty, but also had difficulty with depositing information in long term memory. Brainerd et al. (1986) further suggested that memory deficits may increase with age in learning disabled children. Swanson (1987b) also suggested that reading disabled children are inefficient in accessing long term memory. He further speculated that reading disabled children do not use a verbal coding system in retrieval, as do nondisabled readers.

In a study by Swanson, Cochran, and Ewers (1990), 25 learning disabled children, 11 slow learners, and 60 average achievers were compared on three memory tasks: 1) high-imagery vs. low-imagery sentence span task; 2) a preload task involving six-digits and a list of words; and 3) a concurrent task which involved an aural presentation of digits while sorting cards. The results suggest that memory in learning disabled children may be related to higher order processes such as central processing ability. Further, the authors found that memory performance was strongly related to academic achievement. As with other research, the children identified as learning disabled were a heterogeneous group of reading, spelling, and/or arithmetic disabled children, which limits what we can ascertain about specific kinds of learning disabilities. However, the
importance of this particular study is that the researchers used a slow learner group which was similar in ability to the learning disabled, but different in memory processes.

There appears to be little doubt among researchers that there are memory deficits (Brainerd, Kingma, & Howe, 1986), as well as memory differences (Swanson et al., 1990) in the learning disabled population. As with other research in the area of learning disabilities, the majority of the memory research with the learning disabled is with reading disabled subjects. Although there has been considerable research in the area of memory and learning disabilities, it has been fragmented and has not provided much insight into memory processes either practically or theoretically (Cooney & Swanson, 1987).

**Memory and Arithmetic**

Memory is a component of all learning, including, of course, mathematical learning. If arithmetic disabilities and memory are to be considered jointly, then it would appear to be important to delineate areas of arithmetic that must require memory, as well as the type of memory required. Researchers have found that students who have difficulty with factual memorization will, in turn, have difficulty with mathematics, often having to resort to tedious, time-consuming counting strategies (Ackerman, Anhalt, & Dykman, 1986). Working memory, or what Atkinson and Shiffrin (1968) also call short-term memory, is also important in arithmetic
computations. In addition to factual recall, algorithmic and problem-solving task sequencing need to be maintained in active working memory during the process of problem-solving (Brainerd, 1983; Levine et al., 1992). When oral drills are employed, short-term auditory memory deficits may impede learning (Bley & Thornton, 1989). In addition, long-term verbal memory is necessary because children must recognize the vocabulary of mathematics in order to comprehend and apply its specialized terminology (Cohn, 1961; Earp & Tanner, 1980). On the other hand, since much of mathematics is presented in a visual-spatial format, the ability to store and recall visual information is critical (McLoed & Crump, 1978). Manifestations of short-term visual-memory deficits can also be seen in the process of copying numbers from a book or chalkboard or in using such study aids as flashcards (Bley & Thornton, 1989). Sequential memory problems, whether verbal or visual, also influence mathematical learning, particularly in such areas as telling time, the use of algorithms, and solving multi-step word problems (Bley & Thornton, 1989). Knowledge in mathematics builds on itself; therefore, cumulative, well organized long-term memory is needed (Levine et al, 1992). In essence, then, memory is critical in learning arithmetic, and neither arithmetic nor memory are unitary entities, but rather complex and interdependent.
Hypotheses

The primary purpose of this study is to determine if there are differences in memory abilities in children with three subtypes of arithmetic learning disability. The WRAML will be used to determine differences in memory abilities (See Appendix I for a table delineating the structure of the WRAML subtests and indices). As in previous studies, the three subtypes will be based on patterns of results on standardized tests of reading recognition, spelling, and arithmetic. The three subtypes will be children who have deficits in reading, spelling, and arithmetic (ARS), those who have deficits in arithmetic and spelling (AS) and those who have deficits in arithmetic (A). An integral component of the primary purpose is to determine if the three subtypes of learning disabled children have different rates of learning and retention dependent upon visual vs. verbal vs. combined presentation. A secondary purpose is to determine if there is a correlation between memory (as measured by the WRAML) and achievement as measured by the Wide Range Achievement Test-Revised (WRAT-R; Jastak & Wilkinson, 1984) Arithmetic, Reading and Spelling subtests, and the Woodcock Johnson Psychoeducational Battery: Tests of Achievement-Revised (WJR; Woodcock & Johnson, 1989) Calculation, Applied Problems, and Quantitative Concepts subtests. Finally, the notion that arithmetic learning disabled children are better able to remember meaningful stimuli compared with
meaningless stimuli will be explored. Ultimately, the intent of the present study is to provide systematic information for clinicians and educators about the unique memory processes of these three subtypes of arithmetic disabled children, with this knowledge ultimately contributing to remedial intervention and memory-based educational programs for arithmetic disabled children.

Hypothesis I

Part A (Visual Memory Index and Verbal Memory Index). The first experimental hypothesis is that there will be a significant difference in the Verbal Memory Index and the Visual Memory Index for the three groups. That is, subjects in the A and AS groups will perform more poorly on the Visual Index, while subjects in the ARS group will perform more poorly on the Verbal Index. A one-way MANOVA will be used to determine if there are group differences based on these two measures. If a difference is found with the MANOVA, then univariate ANOVA can be run to determine which groups are different with respect to each measure. To determine the verbal vs. visual relationship for each group, a paired t-test will be used for each group.

This hypothesis is derived from the evidence which suggests that children with arithmetic only and arithmetic and spelling disabilities generally perform poorly on visual tasks, while those who are disabled in arithmetic, spelling,
and reading perform poorly on verbal and visual memory tasks, but more poorly on verbal tasks (Fletcher, 1985).

Part B (Learning Index subtest scores). To further investigate, a more specific hypothesis is that the three groups will obtain significantly different scores on the three subtests of the Learning Index: Verbal Learning, Sound Symbol, and Visual Learning. Particularly, the A and AS subgroup will obtain lower scores on Visual Learning, and the ARS subgroup will obtain lower scores on Sound Symbol. A one-way ANOVA will be used to determine if there is a significant difference. If a significant difference between groups is found, then a further exploratory hypothesis will be investigated using discriminant analysis to discern a possible pattern of variables of the three types of presentation of tasks (verbal, visual, and verbal/visual). It is hypothesized that if there is a significant difference between groups, a pattern will be found for performance on the Learning Index of the WRAML.

The above initial hypothesis was derived from evidence that different groups of learning disabled children have strengths and weaknesses in verbal and visual modalities, as well as the combination of both. Previous research suggests that both the arithmetic disabled group and the arithmetic and spelling disabled will perform poorly on the visual learning task, while the reading, spelling, and arithmetic
group will perform poorly on the combination task (Sound Symbol) (Siegel & Linder, 1984).

**Part C. (Trial learning on the Learning Index subtests).** Further investigation of the primary hypothesis is that the three groups will differ not only in the total learning but the amount of learning over each of the four trials of the three Learning Index subtests: Verbal Learning, Sound Symbol, and Visual Learning. The A and AS subgroups will learn more rapidly on the Verbal Learning subtest, while the ARS subgroup will learn more rapidly on the Visual Learning subtest. Repeated measures ANOVA will be used to investigate.

This hypothesis is derived from evidence that suggests that the short-term memory (working memory) of various groups of learning disabled children varies (Siegel & Ryan, 1988). Children with various subtypes of arithmetic learning disability are expected to learn at different rates depending on the modality of presentation.

**Part D (Delayed recall on the Learning Index subtests).** The next part of the primary hypothesis is that there will not be a significant difference in the delayed recall component of the Verbal Learning, Sound Symbol, and Visual Learning subtests for the three groups of arithmetic disabled children. That is, all three subgroups will retain previously learned information at a similar level. At the same time, however, it is further hypothesized that the
means of the delay scores will be below average. Using means and standard deviations for each delay task as developed by Adams, Sheslow, & Wilkinson (1991), obtained scores will be converted to T scores and then compared using three one-way ANOVA. Three one sample t-tests will be used to determine if the scores are below average.

This hypothesis is derived from research on short term memory as well as observations of long term memory in learning disabled children. It is surmised that children with various subtypes of learning disabilities are not different in their ability to retain information. They generally have poor long term memory regardless of the modality of input (Swanson et al., 1990).

Part E (Fourth trial vs. delayed recall on the Learning Index subtests). In parallel with the above hypothesis, the expanded hypothesis is that the three groups will differ based on the comparison of the fourth learning trial and the delay trial for each of the three Learning Index subtests. Specifically, the A group will have significantly lower scores when scores on the Visual Learning subtest are compared. The ARS group will have significantly lower scores on the Verbal Learning and Sound Symbol subtest. A repeated measures ANOVA will be used on each measure for each group to compare the groups and to see if the differences between trials are the same for each group.
This hypothesis is an extension of the Part D hypothesis, taking into consideration what was learned initially. Previous research has suggested that children with an arithmetic only learning disability retain information less well when presented visually. If this is the situation, it is then surmised that not only will these children initially retain less visually presented information, but they will forget more (Fletcher, 1985).

Hypothesis II

In looking specifically at the achievement of the subjects, the second major hypothesis is that there will be a significant positive correlation for each group between scores on the WRAT-R Arithmetic subtest and the WJR Calculation subtest and each of the Visual Memory Index subtest scores and a positive correlation between the WRAT-R Reading subtest and each of the Verbal Learning Index subtest scores. In addition, it is hypothesized that each of the three Verbal Memory Index subtests will correlate significantly with subtest scores on the WJR Applied Problems and Quantitative Concepts. It is also hypothesized that there will be a positive correlation between the WRAT-R Spelling subtest and Number/Letter and Finger Windows, but not with other subtests that make up the Verbal and Visual Memory Indices. Pearson Product Moment Correlations will be used.
This hypothesis is based on the concept that achievement in various academic areas parallels visual and verbal processes (Rourke, 1993). It is further suspected that spelling is a sequential task and so will correlate with tasks requiring sequential memory (Rourke, 1983). In addition, some researchers (Swanson, Cochran, & Ewers, 1990) have found that memory parallels achievement in the learning disabled child, while authors of the (Sheslow & Adams, 1990) have found mixed results in correlation studies with achievement tests.

Exploratory Hypothesis

It is hypothesized that there will not be a significant difference between scores on subtests using meaningless stimuli in each modality, Finger Windows and Number Letter Recall, versus the subtests using the most meaningful stimuli, Story Memory and Picture Memory. Mean scores for each of the two subtest groups will be calculated as follows:

Finger Windows score + Number/Letter Score = Mean
\[ \frac{2}{2} \] (Less meaningful)

and

Story Memory score + Picture Memory Score = Mean
\[ \frac{2}{2} \] (More meaningful)

Collapsing all three groups into one, one paired t-test will then be performed with the data.
This hypothesis stems from the concept that meaningful material is more readily remembered than non-meaningful material (Craik & Lockhart, 1972). If this is the case with an arithmetic disabled population, using standard subtest scores based on standardized norms, there should be no difference between the subtest scores for individuals. It would be valuable to know if this concept can be confirmed with an arithmetic disabled population, since much of what is learned in arithmetic is cumulative, building on previously learned meaningful material.

Assumptions and Limitations

The generalizability of the findings will be constrained by the choice of subjects. The subjects are from a clinic which takes no information on socioeconomic status or ethnicity, so there is no previous knowledge of either of these variables. However, the clinic is located in a large metropolitan area, so a diverse sample is expected. In addition, socioeconomic data will be collected at the time of testing, so the information will be available.

The very definition of learning disabilities is the cause for much debate (Hammill, 1990; Moats & Lyon, 1993). Any operationalizing of a learning disability is subject to question and scrutiny (Council for Learning Disabilities Research Committee, 1993). Therefore, results of the
present study are constrained by the discrepancy method used to select subjects.

There are many ways to determine subgroups of arithmetic disabled children. Children were chosen according to specific guidelines outlined in the methods section. According to several authors (Fletcher, 1985; Rourke, 1992; Siegel & Ryan, 1989), selection of subjects based on patterns of achievement is valid. It is assumed that the subgroups identified for this study are indeed three distinct subgroups.

Children in the study are aged 9 years, 0 months through 13 years, 11 months. Even though age appropriate norms will be utilized, developmental variations and academic interventions within this 5 year span may impact results.

Gender differences are not a consideration of this research. Although some (Rourke, 1992) maintain that gender is not an issue in the realm of arithmetic disabilities, others (Share, Moffitt, & Silva, 1988) have found differences between boys and girls with arithmetic learning disabilities. Therefore, a bias of the present study is the lack of consideration of gender differences.

Subjects were selected for inclusion in the study and placed in subgroups based on previous testing at the hospital clinic. It is possible that subjects may have met criteria as learning disabled because of such variables as
academic intervention, maturation, or first-time test anxiety, rather than a true learning disability.

Operational Definitions

For the purpose of this study, the major variables are operationally defined as:

Memory--Memory is defined as the encoding, storage, and retrieval of material. It is operationally defined as scores obtained on the WRAML. Items presented visually are defined as tapping visual memory, and visual memory is operationally defined as the Visual Memory Index of the WRAML. Items presented verbally comprise the Verbal Memory Index and it is considered the operational definition of verbal memory.

Learning Disability--A specific learning disability is defined as a heterogeneous group of intrinsic disorders that manifests itself as difficulty in the use of listening, speaking, reading, writing, reasoning, or mathematical abilities (Hammill, 1990). A learning disabled individual is operationally defined as an individual with average or better intelligence, that is an IQ greater than or equal to 90 as measured by the WISC-R, who demonstrates a severe discrepancy between intelligence and achievement as measured by either the WRAT-R or the WJR. The severe discrepancy is further defined as fifteen standard score points. In addition, since this study is limited to subtypes of
arithmetic disabled children, a severe discrepancy in arithmetic is necessary to be included in the sample.
CHAPTER II

METHOD

Subjects

Sixty-two subjects with arithmetic learning disabilities participated in this study. In a preliminary study, records of 1656 children who were evaluated in a hospital outpatient child development clinic over the previous 15 month period were reviewed. All subjects had been referred for evaluation of suspected learning disabilities. Graduate students searched the clinic records to identify children with arithmetic disabilities as defined below and data were extracted directly from those records. Data included the age and grade of the child, Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974) IQ scores, achievement scores from the WRAT-R Reading and Spelling subtests and either the Wide Range Achievement Test-Revised (WRAT-R; Jastak & Wilkinson, 1984) Arithmetic subtest or the Woodcock-Johnson Psychoeducational Battery - Revised: Tests of Achievement (WJR; Woodcock & Johnson, 1989) Calculation or the Applied Problems subtests.

Criteria for selection included a Full Scale IQ score greater than or equal to 90 with a severe discrepancy (greater than or equal to 15 standard score points) between
Full Scale IQ or the higher of Verbal IQ or Performance IQ and achievement in arithmetic. Achievement in arithmetic was measured with either the WRAT-R Arithmetic subtest, the WJR Calculation subtest. Further, the standard score in arithmetic had to be 90 or below. Discrepancies in reading and spelling were determined in a similar fashion. Although subjects were originally chosen using an ability-achievement discrepancy based on either Verbal, Performance or Full Scale IQ, criteria were narrowed to include only those with a Full Scale IQ and achievement discrepancy, in an attempt to identify a more uniform sample. The subjects ranged in age from 7 to 12 years at the time of the initial clinic evaluation. Children were excluded who had acquired or other medical conditions involving the central nervous system. The final sample included 284 children.

The subjects were further divided into subtypes:

A - These subjects had a significant discrepancy between IQ and arithmetic only \((N = 45)\).

AS - These subjects had a significant discrepancy between IQ and both arithmetic and spelling \((N = 35)\).

ARS - These subjects had a significant discrepancy between IQ and the three academic areas of arithmetic, reading, and spelling \((N = 204)\).

Seven subjects constituted a specific subtype who had deficits in reading and arithmetic only; although these
subjects represent a legitimate group, their number was not sufficient to be included as a subsample in the present study. Since the ARS group was so large, subjects were chosen using random number assignments.

Sixty-two subjects were tested for the present study comprised of 22 A, 19 AS and 21 ARS subjects. The mean age for the sample was 11.85 years (SD = 1.05; range = 9.67 to 13.92, with a mean grade level of 5.74 (SD = 1.19; range = 3.0 to 8.0). The mean age and grade for each of the subtypes is presented in Table 1.

Table 1

Mean and Standard Deviation of Age and Grade by Subtype

<table>
<thead>
<tr>
<th>Subtype</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
<th>Mean</th>
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<tbody>
<tr>
<td></td>
<td>Age</td>
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<td>Grade</td>
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<tr>
<td>A</td>
<td>12.2</td>
<td>.9</td>
<td>10.42-13.58</td>
<td>6.1</td>
<td>.9</td>
<td>4 - 8</td>
</tr>
<tr>
<td>AS</td>
<td>11.8</td>
<td>.9</td>
<td>10.33-13.50</td>
<td>5.8</td>
<td>.9</td>
<td>4 - 7</td>
</tr>
<tr>
<td>ARS</td>
<td>11.5</td>
<td>1.3</td>
<td>9.67-13.92</td>
<td>5.3</td>
<td>1.6</td>
<td>3 - 8</td>
</tr>
<tr>
<td>All</td>
<td>11.9</td>
<td>1.1</td>
<td>9.67-13.92</td>
<td>5.7</td>
<td>1.2</td>
<td>3 - 8</td>
</tr>
</tbody>
</table>
The mean age between subtypes did not differ significantly ($F(2,59) = 2.38, \ p = .10$), although the age range in the ARS group was broader. Mean intelligence scores were well within the average range with a mean Full Scale IQ of 107.02 as measured by the WISC-R. IQ scores by subtype are included in Table 2.

Table 2

<table>
<thead>
<tr>
<th>WISC-R Scores by Subtype</th>
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<tr>
<td></td>
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<tr>
<td><strong>IQ Score</strong></td>
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<td>A</td>
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<td><strong>VIQ</strong></td>
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<td>Mean</td>
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<td><strong>PIQ</strong></td>
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<td>SD</td>
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<tr>
<td>Range</td>
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<tr>
<td><strong>FSIQ</strong></td>
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<tr>
<td>Mean</td>
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<td>SD</td>
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<tr>
<td>Range</td>
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</tbody>
</table>
There was no significant difference in Full Scale IQ for the three subtypes ($F(2, 59) = 1.62, p = .21$). Since the hypotheses involve verbal and nonverbal memory, Verbal and Performance IQ scores were also analyzed using ANOVA. There was no significant difference for the three subtypes on either Verbal IQ ($F(2, 59) = 1.56, p = .22$) or Performance IQ ($F(2, 59) = 1.94, p = .15$). There were 48 boys and 14 girls, yielding a ratio of about 3 to 1. The sample was largely Caucasian, with only 2 African Americans, and 1 Hispanic subject. Using the Hollingshead Four Factor Index (Hollingshead, 1978), the average SES was 47.64. Using the divisions defined by Hollingshead (1975): 1 family met criteria as semi-skilled, 10 as skilled, 34 fell into the technical category, and 17 were considered professional. The average of 47.64 which is in the technical, medium business, minor professional category.

Information on supplemental educational intervention is also included to serve as a general guide for a more specific description of the subject population for the present study. Since few, if any, intervention coding systems exist, the following divisions will be utilized for the purposes of this study: 8 subjects had no supplemental intervention reported; 8 subjects had participated in some form of tutoring or summer school; 2 children had received some sort of non-special education services in their school (Chapter 1 reading, special dyslexia class, etc.) for one to
three years, 1 subject for more than three years; 16 subjects had received special education services as part of an adjunct to regular classes (such as content mastery, resource room, learning lab, etc.) for one to three 3 years; 20 subjects received pull-out services for three years or more; 4 subjects had attended either a self-contained special education class in public schools or a private school for children with learning disabilities for one to three years; and 3 subjects had participated in full-time classes for children with learning disabilities for three years or more. The majority of the children in this study had participated in a regular education program, with special education services provided on a supplementary basis. See Table 12 in Appendix B.

Instruments

Wide Range Assessment of Memory and Learning. The Wide Range Assessment of Memory and Learning (WRAML; Sheslow & Adams, 1990) measures various components of memory. Norms are provided for children, 5 through 17 years of age. The test has two different levels (5 through 8; 9 through 17). Since the present study includes only children aged 9 and over, the older children's portion of the battery was utilized. The test is comprised of 9 subtests which yield scaled scores with a mean of 10 and a standard deviation of 3. The subtests are Picture Memory, Design Memory, and Finger Windows (which comprise the Visual Memory Index);
Story Memory, Sentence Memory, and Number/Letter (which make up the Verbal Memory Index); and Verbal Learning, Sound Symbol, and Visual Learning (which constitute the Learning Index). A description of each subtest is contained in Appendix A. The three indices are then combined to produce a General Memory Index. All four of the index scores are presented as standard scores with a mean of 100 and a standard deviation of 15. The E subtests contain a common factor, memory and, as expected, the subtests are intercorrelated. Correlations are low to moderate (low of $r = .156$ for Design Memory and Number Letter and a high of $r = .605$ for Sentence Memory and Number Letter). A complete table of subtest correlations is in Appendix A. Information for a sample similar age group regarding the correlation of the Visual and Verbal Index is not furnished in the manual. Correlations are presented for the 6 through 8 and the 16 through 17 age group ($r = .517$, $p < .05$; $r = .435$, $p < .05$). Reliability indices calculated for the E include coefficient alpha, person separation, and test-retest. The median individual subtest coefficients range from .78 to .90, while the General Memory Index coefficient alpha is .96. The Person Separation Indexes for the individual subtests ranges from .79 to .94. The overall results from these methods of reliability investigations are acceptable according to usual criteria (Sheslow & Adams, 1990). It is in the area of test-retest reliability that difficulties arise because of
the nature of memory tests (Delis, Kramer, Kaplan, & Ober, 1987; Sheslow & Adams, 1990). There could be considerable carry-over memory from one administration to the next, so the authors separated test-retest administration by at least 60 days. Test-retest coefficients ranged from .61 to .84. These measurements of stability should be used cautiously (Sheslow & Adams, 1990). More detailed information about the WRAML can be found in the manual (Sheslow & Adams, 1990).

Wide Range Achievement Test - Revised (WRAT-R). The WRAT-R measures the basic school academic skills of reading recognition, written spelling and arithmetic. Norms are furnished for individuals aged 5 years to 75 years. The test is divided into two levels, Level 1 for children age 5 through 11 years, 11 months and Level 2 for individuals age 12 through 74 years, 11 months. For the present study, age appropriate levels were used. The subtests are Reading, Spelling, and Arithmetic, and each yields a standard score with a mean of 100 and a standard deviation of 15. The Reading subtest consists of a list of words to be read, that is, it is limited to word recognition. The Spelling subtest is a list of spelling words presented to the subject in a school spelling test format, that is, the examiner says the word, uses it in a sentence, and says the word. The subject is to write the word on the appropriately numbered line in the test booklet. The Arithmetic subtest consists of a
number of written arithmetic problems presented in order of increasing difficulty, and the subject is given ten minutes to complete as many problems as possible. Test-retest reliability coefficients range from .92 to .95 on the subtests when Level 1 and Level 2 were combined. More detailed information is available in the WRAT-R manual (Jastak & Wilkinson, 1984).

Woodcock-Johnson Psychoeducational Battery: Tests of Achievement - Revised (WJR). The WJR Tests of Achievement is comprised of nine subtests. For purposes of the present study only three of the subtests will be used. The subtests are Calculation, Applied Problems and Quantitative Concepts. Calculation measures an individual’s ability to perform mathematical calculations, Applied Problems measures skill in analyzing and solving practical problems in mathematics, and Quantitative Concepts measures knowledge of mathematical concepts and vocabulary. Calculation and Applied Problems scores are combined to produce a Broad Mathematics Score. Norms are provided for individuals aged 2 years to 90+ years. Each of the subtests yields a standard score with a mean of 100 and a standard deviation of 15. Scores can be based on age or grade. For the present study, age norms were utilized. Internal consistency reliability coefficients for 9 year old children range from .86 to .90 for the three subtests used in the present study. More
detailed information is available in the WJR manual (Woodcock & Mather, 1989).

Procedure

The subjects were tested using the WRAML, the WJR, and the WRAT-R as a part of a larger test battery. The test examiners included a master's level graduate student, two doctoral level graduate students, and a licensed psychologist. All examiners had extensive experience with the two achievement tests and training and practice sessions with the WRAML. Tests were scored by one of the four test examiners and checked by another examiner.

Parents of all the children in the A and AS group were contacted and asked to participate in the study. Using random number assignments, 60 subjects were selected in the ARS group and those parents were contacted. Letters were sent to the parents of the children asking them to allow their children to participate in the research study (see Appendix C for a sample of the letter). In the A group, 26 of the subjects' parents agreed to testing. Of this group of 26, 22 met the more stringent criteria introduced using only Full Scale IQ discrepancy. In the AS group of the 25 subjects who agreed to testing, 19 met the above criteria. Selecting form the larger pool of 60 subjects, 28 agreed to testing and 21 met criteria to be included in this study. The children were offered a free movie ticket and the parents received a report of the results of testing (See
Appendix C for a sample of feedback.) Data were recorded by this author into the computer as an ASCII file.

**Analysis**

To test Hypothesis I - Part A (Visual Memory Index and Verbal Memory Index), a MANOVA was performed and when significance was found, ANOVA were used, as well as paired t-tests. Three ANOVA were used to test Hypothesis I - Part B (Learning Index subtest scores) and although it did not yield significant results, a discriminant analysis was used to further explore the use of the Learning Index subtests. Three repeated measures ANOVA were employed for Hypothesis I - Part C (Trial learning on the Learning Index subtests). Three ANOVA as well as three one sample t-tests were used for Hypothesis I - Part D (Delayed recall on the Learning Index subtests). For Hypothesis I - Part E (Fourth trial vs. delayed recall on the Learning Index subtests), three repeated measures ANOVA were employed. Pearson product moment correlations were calculated for Hypothesis II. For the Exploratory Hypothesis, a paired t-test was used. All analyses were carried out using SASS.

A note on exploratory research is included here. Discriminant analysis is particularly suited to this type of research according to Klecka (1980). The assumptions of discriminant analysis are that the study must have two or more groups, there must be at least two cases per group, and there can be any number of discriminating variables,
provided that it is less than the total number of cases minus two. The present research study had three groups, three discriminating variables, and 62 subjects, so the above criteria are met. In addition, it was assumed that the discriminating variables are measured on an interval level, that no variable is a linear combination of other variables, and that each group was drawn from a population with a normal distribution, further conditions that are met by the study.
CHAPTER III

RESULTS

General Results on Tests Used in the Study

Table 3 presents the means and standard deviations of the scores on the Wide Range Achievement Test - Revised (WRAT-R).

Table 3
Means and Standard Deviations for the WRAT-R

<table>
<thead>
<tr>
<th>Subtype</th>
<th>Reading Recognition</th>
<th>Spelling</th>
<th>Arithmetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>98.1 (8.8)</td>
<td>94.5 (6.6)</td>
<td>86.6 (15.7)</td>
</tr>
<tr>
<td>AS</td>
<td>95.9 (7.5)</td>
<td>83.0 (5.7)</td>
<td>80.9 (5.2)</td>
</tr>
<tr>
<td>ARS</td>
<td>70.8 (9.5)</td>
<td>70.7 (9.0)</td>
<td>80.3 (10.8)</td>
</tr>
<tr>
<td>Total Group</td>
<td>88.0 (15.3)</td>
<td>82.9 (12.4)</td>
<td>84.1 (14.8)</td>
</tr>
</tbody>
</table>

The mean of 84.10 for the total group for arithmetic was more than one standard deviation below the mean of the Full Scale IQ (107.02), suggesting that this group as a whole is disabled in arithmetic as measured by the WRAT-R. In addition, the mean of 84.10 on Arithmetic was also below the
25th percentile, which is a commonly employed indicator of learning disabilities. There was no significant difference between the subtypes on Arithmetic ($F(2,58) = 1.07, p = .35$), but as expected, because of the parameters used to determine subtypes, there was a significant difference between the subtypes on Reading Recognition ($F(2,58) = 63.08, p < .001$) and on Spelling ($F(2,58) = 56.84, p < .001$).

Results of the mathematics components of the Woodcock Johnson Psychoeducational Battery - Revised: Tests of Achievement (WJR) are displayed in Table 4.

Table 4

Means and Standard Deviations on the WJR Mathematics Tests

<table>
<thead>
<tr>
<th>Sub-type</th>
<th>Calculation</th>
<th>Applied Problems</th>
<th>Quantitative Concepts</th>
<th>Broad Math</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>95.4(10.2)</td>
<td>97.4 (7.7)</td>
<td>93.0 (9.1)</td>
<td>95.3 (9.7)</td>
</tr>
<tr>
<td>AS</td>
<td>81.7 (6.3)</td>
<td>102.3(13.1)</td>
<td>94.6(11.0)</td>
<td>93.4(12.8)</td>
</tr>
<tr>
<td>ARS</td>
<td>86.2(10.1)</td>
<td>96.7 (9.8)</td>
<td>83.0(11.1)</td>
<td>89.7(10.1)</td>
</tr>
<tr>
<td>Total</td>
<td>90.8(11.6)</td>
<td>97.3 (8.6)</td>
<td>90.1(11.4)</td>
<td>92.8(10.9)</td>
</tr>
</tbody>
</table>

The Calculation score for the total group was 90.77, which was greater than one standard score deviation below the mean Full Scale IQ (107.02) for the sample. There was no
significant difference between the subtypes on WJR Broad Math \( F(2,59) = 1.48, \ p = .24 \). There was, however, a significant difference on the WJR Calculation subtest \( F(2,59) = 3.74, \ p < .05 \), while there was no significant difference on the WJR Applied Problems subtest \( F(2,29) = .10, \ p = .90 \). It would appear that the WJR Broad Math combined subtest score can camouflage the difference between the two math subtests, providing biased information as a consequence.

Table 13 in Appendix B lists the means and standard deviations for all the subtests of the Wide Range Assessment of Memory and Learning (WRAML). Except for the score on Number/Letter Memory for the ARS subtype, all of the mean subtest scores were within one standard deviation of the subtest standardized mean of 10. Overall, it would appear that subjects in this study had not only average IQ scores as a group, but also were within the average range for memory measures on the WRAML.

Table 5 contains the means and standard deviations of the four indices on the WRAML: the Verbal Memory Index derived from scores on Story Memory, Sentence Memory, and Number/Letter Memory; the Visual Memory Index derived from scores on Picture Memory, Design Memory, and Finger Windows; the Learning Index derived from scores on Verbal Learning, Sound Symbol, and Visual Learning; and the General Memory Index which is the total composite score for the test.
Table 5

Means and Standard Deviations for the WRAML Indices

<table>
<thead>
<tr>
<th>Index</th>
<th>A</th>
<th>AS</th>
<th>ARS</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal</td>
<td>96.2(13.5)</td>
<td>99.6(8.6)</td>
<td>88.1(9.5)</td>
<td>94.5(11.7)</td>
</tr>
<tr>
<td>Visual</td>
<td>100.9(16.6)</td>
<td>99.2(11.9)</td>
<td>98.2(11.0)</td>
<td>99.5(13.4)</td>
</tr>
<tr>
<td>Learning</td>
<td>105.2(16.2)</td>
<td>102.6(15.6)</td>
<td>94.8(11.8)</td>
<td>100.9(15.1)</td>
</tr>
<tr>
<td>General</td>
<td>100.5(15.5)</td>
<td>100.5(10.7)</td>
<td>92.1(10.5)</td>
<td>97.7(13.0)</td>
</tr>
</tbody>
</table>

The means for the indices on the AR ranged from a low of 88.1 for the ARS subtype on the Verbal Memory Index to a high of 105.2 for the A subtype on the Learning Index. All means were within one standard deviation of the Index means of 100. As noted above, when discussing the subtest means, it seems evident that this group of subjects was within the average range in terms of memory as measured by the WRAML.

Hypothesis I

Part A (Visual Memory Index and Verbal Memory Index).

MANOVA was computed, with subtypes as the independent variable and the Verbal and Visual Memory Indices as the dependent variables. The results were significant (Wilks' Lambda ($\lambda$) = 2.95, $p < .05$), indicating that there were subtype differences on these two measures. Univariate ANOVA were computed to explore the sources of this general difference. There was no significant difference among
subtypes on the Visual Memory Index ($F(2,58) = .17, \ p = .84$). There was, however, a significant difference among subtypes on the Verbal Memory Index ($F(2,58) = 5.98, \ p < .01$). Post-hoc analysis using Tukey’s Studentized Range Test indicated that the ARS subgroup was significantly different from the A and AS subgroups, but the A and AS subgroup were not significantly different from each other.

Finally, a $t$-test was performed and a Bonferroni adjustment to the critical $p$-value was computed ($p = .017$). The $t$-test revealed that there is no significant difference between the Visual Memory Index and the Verbal Memory Index for the A ($p = .25$) and AS ($p = .90$) subgroup, but that the ARS subgroup had significantly lower scores on the Verbal Memory Index as compared to the Visual Memory Index ($p < .001$). The visual vs. verbal memory hypothesis was partially supported. That portion of the hypothesis suggesting that the A and AS subgroup would perform more poorly than the ARS subgroup on the Visual Memory Index was not supported; nor did they perform more poorly on the Visual Memory Index as compared to the Verbal Memory Index. The portion of the hypothesis related to ARS subgroup performance was, however, supported. Not only did the ARS subgroup have significantly lower scores on the Verbal Memory Index compared to the A and AS subgroup, but the ARS subgroup also performed more poorly on the Verbal Memory Index compared to the Visual Memory Index. Therefore, it
appears that although there is a difference in subtypes in verbal memory, the predicted difference for visual memory did not emerge.

**Part B (Learning Index subtest scores).** The three learning subtests (Verbal Learning, Visual Learning, Sound Symbol) were used to test this part of the first hypothesis. On the Verbal Learning subtest there was no significant difference between the subgroups \( F(2,59) = .93, p = .40 \), nor was there a significant difference on the Visual Learning subtest \( F(2,59) = .23, p = .80 \). There was, however, a significant difference between subgroups on the Sound Symbol subtest \( F(2,59) = 6.66, p < .01 \). Once again, a post-hoc Tukey Studentized Range Test indicated that the ARS subgroup was significantly different from the A and AS subgroup, but that A and AS were not significantly different from each other, thus partially supporting the hypothesis. It was hypothesized that the A and AS subgroups would obtain lower scores on the Visual Learning subtest, but this visual factor was again unsupported. There was also no significant difference between the subgroups on the Verbal Learning subtest. The ARS subgroup, however, did produce significantly lower scores on the Sound Symbol subtest, as had been demonstrated for other variables.

Although significant differences were not found on two of these measures, a discriminant analysis was attempted. However, as illustrated in Table 6, the classification using
the analysis would not be statistically useful in discriminating subtypes.

Table 6

**Discriminant Analysis using the Learning Subtests of the WRAML**

<table>
<thead>
<tr>
<th>From Subtype</th>
<th>A</th>
<th>AS</th>
<th>ARS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>11</td>
<td>3</td>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>AS</td>
<td>10</td>
<td>3</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>ARS</td>
<td>3</td>
<td>3</td>
<td>15</td>
<td>19</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>9</td>
<td>29</td>
<td>62</td>
</tr>
<tr>
<td>Percent</td>
<td>39%</td>
<td>15%</td>
<td>47%</td>
<td>100</td>
</tr>
</tbody>
</table>

The entries indicate that 11 subjects in the A subgroup, 3 subjects in the AS subgroup, and 15 in the ARS subgroup were correctly classified, correctly identifying only 29 of 62 subjects or 47%. Thus, the three Learning Index subtests appear to offer no unique discriminating power to classify the three arithmetic disabled subtypes.

**Part C (Trial learning on the Learning Index subtests).**

(See Tables 14, 15, and 16 in Appendix B.) The repeated measures ANOVA indicated that there was no significant difference in learning by subtype on the Verbal Learning
subtest ($F(2, 59) = 1.2, p = .31$) or the Visual Learning subtest ($F(2, 59) = .47, p = .63$), and although overall learning did increase significantly on both subtests ($p < .001$; $p < .001$), there was no significant difference by subtype ($p = .13; p = .18$). On the Sound Symbol Subtest, however, a significant difference in learning by subtype was found ($F(2, 59) = 1.2, p < .001$). In addition, there was a significant difference over time ($p < .001$), but the interaction was not significant ($p = .14$). Tukey Studentized Range Tests revealed that the ARS subgroup achieved a significantly lower number of correct responses than the A subgroup on each of the four trials and a significantly lower number of correct responses than the AS subgroup on trials 3 and 4. That is, although the rate of learning did not differ for the three subgroups, since the ARS subgroup learned less on the first trial, they ultimately learned less overall. Therefore, only partial support accrues to the hypothesis.

Part D (Delayed recall on the Learning Index subtests).

In considering the delayed recall component of the three learning subtests, ANOVA results were mixed. Neither the Verbal Learning nor the Visual Learning subtests yielded significantly different scores by subtype ($F(2, 59) = 1.01, p = .37; F(2,59) = .17, p = .84$), but results on the Sound Symbol subtest were significant ($F(2,59) = 5.11, p < .01$). Post hoc analysis using the Tukey Studentized Range Test
indicated A and AS subgroups performed significantly better than the ARS subgroup, but there was no significant difference between the A and AS subgroups. Once again, when compared with the other two subgroups, the ARS subgroup recalled less on Sound Symbol delayed recall.

Going one step further, using one tailed t-tests with a Bonferroni adjustment to the critical p-value (p = .0167), the total sample of arithmetic disabled subjects when compared with the norms for the WRAML, did not perform at a significantly below average level on the delayed trials of the Verbal Learning (p = .30), Sound Symbol (p = .05), or on Visual Learning subtests (p = .04). Therefore, the hypothesis that there would be no difference between subtypes on delayed recall was not supported, because a difference was found for the ARS subgroup on the Sound Symbol subtest. In addition, the hypothesis regarding the total arithmetic disabled group achieving lower than average delayed recall scores was not supported.

Part E (Fourth trial vs. delayed recall on the Learning Index subtests). Using repeated measures ANOVA, there were no significant differences by subtype on Verbal Learning ($F(2,59) = .77, p = .47$) or Visual Learning ($F(2,59) = .36, p = .70$) for the fourth (and last) learning trial or the delayed recall trial. There was a significant difference from the fourth learning trial to the delay trial on Verbal Learning ($F(2,59) = 23.82, p < .001$), but this discrepancy
was not significant by subtype ($F(2,59) = 2.26, p > .11$).
That is, on Verbal learning less was remembered on the delayed trial compared to the fourth trial for all three subtypes. On Visual Learning, however, there was no significant difference from the fourth learning trial to the delay trial ($F(2,59) = .99, p = .32$) nor by subtype ($F(2,59) = .45, p = .64$). That is, on Visual Learning items were remembered from the fourth to the delayed trial for all three subtypes. This would appear to indicate that visually retrieved fourth trial information was retained, while verbally retrieved information was not.

There was a significant trial and subtype difference for the Sound Symbol subtest ($F(2,59) = 7.74, p < .001$; $F(2, 59) = 11.40, p < .001$, respectively) but the interaction was not significant ($F(2,59) = .57, p = .57$). A post hoc Tukey Studentized Range Test indicated that, on the fourth learning trial, the A and AS subgroup were significantly different from the ARS subgroup, and this difference was maintained on the delayed recall trial. Results would appear to indicate that the ARS group learned less over four trials on Sound Symbol, a finding parallel to similar findings for parts C and D above, and retrieved less on the delayed recall trial. The result was that the ARS group (a group of considerably less interest regarding pure arithmetic disability than either the more pure A or AS group) did learn and retain less on the Sound Symbol
subtest, but did not show important differences on Verbal Learning. The pure A group did not obtain the predicted lower scores for Visual Learning.

Overall results for Hypothesis I were mixed. Portions of the hypothesis involving the Visual Memory Index or the Visual Learning subtest were not supported by the results: A and AS subgroups did not perform more poorly on these measures than the ARS group. The ARS subgroup was significantly different, however, from the A and AS group on the Verbal Memory Index, achieving consistently lower scores. Portions of the hypothesis involving the Verbal Learning subtest were also unsupported.

Likewise, the ARS subgroup acquired Sound Symbol information at a rate comparable to other groups but did not learn as much over four trials nor retain as much over the delay interval. In terms of major memory measures if the WRAML, there do not seem to be any significant difference between the A and AS subgroup while the ARS subgroup is frequently inferior to the other two.

Hypothesis II

This hypothesis concerns correlations among WRAML memory components and WRAT-R/WJR achievement measures. It was hypothesized that the WRAT-R Arithmetic and the WJR Calculation subtests would positively correlate with the Visual Learning Index subtests of the WRAML. Bonferroni
adjustment to the critical p-value was calculated for the 18 correlations (p = .003). Results are delineated in Table 7.

Table 7

Correlations for the WRAML Visual Memory Index Subtests

<table>
<thead>
<tr>
<th>Visual Memory Index Subtests</th>
<th>WRAT-R Arithmetic</th>
<th>WJR Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>AS</td>
</tr>
<tr>
<td>Picture Memory</td>
<td>.12</td>
<td>.07</td>
</tr>
<tr>
<td>Design Memory</td>
<td>.34</td>
<td>.10</td>
</tr>
<tr>
<td>Finger Windows</td>
<td>.72*</td>
<td>.37</td>
</tr>
</tbody>
</table>

* p < .003

Taking into consideration the Bonferroni p-value adjustment, the only significant correlation was for Finger Windows, which correlated significantly with the WRAT-R Arithmetic subtest for subgroup A. The other crucial correlations for support of this hypothesis were not significant.

It was also hypothesized that the WRAT-R Reading, WJR Applied Problems, and WJR Quantitative Concepts would correlate with the subtests of the WRAML Verbal Learning Index. Results are presented in Table 8.
Table 8

**Correlations for the WRAML Verbal Memory Index Subtests**

<table>
<thead>
<tr>
<th></th>
<th>WRAT-R Reading</th>
<th>WJR Applied Problems</th>
<th>WJR Quantitative Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A Subgroup</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Story Memory</td>
<td>-.38</td>
<td>-.01</td>
<td>.14</td>
</tr>
<tr>
<td>Sentence Memory</td>
<td>-.24</td>
<td>.19</td>
<td>-.13</td>
</tr>
<tr>
<td>Number Letter</td>
<td>-.12</td>
<td>-.16</td>
<td>-.34</td>
</tr>
<tr>
<td><strong>Subgroup AS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Story Memory</td>
<td>.18</td>
<td>.12</td>
<td>.03</td>
</tr>
<tr>
<td>Sentence Memory</td>
<td>-.18</td>
<td>-.16</td>
<td>.24</td>
</tr>
<tr>
<td>Number Letter</td>
<td>.38</td>
<td>.29</td>
<td>.20</td>
</tr>
</tbody>
</table>

(Table continues)
A further correlational hypothesis was that WRAT-R Spelling would correlate positively with Number Letter and Finger Windows, but with none of the other subtests that make up the Verbal and Visual Memory Indices on the WRAML. Again a Bonferroni adjustment to the critical p-value was employed ($p = .003$). Table 9 presents these results.
Table 9

Correlations with WRAT-R Spelling

<table>
<thead>
<tr>
<th>Subtest</th>
<th>A</th>
<th>AS</th>
<th>ARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number Letter</td>
<td>-.30</td>
<td>.21</td>
<td>.51</td>
</tr>
<tr>
<td>Finger Windows</td>
<td>.14</td>
<td>-.08</td>
<td>.22</td>
</tr>
<tr>
<td>Picture Memory</td>
<td>.31</td>
<td>-.16</td>
<td>-.27</td>
</tr>
<tr>
<td>Design Memory</td>
<td>-.29</td>
<td>.18</td>
<td>.08</td>
</tr>
<tr>
<td>Sentence Memory</td>
<td>-.20</td>
<td>.23</td>
<td>.10</td>
</tr>
<tr>
<td>Story Memory</td>
<td>-.11</td>
<td>-.29</td>
<td>-.02</td>
</tr>
</tbody>
</table>

*Note.* When the Bonferroni correction is taken into account, none of the correlations was significant.

* p < .003

Achievement in various academic areas did not parallel visual and verbal memory processes as measured by the WRAML except in one isolated case. Not only was correlation for the A subgroup between Finger Windows and WRAT-R Arithmetic ($r = .72, p < .01$) significant, it was highly significant accounting for over 49% of the variance.

**Exploratory Hypothesis**

It was hypothesized that there would be no difference between subtests requiring memory for meaningful stimuli (Story Memory and Picture Memory) and those containing less
meaningful stimuli (Number/Letter and Finger Windows). Using a paired t-test, mean scores on subtests divided by the meaningfulness of stimuli were found to be significantly different ($p < .001$) for the total arithmetic disabled sample. As a total group, arithmetic disabled subjects achieved better scores on the tests with more meaningful stimuli, but there were no significant subtype differences with more meaningful ($F(2,59) = 1.96$, $p = .15$) or with less meaningful ($F(2,59) = .20$, $p = .82$) stimuli.
CHAPTER IV

DISCUSSION

Memory and Arithmetic Disabilities

This study attempted to demonstrate the nature of the relationship between subtypes of children with arithmetic learning disability and memory skills measured by a standardized memory test battery. Most hypotheses deriving from predictable involvement of memory in learning processes were not supported with the arithmetic disabled subtypes, while some unexpected links between memory and arithmetic disabilities did emerge. Three subtypes were investigated, those children with a learning disability in arithmetic only (A), a learning disability in arithmetic and spelling (AS), and a learning disability in arithmetic, spelling and reading (ARS).

The body of literature on arithmetic disabilities strongly suggests that children with arithmetic only learning disabilities have difficulty in areas requiring visual processing which includes visual memory. Results of the present study do not support this premise. Visual memory as measured by the Wide Range Assessment of Memory and Learning (WRAML) did not differentiate subtypes in this study. Consistent with findings by Pieper and Deshler
(1980), a possible explanation may be that memory is not the problem for arithmetic disabled children. If a child can process the visual input, he or she can remember it as the subjects did on the visual memory components used in this study. It may be that other aspects of processing are the impediment to learning, and not memory. Alternately, as Swanson (1987a; 1993a) suggests, it may not be difficulty in any one specific process but rather the coordination of several processes that presents difficulty for the learning disabled child. To relate these findings to practical circumstances, visual tasks presented simply and briefly may help arithmetic disabled children to learn more.

Results indicated that children in the ARS subtype had more difficulty on tasks requiring verbal memory. Not only did the ARS subtype perform more poorly on verbal memory tasks compared to the other subtypes, but they performed more poorly on verbal memory tasks as compared to visual memory tasks. This finding would appear to support the contention that reading disabilities and verbal memory problems have a close connection.

However, when verbal versus visual learning over trials was compared, the ARS group demonstrated no difference from the A and AS subtype. When memory processing required both visual and verbal components as in the WRAML Sound Symbol subtest, the ARS group showed a difference in memory as compared to the other subtypes. More specifically, in
learning that required the connection of a visual symbol and a verbal symbol, the ARS subtype appears to remember less on the first trial, to learn at a similar rate over trials, but also to remember less than the other subtypes by the final trial.

This finding may be useful in suggesting that the multisensory remedial teaching approach may not be the most efficient in teaching certain subtypes of learning disabled children. In a review of the research, Lloyd (1988) concluded that research in the area of multisensory interventions training yielded inconsistent results. It may be that involving two learning modalities in teaching some learning disabled children would actually interfere with, rather than enhance, learning. This type of learning includes the phonetic approach, as well as the "sight" method, both of which involve repetitive exposure to visual symbols that correspond to verbal sounds.

Consideration could be given to the idea of more extensively and repetitively exposing the ARS subtype to visual symbols and their discrimination without initial verbal connection (Feagans & Merriweather, 1990). Likewise, research in the area of phonological awareness lends some credibility to the concept of teaching verbal/auditory discrimination without the initial use of visual symbols (O’Connor, Jenkins, Leicester, & Slocum, 1993; Stanovich, 1989). The other factor involved here would seem to be that
if a complex learning task similar to that in Sound Symbol
is to be grasped, a certain type of learning disabled child
may need to have extensive repetition. Although learning
rate may be similar, the initial acquisition is not, and the
child does not "catch up."

An alternative interpretation of this finding is that
it simply reflects the initial encoding difficulties of a
reading disabled child. That is, reading disabled children
often have difficulty with phonetic reading which is based
on the relationship of sound and symbol. It may be that the
entire symbolic number system, that is, the written numeral
rather than the abstract concept of number, is a prominent
source of difficulty in arithmetic for the ARS subtype.

Another important question with regard to memory is
whether the information that is acquired can be retained or
retrieved. After the delay interval on the Sound Symbol
subtest, the ARS group was not able to remember as many
items as the A and AS groups; that is, the ARS group
initially learned less but also forgot more. This was not
the case with simple visual or verbal learning, so again the
idea of the visual-verbal interaction as especially
problematic for the ARS group is affirmed. Although not
specifying a particular subtype, Goldman, Pellegrino and
Mertz (1988) found that extended practice may aid learning
disabled children. Repetition may then prove to be an
essential remedial strategy for the ARS group, even though
it is a teaching technique that is generally out of favor. These empirical findings may reinforce the legitimacy of attending to the typical anecdotal lament of the teacher and the learning disabled child, "he/she (I) knew it yesterday!"

Often the weaknesses of learning disabled children are the topic of discussion, but one finding in the present study may demonstrate a strength. On the Visual Learning subtest, no significant difference occurred between what had been learned by the fourth learning trial and what was remembered on the delay task across subtypes. Again, this could be a pedagogical consideration. Primary utilization of the visual modality to teach arithmetic disabled children may be a more efficacious teaching method for insuring greater retention in arithmetic (Woodward, 1991). It could be that when an arithmetic disabled child learns something that is visually presented, he/she retains it better then when presented in other ways, thus lending some support to the notion that a visual approach in teaching mathematics is central.

This is especially surprising since the main thrust of previous research (Rourke, 1989) has been to raise suspicion regarding the integrity of visual spatial systems in arithmetic learning disabilities. It may be only the encoding of visual components that deserves this reputation, with visual memory relatively preserved as a useful teaching modality. That is, the dissociation of visual encoding and
visual retrieval capacities in arithmetic learning disabilities is an important theoretical implication of the present data.

In the present work, however, there was a significant difference between the last learning trial and the delay trial on the Verbal Learning subtest, and since this was not the situation with the Visual Learning subtest it appears that the visual mode may be the better channel for retention in arithmetic disabled children. Simplicity and a precise analysis of the visual spatial task demands inherent in any classroom task would appear to be important considerations in teaching arithmetic disabled children in the visual mode.

Memory and Achievement

It is often assumed that various types of memory are important with regard to certain types of achievement. Findings in the present study did not distinguish any obvious pattern in memory performance that is associated with arithmetic achievement tasks. These results are consistent with the findings of the authors of the WRAML (Sheslow & Adams, 1990), who found mixed results when comparing the WRAML scores with achievement scores in an older age group. Finger Windows, which requires sequencing of visual spatial input with no apparent significance or purpose, was positively correlated with the Wide Range Achievement Test-Revised (WRAT-R) Arithmetic subtest for only the A subtype.
Visual sequencing is an important component of arithmetic operations and may be problematic for the A subtype, except that on a test similar to WRAT-R Arithmetic, the Woodcock-Johnson Tests of Achievement - Revised (WJR) Calculation subtest, a significant correlation was not found. It may be some peculiarity of WRAT-R Arithmetic that lends itself to correlation with Finger Windows for the A subtype. A cursory review of the differences between the two tests reveals:

1) the WRAT-R is timed, while WJR Calculation is not timed and requires the examiner to monitor progress on the test to determine the basal and ceiling level;

2) the WRAT-R presents the problems in rows, with little to separate the problems, while the WJR Calculation subtest presents each problem in its own box;

3) the WRAT-R contains some problems related to measurement, while the WJR Calculation requires only arithmetic calculation, and;

4) the WRAT-R has two levels of difficulty, the second of which older children receive and on which there are very few simple problems, while the WJR Calculation subtest has an entire range of problems that can be administered to all ages.
Further investigation using these two tests would seem an important component in determining how the different formats impact different types of arithmetic disabled children.

The lack of many significant positive correlations and the occasional emergence of negative correlations could suggest the contradiction of the concept of the specificity of achievement-memory relationships in arithmetic disabilities, suggesting that other psychological processes more meaningfully mediate the hypothesized relationships. Since the subjects of reading, spelling and arithmetic tend to become less specific and more interrelated as a child progresses through school, careful demarcation of age cohorts might allow meaningful achievement-memory relationships to emerge.

Unexpectedly, meaningfulness of stimuli appeared to impact both visual and verbal memory in arithmetic disabled children. One of the specific, intentional components of the WRAML was the use of a continuum of subtests from less meaningful to more meaningful. It is also noteworthy that sequencing is required on the WRAML subtests with the least meaningful stimuli, but not on the subtests with the most meaningful stimuli. Interpretation of these results would suggest that processing of information is dependent on the meaningfulness of information to the subject. Theoretically, the more a piece of information has meaning to a person, the greater its probability of being
remembered. Postulating for a moment that meaningfulness is a more crucial intervening variable for the arithmetic disabled child than it is to others, and extending the study's results to teaching, it may be valuable to integrate new learning with overlearned or long-term memory on an ongoing basis, rather than allowing new concepts to stand alone during training. This speculation parallels findings by Gagne, Yarbrough, Weidemann, and Bell (1984) that the meaningfulness to the individual of the content of reading material affects original and long-term learning. In addition, it is consistent with recommendations by Baroody and Hume (1991) that mathematical learning for learning disabled students should be meaningful, purposeful, and interesting.

Intervention and Arithmetic

Another area often neglected in learning disabilities research is the role of intervention and, although it is well beyond the scope of this study, some information can be gleaned from the parent reports of the extent of intervention provided for their children. For example, most remarkable is that the children with a learning disability only in arithmetic received the least intervention.

Many explanations for this relative absence of intervention can be offered, one being that no intervention was deemed necessary. This could be further extended to the lack of importance often accorded to mathematics in our
society (Fleischner, 1994), perhaps a very poor prioritization given the necessity of mathematics to our high tech infrastructure. Given our society’s emphasis on reading disabilities, as well as the documented lack of training by special education teachers in arithmetic, it is quite conceivable that sophisticated intervention was not available as an option. Perhaps even more lamentable is that schools are so backward in teaching mathematics that children with arithmetic learning disabilities go unnoticed. Likewise, in parallel with the previous speculation, it may be that our overall standards in mathematics are so low that poorly performing subjects are not clearly discriminated from others. For example, to achieve a sixth grade level on many individualized standardized achievement tests, a child is not required to solve any problems involving fractions or division, yet these basic skills are taught in most schools considerably before the sixth grade. Whatever the reasons, these observations allude to the lack of prominence of mathematics in our societal priorities.

Subject Selection

Another striking bit of information can be gleaned from the subject selection process. In the A and AS group, better than fifty percent of parents agreed to allow their children to participate in the study. The ARS group, however, had a considerably smaller percentage of parents agree to have their children participate. One would think
that parents of such globally deficient students would be most eager to participate and would be able to make good use of extensive test results. Alternatively, since the ARS group appears to receive the most services in terms of intervention, the parents may not have deemed it efficacious to receive even more information about their children. Likewise, these children may come from more educationally disadvantaged and disorganized home situations, so that parents were less motivated or less able to take advantage of the testing offered. Perhaps achievement motivational variables across generations may undergird the entire phenomenon observed in the ARS group, in which case, other family members may have had multiple sources of difficulty in following through with research participation.

Limitations

Other factors demand consideration in the present study. First of all, the sample used was very stringently defined: a group of children with average or better Full Scale IQs with not only a severe discrepancy in achievement but achievement below the 25th percentile. Although this sample was well defined, it did encompass the entire lowest quartile of achievement in arithmetic. Some authors (e.g. Keogh, 1988; McLeskey, 1989) note that there is considerable murkiness in regard to the separation of low achievement and learning disability. The upper end of the lowest quartile
may be more indicative of a low average learner than of a disabled learner. Therefore, although the use of clearly delineated criteria could be considered a strength, the actual criteria used to define a learning disability in this study may be a limitation. At the same time, this sample may also be representative of children seen in clinical and educational settings, which could be considered a strength. This is another example of the age-old problem of defining learning disabilities, a diagnosis without definitive criteria (Kavale, 1988; Kavale & Nye, 1981; Keogh, 1988).

If the operational definition of learning disabilities is ambiguous, then the subtyping of learning disabilities presents even more of a quandary. Ultimately, the entire idea of classification of learning disabilities using academic subjects as the delimiters could be considered a limitation. Although many researchers (e.g. Rourke & Strang, 1978; Siegel & Ryan, 1989; Swanson; 1993b) use academic achievement variables to define arithmetic learning disability, Lyon and Risucci (1988) argue that the theoretical basis for proposed arithmetic subtypes is linked only loosely to available evidence on hemispheric differences and stems mostly from clinical experience. Kavale (1988) asserts, however, that given the state of the field, many conceptualizations may be appropriate and justified at present including the study of achievement based subtypes.
In a multitude of learning disability studies, it can be hypothesized that what has ultimately been studied is a group of children with below average intelligence (e.g., Cawley & Miller, 1989; Snow, 1992). It is definitional that such children have at least some learning problems, if not the generalized problems seen in the present study's ARS group. It would appear that such lower IQ learning disabled groups are a very different and probably a much more impaired group than the subjects used in the present study. Perhaps researchers have strayed too far from the original concept of a learning disabled child (including average or better IQ) and are studying very different populations. Unfortunately, as Keogh (1990) contends, differences should be expected when subjects are selected for research focused on differing aspects of learning disabilities.

Similar to findings by Fletcher (1985), the A and the AS group did not appear to differ significantly from one another on the memory measures investigated in the present study. Gerber and Hall (1987) allude to the possibility that spelling may be the most common identifying characteristic of learning disabilities and, as such, may not be a powerful discriminator for subtype research. In addition, to further confound the use of spelling, Moats (1994) contends that spelling is inherently difficult for the average person, not only the learning disabled.
Therefore, using spelling as a differential criteria may have limited significant findings in this study.

The use of the WRAML could be considered a limitation because, although the WRAML is a standardized test of memory, it does not have a significant body of literature to support its validity, reliability, or usefulness in assessment of learning disabled children. Further, the components of memory measured by the WRAML are limited, and therefore, constrain the scope of findings. At the same time, it should be remembered that the WRAML is one of the first standardized measures of memory for children.

Future Research

Since the present study was based on subtyping, it might be profitable to conduct a similar study using other subtypes based on ability-achievement discrepancy, such as a reading only and reading/spelling subtype. It would be interesting to know if deficits in verbal memory as measured by the WRAML would be upheld for other subtypes of learning disabilities that include reading.

Given our society's trend to afford mathematical learning more importance, it may be that children with difficulties in learning mathematics will receive more attention (Rivera, 1993). Therefore, it would be prudent, if not imperative to continue to research the area of arithmetic learning disabilities. One of the major difficulties is how the subtypes are selected, so it may be
beneficial to research levels of disability in arithmetic, as well as arithmetic disability with and without disability in other academic areas. It seems particularly important as research becomes more heterogeneous, that the selection of subtypes be clearly defined.

With the advent of several standardized memory measures (e.g. WRAML: Test of Memory and Learning (TOMAL); California Verbal Learning Test - Children's Revision (CVLT-C)), it seems essential that research in the area of learning disabilities include some type of memory measures. Although the memory measure used in this study did not yield expected results, this does not preclude that some findings were significant (meaningful vs. meaningless). In addition, it seems that the information gleaned from a memory test and particularly the learning tasks of the WRAML may be valuable in a clinical as well as an educational setting. The body of literature is sparse on the WRAML and research is needed not only to lend more validity to it, but also to aid clinicians in interpretation. Finally, using the WRAML or any other standardized test of memory in relation to educational interventions would be a logical and practical progression for research in this area.

**Conclusion**

Overall, it appears from study results that memory as measured in this study is not a cardinal feature in arithmetic only or arithmetic/spelling disabilities.
Although previous researchers have described arithmetic disabled children as having deficits in visual processing, those deficits do not appear to extend to visual memory. Results from the present study do support the idea that the ARS group is somehow different from the other two groups and that generally this group is a poor representative of arithmetic learning disability. Even though the major hypotheses—deriving by inference from studies of other nonarithmetic learning disabled populations—were not supported, there were some isolated, surprising results. For the arithmetic disabled group, achievement-memory relationships do not appear to be specific. Tasks presented simultaneously visually and verbally appear to hinder learning for the ARS subtype. All the subtypes appear to retain information better when it is presented visually only. Meaningfulness of the material presented also appears to play an important role in learning for arithmetic disabled children. Several practical pedagogical implications of the results appear to be that arithmetic disabled children can remember information presented in the visual modality if it is simple enough to be processed, that meaningfulness of the stimuli seems to be particularly important, and, finally, that repetition is unexpectedly important for retention.
APPENDIX A

INFORMATION ON THE WRAML
Table 10

Description of the Subtests

**Verbal Memory Scale**

**Number/Letter** – The task requires repetition of a random mix of numbers and letters presented in strings of 2 to 10 units. The number and letter combination was chosen to prevent "chunking."

**Sentence Memory** – The child is asked to repeat meaningful sentences beginning with a 3 word sentence.

**Story Memory** – Two short stories are read and the child is asked to recall as many parts of the story as can be remembered.

**Visual Memory Scale**

**Finger Windows** – A card (the plain white side to the child) with nine holes on it is held up in front of the child. The examiner than using coded random sequences (and the numbered side of the card) puts a pencil in 2 through 9 windows, progressively. The child is then asked to reproduce the spatial sequence by putting his or her finger through the holes in the order presented.
Table 10 - continued

Design Memory - After a presentation of 5 seconds and a
delay of 10 seconds, the child is asked
to reproduce four designs.

Picture Memory - After viewing a complex meaningful scene
for 10 seconds, the child is shown a
similar scene and asked to mark all the
items that have been added or changed.
Four sets of scenes are used.

Learning Scale

Verbal Learning - A list of 16 simple words is read to the
child followed by immediate recall.
Three additional presentation/recall
trials follow.

Visual Learning - A board with 14 designs is presented to
the child. The designs are uncovered
for one second each. The child is then
presented with each design and asked to
recall its location on the board. The
set of 14 designs is presented 4 times.

Sound Symbol - The child is asked to recall sounds
associated with various abstract
figures. There are 14 paired associates,
and after an initial "learning trial,"
they are presented/recalled four times.
Table 10 - continued

Delayed Recall

Four Scales  - Delayed recall subtests are included for Verbal Learning, Visual Learning, Sound Symbol, and Story Memory. The delayed memory subtests are optional, but were used as a part of the battery.

Recognition  - In addition to delayed recall on Story Memory, there is a recognition subtest using a multiple choice format regarding the second story.

Table 11

**Correlation Matrix of WRAML Subtests - (9 & Older)**

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Pic</th>
<th>Dsgn</th>
<th>Verb</th>
<th>Stor</th>
<th>Fgr</th>
<th>Snd</th>
<th>Sent</th>
<th>Vis</th>
<th>Num/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mem</td>
<td>Mem</td>
<td>Lng</td>
<td>Mem</td>
<td>Win</td>
<td>Sym</td>
<td>Mem</td>
<td>Lrn</td>
<td>Let</td>
</tr>
<tr>
<td>Picture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>.390</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal</td>
<td>.233</td>
<td>.306</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Story</td>
<td>.315</td>
<td>.304</td>
<td>.353</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finger</td>
<td>.211</td>
<td>.247</td>
<td>.248</td>
<td>.244</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound</td>
<td>.254</td>
<td>.283</td>
<td>.330</td>
<td>.374</td>
<td>.247</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentence</td>
<td>.181</td>
<td>.223</td>
<td>.302</td>
<td>.435</td>
<td>.300</td>
<td>.352</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>.294</td>
<td>.418</td>
<td>.310</td>
<td>.329</td>
<td>.272</td>
<td>.378</td>
<td>.234</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Number/</td>
<td>.143</td>
<td>.156</td>
<td>.202</td>
<td>.234</td>
<td>.280</td>
<td>.306</td>
<td>.605</td>
<td>.198</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Table 11 - continued

All significantly correlated at the .001 level (N = 1460).

Table 12

**Intervention by Subtype**

<table>
<thead>
<tr>
<th>Description</th>
<th>A</th>
<th>AS</th>
<th>ARS</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No supplemental intervention reported</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>2. Subject received tutoring or summer school</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>3. Subject participated in a school intervention program such as Chapter 1 or a special dyslexia class for 1 to 3 years</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>4. Subject participated in a school intervention program such as Chapter 1 or a special dyslexia class for more than three years.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5. Subject participated in a special education program supplemental to regular education, such as the resource room or content mastery for 1 to 3 years.</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>6. Subject participated in a special education program supplemental to regular education, such as the resource room or content mastery for more than 3 years.</td>
<td>6</td>
<td>2</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>7. Subject was in a self-contained special education classroom or in a private school for children with learning disabilities for 1 to 3 years.</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
Subject was in a self-contained special education classroom or in a private school for children with learning disabilities for more than 3 years.
Table 13

Means and Standard Deviations for the WRAML Subtests

<table>
<thead>
<tr>
<th>Subtest</th>
<th>A</th>
<th>AS</th>
<th>ARS</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.5 (3.0)</td>
<td>11.0 (2.4)</td>
<td>10.0 (2.2)</td>
<td>10.5 (2.6)</td>
</tr>
<tr>
<td>Story Memory</td>
<td>9.6 (2.5)</td>
<td>9.8 (2.3)</td>
<td>7.6 (2.3)</td>
<td>9.0 (2.5)</td>
</tr>
<tr>
<td>Sentence Memory</td>
<td>9.1 (2.8)</td>
<td>9.0 (2.0)</td>
<td>6.8 (2.2)</td>
<td>7.9 (2.5)</td>
</tr>
<tr>
<td>Number Letter Memory</td>
<td>10.9 (3.7)</td>
<td>10.6 (2.7)</td>
<td>10.7 (2.9)</td>
<td>10.8 (3.1)</td>
</tr>
<tr>
<td>Picture Memory</td>
<td>10.5 (3.7)</td>
<td>10.6 (2.4)</td>
<td>10.5 (3.4)</td>
<td>10.5 (3.2)</td>
</tr>
<tr>
<td>Design Memory</td>
<td>9.0 (3.8)</td>
<td>8.4 (2.5)</td>
<td>8.1 (3.7)</td>
<td>8.5 (3.4)</td>
</tr>
<tr>
<td>Finger Windows</td>
<td>11.3 (3.0)</td>
<td>10.5 (3.8)</td>
<td>10.1 (2.1)</td>
<td>10.7 (3.0)</td>
</tr>
<tr>
<td>Verbal Learning</td>
<td>10.6 (3.4)</td>
<td>10.2 (2.7)</td>
<td>7.7 (2.2)</td>
<td>9.5 (3.1)</td>
</tr>
<tr>
<td>Sound Symbol</td>
<td>10.3 (3.1)</td>
<td>10.5 (2.8)</td>
<td>9.9 (2.9)</td>
<td>10.2 (2.9)</td>
</tr>
</tbody>
</table>
Table 14

Learning by Trial on the WRAML Verbal Learning Subtest

<table>
<thead>
<tr>
<th>Sub-type</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.3</td>
<td>8.9</td>
<td>10.7</td>
<td>10.9</td>
<td>10.4</td>
</tr>
<tr>
<td>AS</td>
<td>5.2</td>
<td>8.2</td>
<td>9.5</td>
<td>11.4</td>
<td>9.0</td>
</tr>
<tr>
<td>ARS</td>
<td>5.1</td>
<td>7.7</td>
<td>9.9</td>
<td>10.5</td>
<td>9.6</td>
</tr>
</tbody>
</table>
Table 15

Learning by Trial on the WRAML Visual Learning Subtest

<table>
<thead>
<tr>
<th>Sub-type</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Delay Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.9</td>
<td>6.8</td>
<td>8.6</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>AS</td>
<td>6.1</td>
<td>7.1</td>
<td>8.3</td>
<td>9.1</td>
<td>9.2</td>
</tr>
<tr>
<td>ARS</td>
<td>4.6</td>
<td>7.1</td>
<td>7.7</td>
<td>8.5</td>
<td>9.0</td>
</tr>
</tbody>
</table>
Table 16

Learning by Trial on the WRAML Sound Symbol Subtest

<table>
<thead>
<tr>
<th>Sub-type</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
<th>Delay Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.9</td>
<td>6.0</td>
<td>7.3</td>
<td>8.5</td>
<td>7.7</td>
</tr>
<tr>
<td>AS</td>
<td>3.6</td>
<td>5.4</td>
<td>6.8</td>
<td>8.4</td>
<td>7.6</td>
</tr>
<tr>
<td>ARS</td>
<td>2.0</td>
<td>3.6</td>
<td>4.4</td>
<td>5.2</td>
<td>4.9</td>
</tr>
</tbody>
</table>
APPENDIX C

PARENT FEEDBACK INFORMATION
October 1, 1993

Office of Research Administration
University of North Texas
Box 5396, Room 310 Admin. Building
Denton, TX 76203-5396

To Whom It May Concern:

Ms. Deborah Pennett has requested permission to use the data associated with an existing research project at Texas Scottish Rite Hospital for Children entitled: "Subtypes of Children with Specific Arithmetic Disabilities" (Project number 01-92-227). She has indicated that the data will be used solely for her dissertation research as part of her Ph.D. studies.

With the understanding that (1) Ms. Pennett will take all normal and reasonable precautions to protect the confidentiality of any patient information, (2) she will not disclose any information that would identify a patient, and (3) she will notify us of her findings prior to their publication, I hereby grant her permission to use the project data in her dissertation research.

Sincerely,

[Signature]
Richard H. Browne, Ph.D.
Administrative Director of Research
Dear [Parent's Name],

In the past, your child was tested at Texas Scottish Rite Hospital. Currently, we are conducting a research study to help us understand better children who have difficulties in learning arithmetic. We have reviewed [Child's Name]'s file and are requesting your assistance. Participation in the study would involve the administration of several cognitive and educational tests. Testing will take one day and is free of charge. A copy of test results will be provided to you.

We shall be contacting you by phone in the near future or you may contact Deborah Pennett at 214-559-7525 to discuss this study and possibly schedule an appointment. We have enclosed an address and phone number update sheet. Your completion and return of this form in the enclosed self-address envelope would be appreciated.

Your child’s involvement in this program will help us explore new ways of teaching mathematics. Thank you for considering our request.

Sincerely,

Jeffrey L. Black, M.D.
Medical Director
Child Development Division

JLB/paw
ARITHMETIC DISABILITIES RESEARCH PROJECT
SUMMARY OF EVALUATION

1-

STUDENT: 2-

Dear 4-:

We have recently finished reviewing the results of testing 3- as a part of the arithmetic disabilities research project. We want to thank you and 3- for your cooperation in coming to our clinic and completing the testing.

Our study examined many areas of 3-’s functioning including 1) math, reading and spelling ability, 2) neuropsychological functioning, 3) language ability, 4) social and emotional functioning, and 5) memory. Results of these tests will be described below.

MATHEMATICS, READING, AND SPELLING ABILITY

The following tests were administered to 3-:

**Wide Range Achievement Test - Revised**

Reading Recognition (WRAT-R Reading) - tests ability to recognize words, it does not include reading comprehension

Spelling (WRAT-R Spell) - tests ability to spell words, it is administered in the form of a usual spelling test

Arithmetic (WRAT-R Arith) - tests ability to add, subtract, multiply and divide whole numbers, fractions and decimals - there is a ten minute time limit on this test

**Woodcock-Johnson Psychoeducational Battery - Revised**

Mathematics Calculation (WJ-R Calcul) - tests ability to add, subtract, multiply and divide whole numbers, fractions, and decimals - there is no time limit on this test

Applied Problems (WJ-R AppProb) - tests ability to solve word problems
Quantitative Concepts (WJ-R QuanC) - tests ability to recognize common mathematical abbreviations and symbols (such as lb., %, and a square root sign)

3-'s grade level scores according to testing are presented in the table below. 30- grade level at the time of testing was 29-.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>WRAT-R Reading</th>
<th>WRAT-R Spell</th>
<th>WRAT-R Arith</th>
<th>WJ-R Calcul</th>
<th>WJ-R AppProb</th>
<th>WJ-R QuanC</th>
</tr>
</thead>
<tbody>
<tr>
<td>23-</td>
<td>24-</td>
<td>25-</td>
<td>26-</td>
<td>27-</td>
<td>28-</td>
<td></td>
</tr>
</tbody>
</table>

NEUROPSYCHOLOGICAL FUNCTIONING:

3- demonstrated 5- integrative problem-solving, which involves doing step by step logical analysis and creating strategies. 31-

6- demonstrated 7- flexibility in thinking, which is the ability to shift from one idea to another when necessary. 32-

Fundamental motor speed was 8-. Hand strength was 9-.

3-'s ability to attend to a rapidly-paced test of attention and concentration was 10-. 30- ability to sustain attention was 11-.

3- 12- on a sensory-perceptual examination which deals with translating incoming information in the visual, tactile, and auditory senses. 13-

LANGUAGE ABILITY:

We administered a brief screening of language functioning. Generally, 3-'s language production 14- and language processing 15-.

EMOTIONAL AND SOCIAL FUNCTIONING:

Information for this section was obtained from two questionnaires completed by you and one questionnaire completed by 3-.

According to your report, 17-. 3-'s self report showed 18-.

On the other questionnaire that you completed, 19-.
MEMORY:

Verbal memory tests evaluate how much of what is heard is remembered. 3~ obtained results in the 20- range in the area of verbal memory. Visual memory tests evaluate how much of what is seen is remembered. 3~ obtained results in the 21- range in the area of visual memory. 22-

Thank you again for participation in our research. If you have questions about the results, please call Pam Wenzel at 559-7525. Please call between 8:00 am and 4:30 pm and mention that you are calling about the Arithmetic Research Project.

Sincerely,

Jeffrey L. Black, M.D.
Medical Director
Child Development Division

Cheryl H. Silver, Ph.D.
Assistant Professor
University of Texas Southwestern Medical Center
FIELDS

1 - Date
2 - Child's Full Name
3 - Name child uses
4 - Parent's name
5 - Level of integrative problem solving (Category and TPT)
   satisfactory difficulties with (see Field #31)
6 - He or she
7 - Level of ability to use flexibility of thinking (Trails & WCST)
   satisfactory use of difficulties with using (see Field #32)
8 - Motor speed (finger tapping)
   within normal limits
   below average. (Child's Name) may be slower in performing speeded motor tasks
9 - Hand strength
   within normal limits
   below average, although this does not generally affect school performance
10 - Attendance to rapidly paced test of attention and concentration (Rhythm)
    within normal limits
    below average. (Child's name) may need more time to "catch" auditory information.
11 - Ability to sustain attention (Speech Sounds)
    within normal limits
    below average. (He or She) may need to have school tasks broken down into smaller parts to maintain attention.
12 - SSPE rating (Sensory Perceptual Exam)
    showed no difficulty
    made mistakes
13 - SSPE further explanation
    blank if "showed no difficulty", but you need to select End Field
    choose the following depending on where errors are:
    This may have been a side-effect of his/her attention problems. (if attention problems noted)
    This is often characteristic of children with learning disabilities. (If FTNW/FAg low)
    You may want to consider an eye exam. (If visual low)
    You may want to consider a hearing exam. (If auditory is low)
14 - Level of language production (CELF)
    was satisfactory
showed difficulties

15 - level of language processing (CELF) showed difficulties
was satisfactory

16 - depending on above two statements add either End Field if both results were satisfactory
if processing low (He or She) may need verbal instructions given
more clearly and in concise language.
if production low (He or She) may have difficulty expressing
him/herself.

17 - SSRS Parent rating level
your child’s social skills are satisfactory
your child may have some difficulty in social
situations, primarily in the area of
responsibility
being assertive
cooperation
self-control

18 - SSRS Child rating level
no difficulty with social skills
no difficulty with social skills, except in the
area(s) of
cooperation
being assertive
understanding other’s feelings
self-control

19 - PIC information
you indicated no marked difficulties with Child’s
Name’s behavior
your answers suggest that Child’s Name has difficulty with
Use appropriate wording for scales above 70

| Achievement-difficulty with academic achievement |
| Intellectual Screening-difficulty with knowledge skills used in school |
| Development-difficulty with his/her general development |
| Somatic Concern-complaints about his/her health |
| Depression-exhibits depressed mood |
| Delinquency-has behavior problems |
| Family Relations-may be troubled by things at home |
| Withdrawal-may be uncomfortable in social situations and prefer to be alone |
| Anxiety-may be worried or anxious about things |
| Psychosis-may be moody or have unusual thoughts or behaviors |
| Hyperactivity-may be restless, impulsive or overactive |
Social Skills—may have difficulty in social activities (Be sure and check SSRS rating before you type the Social Skills statement)

Other areas were within normal limits

20 - Verbal Memory (WRAML)
above average
average
below average

21 - Visual Memory (WRAML)
above average
average
below average

22 - if both types of memory are average or above, press End Field
If both types of memory are below average—You may want to give less information at a time, repeat the information, have Child's Name repeat the information back to you, and/or help him/her write it down.

below average visual memory—You may want to explain things in words rather than showing Child's Name what to do.

below average verbal memory—You may want to show Child's Name what to do rather than explaining things in words.

23 - WRAT-R Reading
24 - WRAT-R Spelling
25 - WRAT-R Arithmetic
26 - WJ-R Calculation
27 - WJ-R Applied Problems
28 - WJ-R Quantitative Concepts
29 - Child's grade level at time of testing
30 - His or Her (Capitalize the H)
31 - (if child had difficulty with Category and/or TPT add this sentence) He/she may need extra structure and guidelines when he/she tries new things.

if no difficulty select End Field

32 - (when child has difficulty with Trails and/or WCST add the following sentence) He/she may need assistance when work requires varying tasks.

if no difficulty select End Field

SAVE UNDER LAST NAME OF CHILD

CONTROL-F9 TO MERGE - PRIMARY FILE NAME: FEEDBACK
SECONDARY FILE NAME: LAST NAME OF CHILD

SAVE MERGED DOCUMENT USING THE CHILD'S FIRST AND LAST NAME
APPENDIX D

INSTITUTIONAL REVIEW BOARD MATERIALS
October 14, 1993

Helene Pennett
6007 Meadowhill Dr.
Colleyville, TX 76034

Dear Ms. Pennett:

Your proposal entitled "Characteristic Memory Functions in Subtypes of Arithmetic Learning Disabled Children," has undergone expedited review and has been approved by the IRB under 45 CFR 46.110.

If you have any questions, please contact me at (817) 565-3946.

Good luck on your project.

Sincerely,

Sandra Terrell, Chair
Institutional Review Board

[Signature]

Sandra Terrell, Chair
Institutional Review Board

ST/II
APPLICATION FOR APPROVAL OF INVESTIGATION INVOLVING THE USE OF HUMAN SUBJECTS
University of North Texas Institutional Review Board for the Protection of Human Subjects in Research (IRB)

This application should be submitted to the Office of Research Administration and Academic Grants, Room 310, Administration Building.

1. Principal Investigator’s Name: Helen Deborah-Lynne Pennett

Department & Campus Address: ____________________________________________

Campus Phone No.: __________________________ Home No.: (940) 365-6352.

2. If you are a student, provide the following:

Home Address of Student: 6007 Meadowhill Dr. Colleyville, TX 76034

Name of Faculty Sponsor: Sander Martin, Ph.D. Phone Ext: 2671

Is this your thesis or dissertation research? Yes X No

3. Title of Project: Characteristic Memory Functions in Subtypes of Arithmetic Learning Disabled Children


5. Is a proposal for external support being submitted? Yes No X

If “Yes,” you must submit one complete copy of that proposal as soon as it is available and complete the following:

a) Is notification of Hum. Subj. Approval Required? Yes No X

b) Is this a renewal application? Yes No

c) Funding agency’s name: ________________________________

6) In making this application, I certify that I have read and understand the guidelines and procedures developed by the University for the protection of human subjects, and I fully intend to comply with the letter and spirit of the University’s Assurance and policy. I further acknowledge my responsibility to report any significant changes in the protocol, and to obtain written approval for these changes, in accordance with the procedures, prior to making these changes. I understand that I cannot initiate any contact with human subjects before I have received approval and/or complied with all contingencies made in connection with that approval.

Signature of Principal Investigator Date

Helen Deborah-Lynne Pennett October 9, 1993

7) Approval by Faculty Sponsor (required for all students): I affirm the accuracy of this application, and I accept the responsibility for the conduct of this research and supervision of human subjects as required by law.

Signature of Faculty Sponsor Date

October 9, 1993
Page Two - Application

8) I have included copies of all pertinent attachments including, but not limited to: questionnaire/survey instrument, informed consent, letters of approval from cooperating institutions, copy of external support proposal if applicable, etc. ...

Yes  No ___ (If no, explain on an attached sheet)

For the following items, attach your answers, appropriately numbered on a separate sheet of paper.

9) Identify the sources of the potential subjects, derived materials or data. Describe the characteristics of the subject population, such as their anticipated number, age, sex, ethnic background, and state of health. Identify the criteria for inclusion or exclusion. Explain the rationale for the use of special classes of subject, such as fetuses, pregnant women, children, institutionalized mentally disabled, prisoners, or others, especially those whose ability to give voluntary informed consent may be in question.

10) Provide a description of the procedures to be used in the study including major hypotheses and description of the research design.

11) Describe the recruitment and consent procedures to be followed, including the circumstances under which consent will be solicited and obtained, who will seek it, the nature of information to be provided to prospective subjects, and the methods of documenting consent. (Include applicable consent forms) for review purposes. If written consent is not to be obtained, specifically point this out and explain why not.

(Note: Informed consent must normally be obtained in a written form which requires the subject’s signature or that of the subject’s legally authorized representative. A waiver of this requirement may be granted by the IRB if adequate justification for the requirement is provided by the investigator in #11. However, if the procedures pose no more than minimal risk to the subjects, informed consent may be documented via a written cover letter which does not require the subject’s signature. In all cases, a copy of the written informed consent must be given to the subject unless this requirement is specifically waived by the IRB. Consult the document “Information on Human Subjects Research” for more information on informed consent requirements and specific examples of possible informed consent documents.)

12) Include a discussion of confidentiality safeguards, where relevant.

13) Describe the anticipated benefits to subjects, and the importance of the knowledge that may reasonably be expected to result.

14) Describe the risks involved with these procedures (physical, psychological, and/or social) and the precautions you have taken to minimize these risks. Do the benefits described above outweigh the described risks?

humansub/humansub.apl
Deborah Pennett  
October 9, 1993

APPLICATION FOR APPROVAL OF INVESTIGATION  
INVolVING THE USE OF HUMAN SUBJECTS

8) I have included a copy of the letter of approval to use the data from Texas Scottish Rite Hospital for Children. Also included is the informed consent form used for the study.

9) Data will be extracted from the testing files of children who are participating in the "Subtypes of Children with Specific Arithmetic Disabilities" project at the Texas Scottish Rite Hospital for Children. The subjects are children aged 9 through 13 years who according to previous testing at Texas Scottish Rite Hospital have a significant discrepancy, defined as 15 standard score points, between their ability level and their arithmetic achievement scores. The IQ scores must be in the average range, that is, 90 standard score points and above. There will be approximately 75 subjects.

10) The subjects are part of a larger study entitled "Subtypes of Children with Specific Arithmetic Disabilities." As a part of the larger study subjects are given the Wide Range Assessment of Memory and Learning (WRAML; Sheslow & Adams, 1990), which will be used in the present investigation. It is hypothesized that the three subtypes of arithmetic disabled children; 1) arithmetic learning disability only (A), 2) arithmetic and spelling disability (AS), and 3) arithmetic, reading and spelling disability (ARS) will perform differently on the visual, verbal, and combined visual/verbal components of the WRAML. One way analyses of variance, t-tests, and correlations will be used to determine the presence or absence of significant differences.


11) Not applicable. Subjects are part of an existing research project at Texas Scottish Rite Hospital. See informed consent.

12) Data will be extracted from testing records and placed on a data base using an identifying number for purposes of data input only. Confidentiality safeguards include the extraction of data from testing records using an identifying number for purposes of data input and verification only. Further, results of the study will be reported using group statistics, not individual scores or
any other individually identifying information.

13) It is hoped that the results of this investigation will illuminate memory characteristics of children with arithmetic learning disabilities. Further, it is anticipated that information gleaned from memory characteristics may be able to aid in helping develop methods of teaching arithmetic based on memory strengths and weaknesses in these children.

14) Not applicable. Subjects are part of an existing study. See informed consent.
October 1, 1993

Office of Research Administration
University of North Texas
Box 5396, Room 310 Admin. Building
Denton, TX 76203-5396

To Whom It May Concern:

Ms. Deborah Pennett has requested permission to use the data associated with an existing research project at Texas Scottish Rite Hospital for Children entitled: "Subtypes of Children with Specific Arithmetic Disabilities" (Project number 01-92-227). She has indicated that the data will be used solely for her dissertation research as part of her Ph.D. studies.

With the understanding that: (1) Ms. Pennett will take all normal and reasonable precautions to protect the confidentiality of any patient information, (2) she will not disclose any information that would identify a patient, and (3) she will notify us of her findings prior to their publication, I hereby grant her permission to use the project data in her dissertation research.

Sincerely,

Richard H. Browne, Ph.D.
Administrative Director of Research
REFERENCES


Council for Learning Disabilities Research Committee:


Hollingshead, A. V. (1975). Four factor index of social status. Unpublished manuscript, Yale University, Department of Sociology, New Haven, CT.


Reynolds, C.R., Bigler, E.D. (1993, October). Memory assessment in children with the Test of Memory and
Learning (TOMAL). Paper presented at the meeting of the National Academy of Neuropsychology, Phoenix, AZ.


