

COGNITIVE CORRELATES OF ARITHMETIC PERFORMANCE IN CLINIC
REFERRED CHILDREN

by

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ABSTRACT

The purpose of this research was to investigate, from quantitative and qualitative viewpoints, the relationship between cognitive functioning and arithmetic performance. Using multiple correlations, the performance of one hundred and thirty-five clinic-referred children on the Arithmetic subtests of the Wechsler Intelligence Scale for Children (WISC) and Wide Range Achievement Test (WRAT) was examined in relation to performance on Verbal, Spatial and Memory dimensions (as measured by the WISC). In addition, a subtyping procedure was used to examine whether the pattern of Arithmetic performance was related to pattern of cognitive abilities. A replication of the preceding was undertaken on a sample of three hundred and fifteen school-referred children. The qualitative approach involved analysis of errors made on arithmetic-related tasks by eighteen learning disabled children.

The results indicated that the Verbal and/or Memory dimensions consistently contributed to arithmetic performance although the relative contributions of each varied by sex,

age and across samples. Qualitative analysis of the performance of children with severely impaired Verbal and Memory abilities was characterized by errors reflecting impaired recollection of basic facts and faulty acquisition of certain mathematical concepts. Contrary to expectations, the Spatial dimension only contributed to the Wechsler Arithmetic subtest for the second sample.

Pattern of cognitive ability had no relationship to the pattern of Arithmetic performance but level of Verbal and Memory abilities differed in relation to pattern of Arithmetic performance.

It was suggested that Spatial ability is necessary to acquire an appreciation of numeration and serves as a basis for the development of mathematical ability but beyond this basis, the degree to which an individual acquires the ability to abstract plays a role in arithmetic performance. Implications and suggestions for future research are briefly presented.

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DEDICATION

This is dedicated to the late Dr. Irving A. Taylor.

INTRODUCTION

Cognitive Contributions To Academic Achievement

Interest in, and assessment of, higher mental processes (or cognition) was an inherent part of the movement which began in the latter part of the nineteenth century and brought clinical and educational psychology into being as disciplines. Among the first researchers to examine the relationship between cognitive functioning and academic achievement were Simon and Binet. Their goal was to design a series of measurements of higher mental processes which could be used to distinguish between children who would and would not benefit from educational training (i.e., for the identification of mentally retarded children). This work culminated in the 1905 scale, the predecessor of modern-day intelligence tests. Subsequently, in revisions to this scale and in the generation of new scales, tests dependent on scholastic abilities such as reading and writing were eliminated from measurements of cognitive functioning and separate measurements of academic achievement were developed. The resulting psychometric distinction between achievement and cognitive ability measures has led to a research strategy of correlating cognitive abilities with scholastic achievement.

A second strategy has evolved which involves the selection of children who experience difficulty in learning, either globally or within specific content areas. Differences in cognitive ability between these children and academically normal achievers are investigated to identify specific cognitive weaknesses characteristic of "learning disabled" students. A central issue in the application of this second approach is the definition of the disabled learner. One stance taken in the literature has been to establish an operational definition for a learning disability and then examine the characteristics of children who fit this definition. Definitions have been developed for learning disabilities generally and disabilities within specific content areas (e.g., reading and arithmetic). Each of these definitions is negative or exclusional in nature. For example, The World Federation of Neurology defines developmental dyslexia or specific reading disability as

A disorder manifest by difficulty in learning to read despite conventional instruction, adequate intelligence, and socio-cultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin (Critchley, 1970, p.11).

Similar definitions which exist for learning disabilities (e.g., Gaddes, 1976) and developmental dyscalculia, arithmetic disability (Kosc, 1974), also exclude severe emotional disturbances.

Although these definitions were established in an effort to clarify the central issues involved, there has been considerable debate in the literature as to their usefulness and validity (e.g., Critchley, 1970; Guthrie, 1978; Mattis, 1978; Rutter, 1978; Taylor, Satz and Friel, 1979). Both the logic behind establishing negative definitions such as these and their effectiveness for guiding day-to-day clinical practice have been questioned (Futter, 1978). In addition, the use of terms such as conventional instruction, adequate intelligence and socio-cultural opportunity are sufficiently vague and open to interpretation as to appear meaningless. As is evident from the accumulated literature employing such definitions, research samples may be constituted which differ with respect to IQ range, socioeconomic status and procedures of screening for emotional disturbances depending on the individual researchers interpretation of the definition.

An alternative approach advocated by Rutter (1978) involves determining how a broad group of disabled learners, whether generally disabled or within a specific content

area, may best be subdivided. For example, Rutter (1978), in a study of poor readers, makes a distinction between general backwardness (i.e., low achievement in relation to the average for that age, but without taking IQ into account) and specific retardation (i.e., achievement which is low after taking both age and IQ into account) which proved useful in terms of prognostic value. It has also been suggested that disabled learners may be categorized according to supposed etiology (e.g., presence or absence of brain damage, emotional disturbance, social disadvantage) or pattern of cognitive deficit shown (Rutter, 1978).

Numerous attempts have been made to classify disabled learners on the basis of performance on measures of cognitive functioning. Since academic achievement is a highly complex activity which places demands on a great number of cognitive and linguistic skills, it would be expected that deficits in any one or a combination of cognitive abilities may interfere with academic achievement. This has prompted the multidimensional search for subtypes of cognitive deficits within groups of children with academic deficits.

The most extensive search for subtypes of cognitive deficits has been conducted with reading disabled children. Various measures and methods have been used in this regard. For example, cognitive deficits have been measured directly

and quantitatively using such instruments as Wechsler Intelligence Scale for Children subtests (e.g., Smith, 1970; Fanatyne, 1974) and neuropsychological test batteries (e.g., Petrauskas and Rourke, 1979), or have been inferred from qualitative performance on actual reading tests (e.g., Border, 1973) though little work has been conducted integrating information obtained from both types of measures.

Both clinical and statistical techniques have been employed as the method of forming subtypes of cognitive deficits. Neither of these approaches is without limitations. Studies which rely solely on clinical interpretation of complex multidimensional data sets often proceed on the basis of a priori classifications and typically result in rigidly defined groups (Satz and Morris, 1980). The statistical techniques commonly employed, such as Q factor analysis and cluster analysis are controversial and may be performed in a variety of ways yielding highly disparate results. Questions of reliability and validity of the generated subtypes have been addressed only by some researchers.

Regardless of the method used to derive subtypes, it has been noted that some poor readers do not exhibit any clear pattern of specific cognitive deficit (Satz and Morris, 1981). Although this may in fact be a limitation of measures and methods currently employed in subtyping procedures

as suggested by Taylor, Fletcher and Satz (1982), it may also indicate that overlapping deficits are to be expected and that some children's reading problems may not be due to a cognitive deficit (e.g., may be due to lack of motivation, content specific anxiety, etc.).

However, given the limitations of the subtype literature, it does appear that a variety of patterns of cognitive deficits may emerge within a group of reading disabled children and there is notable similarity of results across investigations in spite of differences in measures and methods used.

With the identification of these different underlying cognitive deficits, work has begun on the development of remedial strategies to match underlying "types" of deficit (Rourke, 1978). This approach is certainly not new to individual educational assessment (Bateman, 1966) but has re-emphasized the heterogeneity of, and need for, individualized remedial programming for learning disabled children.

Cognitive Contributions to Arithmetic Achievement

Although much literature has been generated concerning cognitive functioning and learning disabilities, most studies have focussed either on general academic deficits or on reading and spelling deficits. Comparatively little information is available concerning cognitive correlates of mathematical performance. This stems from the conventional view that reading and spelling are of utmost importance for intellectual development and independent functioning. Hence, most educators emphasize the learning of reading and spelling. However, some researchers have recognized the importance of arithmetic performance to daily functioning (e.g., Halpern, 1981) and have studied its correlation with cognitive functioning.

A central issue to the study of mathematical performance, in relation to cognitive skills, is the diversity of subject matter. Mathematics has been defined as

the abstract science of space and number which deals with space and configuration and interrelations and abstractions of number. Arithmetic is a branch of mathematics that deals with real numbers and their computations (Chalfant and Scheffelin, 1969, p.119).

Children may show significant dissociation between performance in one area of mathematical performance (e.g., geometry) and another (e.g., calculations) (Weinstein, 1979) and it may be expected that different areas of mathematical performance may place different relative demands on cognitive skills.

The ability to perform basic arithmetic computations rests on the development of a number of prerequisite skills. Initially, the child recognizes objects in the environment and later experiences them as groups or classes. With the vehicle of language, a child learns to name numbers of things and later to relate numbers serially (counting). Correspondence between number morphemes and elements then develops (one to one correspondence). Once the child has acquired the correspondence between quantity and verbal labels (number names), he is then equipped to perform serial computations, initially utilizing counting and concrete objects (e.g., blocks, fingers) as aids and later perhaps carrying out counting operations on a mental level or developing methods of written symbolism (e.g., tallying) (Ginsberg, 1977).

In learning to read and write numbers, children must develop a correspondence between number sound, quantity and symbolic visual representations of numbers as well as learn

how to form the graphical representations of numbers. The child must also learn the rules of numeration, based on place value (Ginsberg, 1977). As the child becomes accustomed to perceiving numbers in terms of units of ten, single digits within multidigit numbers can be isolated meaningfully and numeration takes on meaning as a structured system consisting of a hierarchy of digits (Luria, 1969).

Calculation is made possible by the combination of number symbols according to different rules (Grewel, 1969, refers to these as syntactic rules) and procedures of regrouping (e.g., carrying and borrowing) which are spatial in nature. Memorization of particular facts (e.g., addition and multiplication tables) facilitates the smooth and rapid performance of calculations. Thus the mastery of number concepts and computations is complex in nature possibly demanding different relative cognitive skills at various levels of attainment.

Quantitative Analyses of Arithmetic Abilities. Many authors in the area of learning disabilities have speculated about cognitive contributions to arithmetic performance (e.g., Aiken, 1972; Bryan and Bryan, 1978; Cohn, 1968; Cohn, 1961; Farnham-Diggory, 1978; Guyer and Friedman, 1975; Homan, 1970; Johnson and Myklebust, 1967; Kaliski, 1967; Kosci, 1974; Moyer and Moyer, 1978; Rourke, 1978; Wallace and McLoughlin, 1979; Wheatley, Frankland, Mitchell and Kraft, 1978; Wood, 1980). Verbal, spatial and memory abilities, the three cognitive abilities most frequently noted, have also been investigated empirically.

Although a number of studies have investigated relationships between arithmetic performance and visuospatial ability in isolation (e.g., Krakow, 1978; Cohn-Jones and Seims, 1978; Edwards, Alley and Snider, 1971), two studies have examined both visuospatial and verbal abilities simultaneously. McLeod and Crump (1978), investigating the relative contribution of verbal and spatial abilities to arithmetic performance in learning disabled children (grades 1-5), found that verbal ability was more closely related to mathematical achievement than visuospatial ability, though a relationship between visuospatial ability and mathematical achievement was also evident.

Whyte (1977) investigated the relationship of cognitive and spatial development to arithmetic achievement at three achievement levels (achievers, underachievers and nonachievers) in 7, 9 and 11 year old children. To clarify the nature of the spatial-motor ability often associated with arithmetic disability, she employed separate measures of perceptual space and cognitive space. The construct of perceptual space was operationally defined by performance on the Frostig Developmental Test of Visual Perception, which includes eye-motor coordination, figure-ground discrimination, form constancy discrimination, position in space and spatial relations subtests. The construct of cognitive space was operationalized by the Performance subtests of the Wechsler Intelligence Scale for Children (WISC) and five Piagetian tests of representational space including stereognostic recognition of shapes, construction of a projective straight line, localization of topographical positions and coordination of perspectives. She found that no measures of cognitive space were related to arithmetic achievement except at age eleven where the understanding of the concepts of opposition of left and right was related. Perception of form and discrimination of figure-ground, both measures of perceptual space, did appear related to arithmetic achievement at ages seven and nine. The author suggests that arithmetic achievement does involve a spatial component but it

is limited to specific aspects of perceptual space in younger children. In addition, Verbal IQ was related to arithmetic achievement and was found to distinguish achievers from the underachievers and the nonachievers. The author suggests that Verbal intelligence is essential to the acquisition of arithmetic understanding across the age range from seven to eleven years.

Two studies have investigated the relationship between memory functions and arithmetic achievement. Morcz (1978) investigated the relationship of memory capacity and organization, in terms of sequential recall, to arithmetic performance in learning disabled children. She concluded that both memory capacity and organization, whether in the visual or auditory modality, are related to arithmetic performance.

Similarly, Webster (1979) found that students proficient in mathematics performed significantly better than either a group of children mildly disabled in mathematics (1-1 1/2 years below grade level) or a group of children severely disabled in mathematics (>2 years below grade level) in ordered recall of items presented in either the auditory or visual modality.

Overall, the research suggests that verbal, spatial and memory abilities may all be related to arithmetic achieve-

ment. However, some additional factors which have been implicated as possibly influencing cognitive contributions to arithmetic performance need to be taken into consideration. These include age, sex and achievement level in other academic areas.

As indicated earlier, a particular cognitive ability may be more related to arithmetic performance at one age than another. This may be due to changes in arithmetic content or perhaps children shift from perceptual to conceptual problem-solving strategies as they grow older (Whyte, 1977).

The relationship of sex differences to mathematical performance is unclear. On one hand, factor analytic studies of mathematical abilities (e.g., Barakat, 1951; Blackwell, 1940) suggest that different factors may emerge for males and females. For example, a space factor has been found to emerge for boys but not for girls (Werdelin, 1961; Mellcne, 1944) and an additional verbal factor has been detected for females in one study (Blackwell, 1940). Nevertheless, Fairweather (1976) reviews a number of studies comparing quantitative ability in boys and girls which are inconsistent in their results.

Sex differences in the development of both verbal and spatial abilities may potentially contribute to any apparent sex differences emerging for mathematical abilities. Howev-

er, Maccoby and Jacklin (1974), in reviewing sex differences in cognitive abilities, suggest that although there are distinct phases in the development of verbal skills in the two sexes through the growth cycle,

for large unselected populations the situation seems to be one of very little sex difference in verbal skills from about 3 to 11, with a new phase of differentiation occurring at adolescence (p. 85).

Moreover, when taken on the whole, no sex differences show up consistently on spatial tasks until adolescence (Maccoby and Jacklin, 1974).

Most studies involving groups academically deficient in one area (e.g., reading or arithmetic) fail to report achievement level in other areas. On the basis of information derived from the examination of the relationship between pattern of academic achievement and cognitive functioning, Rourke (1978) has maintained that it is no longer acceptable within the field of learning disabilities to constitute groups solely on the basis of level of performance in one academic area. For example, two groups of 15 children equated for deficient arithmetic performance but differing with respect to achievement in reading and spelling exhibited vastly different performances on verbal and visuospatial

tasks (Rourke and Finlayson, 1978). Verbal deficits were evident for the group with reading and spelling more impaired than arithmetic whereas visuospatial deficits were evident for the group with normal reading and spelling but deficient arithmetic skills.

McAllister (1981) also subgrouped learning disabled children according to patterns of reading and arithmetic achievement and examined patterns of cognitive abilities within the academic subgroups. Of the 109 learning disabled children examined 94 showed reading deficits and 82 showed arithmetic deficits. Of these, 67 had severe deficits in both areas, 13 had isolated reading deficits and 6 exhibited isolated arithmetic deficits.¹ Comparing the cognitive abilities (as measured by the WISC) of the groups, the mean profile for the group with dual deficits indicated that spatial ability was superior to conceptual (or verbal) ability which, in turn, was superior to sequencing ability. However, inspection of the frequency of occurrence of this pattern within this group indicated that only 59 percent individual children exhibited this profile. Only 33 percent of the isolated reading deficit group exhibited this pattern. Although $4/5^2$ children with isolated arithmetic deficits

¹ The remaining children in each group exhibited mild reading or arithmetic deficits.

² WISC scores were not available for one of the six children

manifest a profile with conceptual ability greater than spatial ability which, in turn, was greater than sequencing ability, this pattern was also found for some subjects in each of the two groups with reading deficits. Although this suggests that neither pattern is unique to a particular pattern of academic deficit, some regularity in the data was noted lending support to the contention that pattern of academic deficit and pattern of cognitive deficit are related.

with specific arithmetic deficits.

Qualitative Analysis of Arithmetic Abilities.

Cognitive deficits may not only be manifest as quantitative deficits on cognitive measures in terms of age-grade norms but may be revealed through qualitative analysis of a child's performance on arithmetic tasks. Cognitive deficits may be inferred either from the type of errors made on calculation tasks or from the selective impairment of the ability to perform certain types of arithmetic tasks.

Many different types of errors may be made when performing basic written calculations (see Burrows, 1976 for review). Feldman (1977 as cited in de Quiros and Schragar, 1978) grouped errors in calculation into seven different types:

- 1) Lack of number concept - inability to perform mental calculations, difficulty manipulating ones, tens, hundreds, etc. and carrying, difficulty establishing the necessary operation for an arithmetic problem, difficulty understanding numerical relations such as more and less;

- 2) Spatial-temporal difficulties - reversal of written numerals, reversal of number order, failure to set numerals in their proper spatial relationship for calculation, performing calculations in reversed order;

3) Figure-ground difficulties - applying the wrong operation such as adding instead of subtracting, not having the concept of the operations or being unable to find the mistake on one's own;

4) Linguistic failure - difficulty understanding a written problem that is overcome when it is read to the child;

5) Bizarre or strange mistakes - mistakes resulting from lack of concrete cognition of the relationship involved in an arithmetic operation;

6) Overstimulation difficulty - mistakes due to the length of a problem; short operations are performed well;

7) Mnestic failure - difficulty remembering number facts such as addition and multiplication tables.

Rourke and Strang (1981) examined errors made by two groups of children impaired on the Arithmetic subtest of the Wide Range Achievement Test (WRAT A), a written calculation test. The groups differed in cognitive skills as measured quantitatively on a battery of neuropsychological tests. The first group exhibited impaired auditory-verbal skills. These children had a tendency to avoid unfamiliar arithmetic

operations. The errors they made ususally reflected some difficulty in remembering arithmetic tables or steps in the procedure for solving a problem. Verbal memory impairment was raised as a possible underlying cognitive correlate of their arithmetic weakness.

The second group exhibited defective visual perception, tactile perception and impaired psychomotor abilities. Qualitative analysis of their arithmetic errors revealed that they attempted calculations for which they had little understanding of the task requirements. Although impoverished understanding of mathematical concepts appeared to be the most pervasive of their limitations, there was also a tendency for these children to misread mathematical signs. Disorganized work and faulty alignment of rows and columns were also evident and entire steps in a calculation process were occasionally omitted. The authors suggest that early impairment of sensory-motor experience may lead to limited development of abstract conceptualization affecting the basic understanding of mathematical operations.

Kosc (1974) suggests it is necessary to differentiate between several relatively isolated abilities or functions which develop unevenly even in normal children. Further, he suggests that not all functions are equally affected in children with arithmetic disorders. He has delineated six

symptoms which may occur in isolation or combinations.

These are:

- 1) verbal dyscalculia - disturbed ability to designate verbally mathematical terms and relations;
- 2) practognostic dyscalculia - disturbance of mathematical manipulations with real or pictured objects;
- 3) lexical dyscalculia - disability in reading mathematical symbols;
- 4) graphical dyscalculia - disturbance of the manipulation of mathematical symbols in writing;
- 5) ideognostical dyscalculia - disability primarily in understanding mathematical ideas and relations and in doing mental calculations;
- 6) operational dyscalculia - inability to carry out mathematical operations.

Kosc suggests that these symptoms usually occur in combinations and are typically found with other symptoms of impaired symbolic functions (i.e., reading and writing disorders).

Both of these approaches to classification of error types (i.e., grouping of error types and selective impairment of

specific arithmetic tasks) imply that particular types of arithmetic deficit may be reflective of specific areas of cognitive weakness. Moreover, Kosc's method of classification implies that some forms of arithmetic disorders may be task dependent. That is, some arithmetic deficits may be manifest only under particular conditions (e.g., mode of presentation or response). Thus, a dissociation between the ability to perform calculation problems presented in different formats (e.g., written computation problems versus computation problems presented orally) may be indicative of particular types of cognitive deficits.

Many tests of mathematical achievement include computations presented in the form of story problems. The ability to solve such problems includes not only computational skills per se but the ability to comprehend and transform the problem from the semantic network of natural language to a more formal network in mathematical language (Radatz, 1979). Casey (1978), Newman (1977) and Clements (1980) have investigated errors made by normal children in computations presented in story form. Their findings suggest that many children cannot select and order the skills they need to solve simple mathematical problems. That is, they have difficulty translating from natural language to mathematical language. However, verbal arithmetic problems were often

easier for children than arithmetic problems involving the direct application of relevant process skills despite the fact that the verbal problems involved more steps and skills for completion (Clements, 1980). Clements (1980) has suggested that in some cases imagery invoked by the verbal problems aids in solving the problems.

A dissociation between performance on orally presented story problems and written calculations has been noted in a learning disabled population by Ackerman, Dykman and Peters (1976). They report a discordance between achievement on the WISC arithmetic problems (WISC A), presented orally, and the WRAT A in a group of learning disabled boys. Although they did not pursue this line of investigation, they did note that children scoring low on the WISC A appeared to have trouble encoding and rearranging the information presented to them. McAllister (1981), studying a learning disabled sample, noted that few children impaired on WISC A performed adequately on the WRAT A although a substantial number of children (50 percent) exhibited a dissociation in the opposite direction.

Although these dissociations may be related to the level of difficulty of the problems involved in the two measures, representing a severity of deficit dimension, it is not inconsistent that different processes involved may be differ-

entially impaired. Differential oral-written (WAIS-WFAT) arithmetic deficits have been noted clinically in adult brain-damaged populations to occur in conjunction with differential cognitive impairment. Lezak (1976) notes that difficulty with immediate memory, concentration, conceptual manipulation and tracking or verbal functions "can prevent even very mathematically skilled patients from doing well on the orally administered test" (p 205) whereas the use of this type of test may not detect profound effects of the spatial type of arithmetic deficit that becomes apparent when the patient must organize arithmetic concepts on paper. Although processes underlying arithmetic discrepancies in adults who have lost specific abilities subsequent to development of adequate skills may differ from those occurring in children who have not yet developed the skills, the fact that dissociations of this nature have been noted in children suggests this issue warrants further investigation.

The research to be reported investigated the oral (as measured by the WISC) and written (as measured by the WFAT) arithmetic performance of clinic referred children. Phase I of this research was exploratory in nature and was directed at characterizing the relationship between the Arithmetic subtests of the WISC and WRAT and Verbal, Spatial and Memory abilities. In Phase II, the robustness of the findings in

Phase I was assessed by determining if the characterization obtained for the first sample also applied to a second sample of clinic referred children. Phase III involved detailed clinical assessments of individual children with arithmetic deficits to further amplify their deficits.

PHASE I

Verbal, Spatial and Memory abilities, as measured by specific subtests of the WISC, were studied in relation to two separate measures of arithmetic performance, one involving orally presented story problems (WISC A) and one involving written calculations (WRAT A).

Specific Questions Investigated

Question 1: What are the relative contributions of verbal, spatial and memory abilities to written and oral arithmetic performance?

In previous research, both Verbal and Memory abilities have consistently been found to be related to arithmetic performance. The relationship of Spatial ability to arithmetic performance has not been found consistently and when found has not been as closely related as Verbal ability. Since the measures of arithmetic functioning employed in these studies have varied, no systematic comparison of rela-

tive contributions to oral and written measures has been possible. However, evidence from the clinical evaluation of brain damaged adults and that of studies cited earlier by Rourke and his associates suggest that spatial ability may play a particularly important role in written arithmetic performance.

Question 2: Do the relative contributions of verbal, spatial and memory abilities to arithmetic performance change as a function of age or sex?

Both age and sex have been implicated as possibly influencing cognitive contributions to arithmetic performance. However, research findings have been equivocal. The instruments employed in this study were well standardized, hence are age-adjusted and no sex effects were found for the standardization samples. However, the population under investigation may differ significantly from the standardization population.

Question 3: What is the relative frequency of the occurrence of different patterns of oral and/or written arithmetic performance? More specifically, do some children, like brain damaged adults, exhibit discrepancies between oral and written arithmetic performance?

In the studies of both Ackerman, Dykman and Peters (1976) and McAllister (1981) discordance between achievement on the WISC A and the WRAT A was noted favoring the WISC A performance in groups of learning disabled children. The observation that few children impaired on the WISC A performed adequately on the WRAT written calculations (McAllister, 1981) and the observation that the level of difficulty varies between the two measures (Ackerman, Dykman and Peters, 1976) suggests that pattern of deficit on the two measures may reflect a severity of deficit dimension.

Question 4: Can children with different patterns of arithmetic performance be distinguished on the basis of their cognitive abilities?

As noted earlier, evidence from clinical evaluation of brain damaged adult patients suggests differential oral-written deficits may occur in conjunction with differential cognitive impairments. Although this issue has not been investigated in children, Ackerman, Dykman and Peters (1976) have noted that children impaired on both the WISC A and the WRAT A appeared to have trouble encoding and rearranging information presented to them.

Question 5: What is the coincidence of particular patterns of cognitive abilities occurring in conjunction with arithmetic (oral and/or written) deficits?

This question may be viewed as a corollary to the previous question. Whereas the previous question was concerned with overall differences, this question was directed toward identifying the frequency of specific patterns of cognitive abilities manifest by individuals with oral and/or written arithmetic deficits. This additional information might aid in disclosing any subtle effects or relations which would otherwise be obscured. For example, a minority of subjects may exhibit discrete spatial disorders which affect arithmetic performance. However, when pooled together with subjects who manifest other cognitive deficits for overall comparisons, this relationship may be masked.

Question 6: What is the coincidence of particular patterns of cognitive abilities occurring without arithmetic deficits?

This information taken in conjunction with the information from question 5 can provide some evidence for the reliability of patterns of cognitive deficit associated with arithmetic deficits.

Question 7: Do children with oral and/or written arithmetic deficits also exhibit other academic deficits?

Based on previous research, it is expected that most children with arithmetic deficits also exhibit deficits in reading and/or spelling. Ackerman, Dykman and Peters (1976), studying patterns of cognitive abilities (as measured by the WISC) to areas of learning deficit in 14 year old boys, noted that children with general learning deficits (as measured by the WRAT) exhibited a somewhat lower mean score on the WISC A than children with specific deficits (e.g., spelling or arithmetic or dual deficits).

Method

Subjects:

Subjects were selected from the files of the Neuropsychology Clinic at the University of Victoria. Most children referred to this clinic have learning problems which have proven to be severe, chronic and resistant to remediation. Often the presence of brain damage is either known or suspected. However, since the relationships between neurological status, area of academic deficit and pattern of cognitive abilities as measured by the WISC has been dealt with elsewhere

(McAllister, 1981), they were not addressed in this study.

Criteria for inclusion were:

- 1) age between 8 and 14 years at the time of assessment
- 2) no history of psychiatric disturbance
- 3) scores available for the WRAT and the WISC

One hundred and thirty-five files met these criteria. Of these, scores on the WRAT A were available for 101 males and 29 females and scores on the WISC A were available for 103 males and 31 females.

Tests:

Scores on two measures commonly employed for clinical and research assessment of children with learning problems were used.

Scores from the WRAT were employed as measures of academic achievement in the areas of Reading (WRAT R), Spelling (WRAT S) and written Arithmetic. Although a fairly narrow sampling of a broad range of tasks within each of these areas are surveyed, good reliability and validity has been reported for this instrument (Jastak and Jastak, 1946, 1965, 1976, 1978).

Scores on seven subtests of the WISC were used. The WISC A was employed as a measure of oral arithmetic performance. The Similarities and Vocabulary subtests were used in combination to operationalize the concept of Verbal ability (or concept attainment expressed verbally). Block Design and Object Assembly were used in combination to define Spatial ability and Digit Span and Coding were used in combination to operationalize the concept of short-term Memory. The approach taken here was to combine subtests that are related statistically as well as conceptually. Factor analytic studies of the WISC support the use of these combinations of subtests (e.g., Cohen, 1959).

Results and Conclusions

The results and general conclusions for each question investigated will be presented. The Statistical Package for the Social Sciences (SPSS) (Hull and Nie, 1981; Nie, Hull, Jenkins, Steinbrenner and Bent, 1975) was used for all analyses. The raw data for all of the subjects in this study are presented in Appendix A.

Question 1 and 2:

What are the relative contributions of verbal, spatial and memory abilities to written and oral arithmetic performance?
Do the relative contributions of verbal, spatial and memory abilities change as a function of age or sex?

To investigate these issues, multiple regression analyses were performed using the WISC A and WRAT A as separate criterion variables. Analyses were performed for the entire sample, for males and females separately and for three age ranges of males: 8 and 9 year olds, 10 and 11 year olds, and 12, 13 and 14 year olds. The summed scaled scores of the two components of each cognitive dimension were entered as predictor variables. Since the purpose of this procedure was to determine the respective contribution of each cognitive dimension, a forward or step-up procedure was used. This procedure entered the predictor variable that accounted for the greatest amount of variance in the criterion variable (arithmetic measure) first; the variable that explained the greatest amount of variance unaccounted for by the preceding variable was entered next and so on. The variance in the criterion variable accounted for by each predictor variable reflected the total influence of that variable. That is, the variance shared with the criterion variable attributed to the first predictor variable included not only the variance unique to that variable but also that portion of the variance which was shared by all of the predictor variables. Similarly, the variance shared with the criterion variable attributed to the second variable included variance unique to that variable and that portion of the variance which was shared by the remaining predictor variables.

Two statistical criteria were used to define which variables were to be included in the regression equation. An F value of .01 defined the minimum F ratio necessary for inclusion. A tolerance of .001 was the second criterion for inclusion. The tolerance of a variable being considered for inclusion is the proportion of the unique variance which the variable may contribute to the regression equation. A tolerance of .001 implies that a variable may be entered only if it contributes at least .1 percent to the variance already accounted for by the other variables. The results of these analyses (see Appendix B) are summarized in Table 1 and Table 2

Entire Sample: The findings, summarized in Table 1, suggest that only the Verbal and Memory cognitive dimensions contributed to the variance accounted for in the arithmetic measures. The Spatial cognitive dimension did not contribute to the variance accounted for in either the oral or written arithmetic measures. These findings support previous research in which both Verbal and Memory abilities have consistently been found to be related to arithmetic performance. However, the finding that only approximately 35 percent of the variance was accounted for by the three cognitive dimensions indicates that these variables, in themselves, are only of modest importance as predictors of arithmetic performance.

TABLE 1

Summary of Regression Analyses for Entire Sample and by Sex

Criterion Variable						
WRAT A				WISC A		
Sample	N	Variables Entered Into Equation	Percent Variance Accounted For	N	Variables Entered Into Equation	Percent Variance Accounted For
Whole Sample	130	Memory	27.28	134	Verbal	26.64
		Verbal	9.33		Memory	9.39

			36.62			

Males Only	101	Verbal	24.68	103	Memory	22.27
		Memcry	7.34		Verbal	8.12

			32.02			

Females Only	29	Memory	59.16	31	Verbal	38.36
					Memory	8.84

			59.16			

TABLE 2

Summary of Regression Analyses for Males by Age

Criterion Variable						
		WRAT A			WISC A	
Sample	N	Variables Entered Into Equation	Percent Variance Accounted For	N	Variables Entered Into Equation	Percent Variance Accounted For
Males Aged 8 and 9 yrs.	28	Verbal	47.15	28	Memory	45.89
			-----			-----
			47.15			45.89
Males Aged 10 and 11 yrs.	43	Verbal	18.36	45	Memory Verbal	16.80 7.50
			-----			-----
			18.36			24.30
Males Aged 12, 13 and 14 yrs.	30	Memory Verbal	19.97 12.33	30	Memory	21.23
			-----			-----
			32.30			21.23

Sex. The findings, summarized in Table 1, suggest that the Verbal cognitive dimension and the cognitive dimension of Memory contribute to arithmetic performance for both males and females though the relative contribution of each varied. The Spatial dimension did not contribute to the variance accounted for in either arithmetic measure for either sex. It appeared that the cognitive dimensions accounted for more of the variance in the arithmetic measures for females than males. However, given the small number of females in this sample (N=29), this result must be viewed with caution.

Age. The findings, summarized in Table 2, suggest that only the Verbal cognitive dimension and/or the cognitive dimension of Memory contribute to arithmetic performance at each age level. The cognitive dimension of memory accounted for the majority of the variance in the oral arithmetic measure at each age level and the Verbal cognitive dimension accounted for the majority of the variance in the written arithmetic measure for two of the age levels. Not surprisingly, these findings are consistent with the overall findings for males. It appeared that the cognitive dimensions accounted for more of the variance in the arithmetic measures for younger subjects (age 8 and 9) than for older subjects. However, given the small number of subjects at each

age level (age 8 and 9, N=28; age 10 and 11, N=43; and 12, 13, 14, N=30), these results must be viewed with caution.

Question 3:

What is the relative frequency of occurrence of different patterns of oral and/or written arithmetic performance? More specifically, do some children, like brain-damaged adults, exhibit discrepancies between oral and written arithmetic performance?

To determine the relative frequency of occurrence of patterns of oral and/or written arithmetic performance, cut-off scores were used to define group inclusion. Children who score greater than one standard deviation below the mean of a local normative sample on the WRAT A (McAllister, 1981) were defined as exhibiting deficient written arithmetic skills (WRAT A-). The cut-off scores for reading, spelling and arithmetic subtests of the WRAT are presented in Table 3 in terms of standard scores derived from the WRAT manual. Children who scored greater than one standard deviation below the normative mean on the WISC A were defined as exhibiting deficient oral arithmetic skills (WISC A-). This procedure resulted in the formation of four groups (see Table 4).

TABLE 3

Cut-off scores for the Wide Range Achievement Test

Achievement Level	Victoria Equivalent	Reading	Spelling	Arithmetic
Impaired	< 1 Standard Deviation Below Mean	0-108	0-103	0-95
Adequate	>1 Standard Deviation Below Mean	109 or greater	104 or greater	96 or greater

TABLE 4

Crosstabulation: Performance on the WISC A and WRAT A

		Entire Sample			
		WISC A-	WISC A+		
WRAT A-	38		71		
WRAT A+	0		21		

		Males Only		Females Only	
		WISC A-	WISC A+	WISC A-	WISC A+
WRAT A-	29		59	9	12
WRAT A+	0		13	0	8

No children with deficits on WISC A performed adequately on the WRAT A. Thirty-eight children (29.2 percent) were impaired on both the written and oral arithmetic measures. Twenty-nine of the males (29 percent) and nine of the females (23 percent) exhibited this pattern of performance. Seventy-one children (54.6 percent) were impaired only on the written arithmetic measure. Fifty-nine of the males (58.4 percent) and 12 of the females (30.1 percent) exhibited this pattern of performance. Twenty-one children (16.2 percent) were not impaired on either the written or oral arithmetic measures. Thirteen of the males (12.9 percent) and 8 of the females (20.5 percent) exhibited this pattern of performance.

These findings are consistent with the observation that few WISC A- children performed adequately on the WRAT A (McAllister, 1981). The majority of the children (54.6 percent) exhibited a discrepancy between oral and written arithmetic performance favouring oral performance.

Question 4:

Can children with different patterns of arithmetic performance be distinguished on the basis of their cognitive abilities?

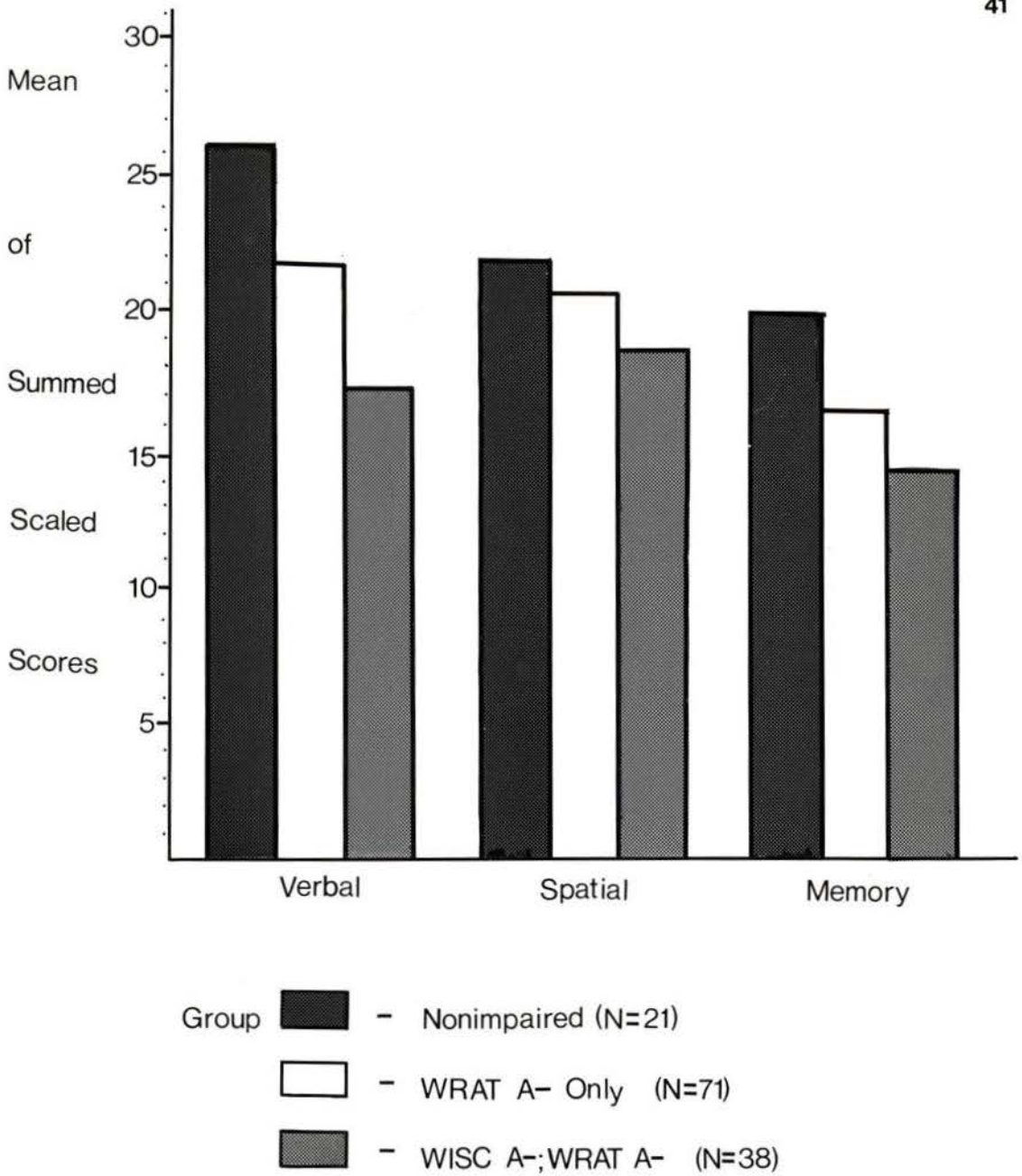
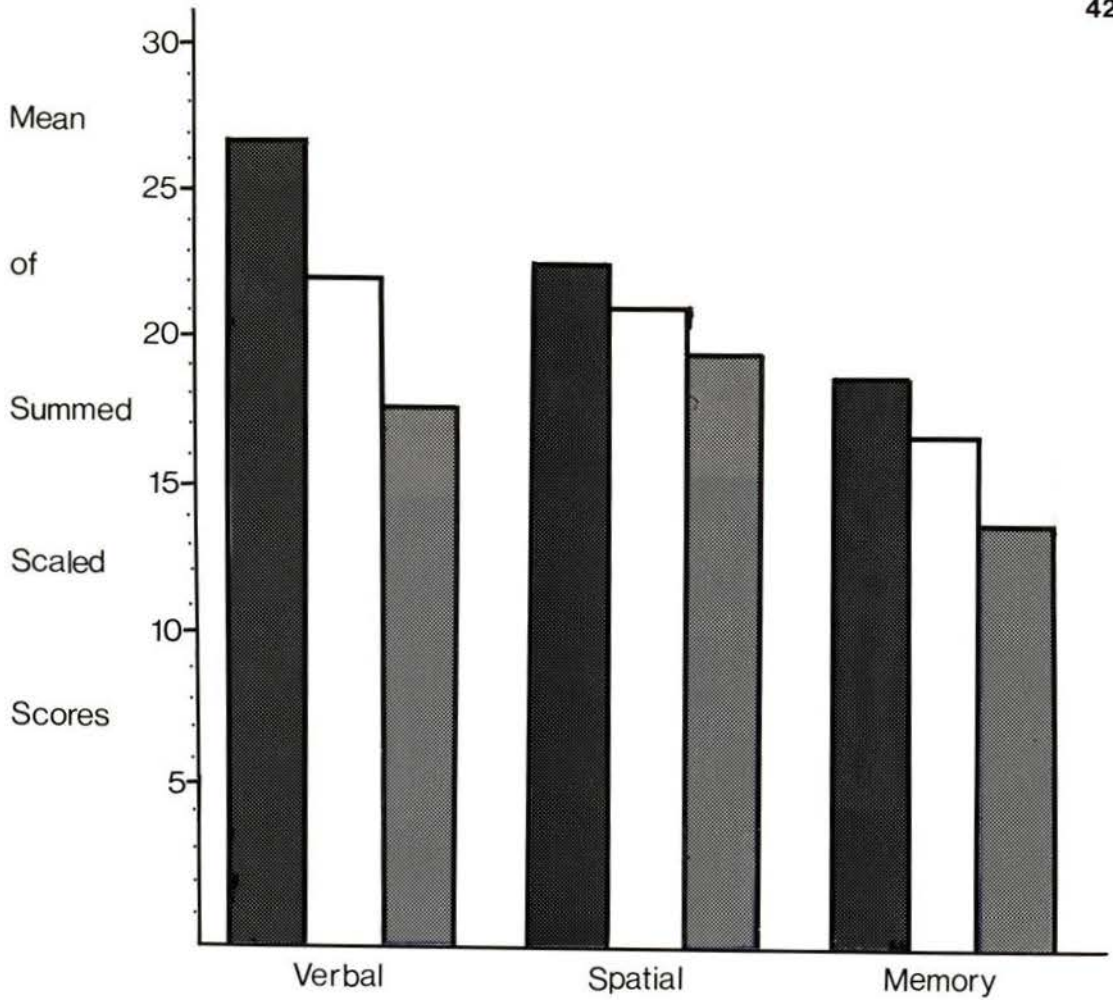
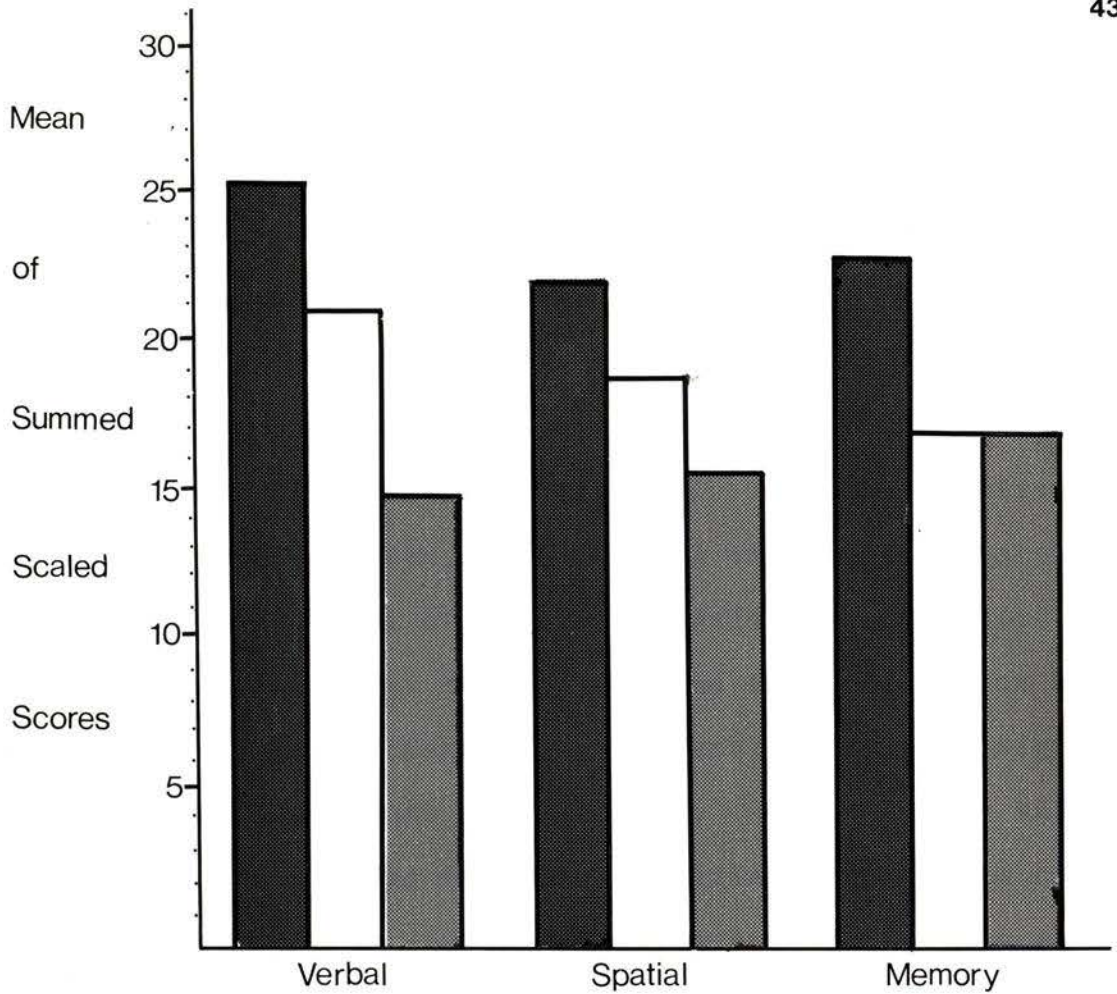


Figure 1: Plot of the Means of the Cognitive Dimensions by Group



- Group  - Nonimpaired (N=13)
-  - WRAT A- Only (N= 59)
-  - WISC A-; WRAT A- (N=29)

Figure 2: Plot of the Means of the Cognitive Dimensions by Group for Males






Group  - Nonimpaired (N=8)
 - WRAT A- Only (N=12)
 - WISC A-;WRAT A- (N=9)

Figure 3: Plot of the Means of the Cognitive Dimensions by Group for Females

Profiles of the means of the three cognitive dimensions for each arithmetic group were plotted for the entire sample (see Figure 1) and for males (see Figure 2) and females (see Figure 3). To determine if the arithmetic groups differed on the cognitive dimensions, multivariate analyses of variance (MANOVAs) were performed. Wilks Lambda, or the averaged F, was the test statistic employed. If the multivariate test was significant, individual univariate analyses were performed for each cognitive dimension. This procedure was adopted in an effort to protect the error rate from being inflated by the performance of several individual significance tests (Hummel and Sligo, 1971). To determine which groups were contributing to overall differences on the cognitive dimensions, a series of multivariate t-tests were performed. A significance level of .01 was adopted for the t-tests in an effort to minimize the probability of making a Type I error over multiple comparisons.

These analyses were performed for the entire sample and for each sex separately. The results of these analyses (see Appendix C) are summarized in Table 5, Table 6 and Table 7. On inspection of Table 5, it appeared that, overall, each group differed significantly from each other group on the Verbal and Memory dimensions. Although the groups differed on the Spatial dimension overall, no two groups differed

TABLE 5

Summary of MANCVAs: Groups by Cognitive Dimensions

Group Comparisons	N	MANOVA level of significance	Univariate ANOVAs level of significance		
			Verbal	Spatial	Memory
WISC A-;WRAT A-	38	+++	+++	+	+++
WISC A+;WRAT A-	71				
WISC A+;WRAT A+	21				
WISC A-;WRAT A-	38	+++	+++		+++
WISC A+;WRAT A+	21				
WISC A-;WRAT A-	38	+++	+++		++
WISC A+;WRAT A-	71				
WISC A+;WRAT A-	71	+++	+++		+++
WISC A+;WRAT A+	21				

+++ - $p < .001$
 ++ - $p < .01$
 + - $p < .05$

TABLE 6

Summary of MANOVAs for Males: Groups by Cognitive Dimensions

Group Comparison	N	MANOVA level of significance	Univariate ANOVAs level of significance		
			Verbal	Spatial	Memory
WISC A-; WRAT A-	29	+++	+++		+++
WISC A+; WRAT A-	59				
WISC A+; WRAT A+	13				
WISC A-; WRAT A-	29	+++	+++		+++
WISC A+; WRAT A+	13				
WISC A-; WRAT A-	29	+++	+++		+++
WISC A+; WRAT A-	59				
WISC A+; WRAT A-	59	++	++		
WISC A+; WRAT A+	13				

+++ - $p < .001$
 ++ - $p < .01$
 + - $p < .05$

TABLE 7

Summary of MANOVAs for Females: Groups by Cognitive Dimensions

Group Comparison	N	MANOVA level of significance	Univariate ANOVAs level of significance		
			Verbal	Spatial	Memory
WISC A-; WRAT A-	9	++	+++		
WISC A+; WRAT A-	12				
WISC A+; WRAT A+	8				
WISC A-; WRAT A-	9	+++	+++		(+++)
WISC A+; WRAT A+	8				
WISC A-; WRAT A-	9				
WISC A+; WRAT A-	12				
WISC A+; WRAT A-	12				
WISC A+; WRAT A+	8				

+++ - $p < .001$
 ++ - $p < .01$
 + - $p < .05$

significantly on this dimension. On inspection of Figure 1 it is apparent that the group impaired on both arithmetic measures exhibited the poorest performance on the cognitive dimensions and the group not impaired on either arithmetic measure exhibited the best performance on the cognitive dimensions with the performance of the group impaired only on the Arithmetic subtest of the WRAT falling in between. Severity of cognitive deficit on Verbal and Memory dimensions appears to correspond to the pattern of arithmetic deficit.

When only males were examined (see Table 6), the results were similar to those of the entire sample. When females were examined (see Table 7), only the nonimpaired group differed significantly from the group impaired on both arithmetic measures on the Verbal dimension. However, on inspection of Figure 3, it is apparent that the level of performance of the groups is similar to that of the overall sample. The pattern of performance of the groups on the cognitive dimensions is also similar to that of the entire sample and of the males but the females in the group impaired on both arithmetic measures appear more impaired on the Spatial dimension than the males in this group.

Questions 5 and 6:

What is the coincidence of particular patterns of cognitive abilities occurring with or without arithmetic (oral and/or written) deficits?

To examine the coincidence of particular patterns of cognitive abilities occurring either in conjunction with or without arithmetic (oral and/or written) deficits, the summed scaled scores for each cognitive dimension were hierarchically organized in terms of relative magnitude for each child within each arithmetic group. The frequency of occurrence of each pattern was then tabulated (see Table 8).

It was possible for twelve different patterns of cognitive abilities to occur with six of the patterns containing two scores of equal magnitude. As would be expected, these six patterns occurred far less frequently (16.1 percent of the sample) than the six patterns with scores differing in magnitude (83.9 percent of the sample). Two hierarchical patterns of cognitive abilities (Verbal>Spatial>Memory and Spatial>Verbal>Memory) occurred more frequently than any other pattern overall (30.8 and 29.2 percent of the sample, respectively) and within each arithmetic group. However, there was no significant relationship between the arithmetic group membership and the frequency of occurrence of the six hierarchical patterns of cognitive abilities (Chi Square=16.93, 10 df, $p<.07$).

TABLE 8

Crosstabulation: Patterns of Cognitive Ability by Group

Pattern of Performance on WISC A and WRAT A

Pattern of Cognitive Abilities	WISC A- WRAT A-	WISC A+ WRAT A-	WISC A+ WRAT A+	Total	Percent of Sample
V>S>M	9	25	6	40	30.8
S>V>M	14	18	6	38	29.2
M>S>V	5	0	0	5	3.8
S>M>V	2	3	1	6	4.6
V>M>S	2	7	5	14	10.8
M>V>S	3	3	0	6	4.6
S=M>V	0	0	0	0	0.0
V=S>M	0	3	0	3	2.3
V=M>S	1	0	1	2	1.5
S>M=V	1	5	0	6	4.6
V>S=M	0	5	2	7	5.4
M>V=S	1	2	0	3	2.3
Total	38	71	21	130	

V=Verbal
S=Spatial
M=Memory

When only males were examined, the distribution of patterns remained the same (see Table 9) and there was no significant relationship between arithmetic group membership and the frequency of occurrence of the six hierarchical patterns of cognitive abilities (Chi Square=11.67, 10 df, $p<.30$). When only females were examined, the Verbal>Spatial>Memory and Verbal>Memory>Spatial patterns were the most frequently observed (see Table 10) but there was no significant relationship between arithmetic group membership and the frequency of occurrence of the six hierarchical patterns of cognitive abilities (Chi Square=14.83, 10 df, $p<.13$).

These results, taken in conjunction with the findings from the previous question suggests that the pattern of cognitive abilities is not as strongly related to the pattern of arithmetic deficit as the level of cognitive ability is. The finding that the Spatial>Verbal>Memory pattern of cognitive abilities accounted for a large proportion of the sample overall is consistent with findings reported in the literature for a number of populations including school-verified disabled learners (Smith, Coleman, Dckecki and Davis, 1977; Vance and Singer, 1979), emotionally disturbed children and nonimpaired children (Clarizio and Ferdinand, 1981). The relative frequency of occurrence of other

TABLE 9

Crosstabulation: Patterns of Cognitive Ability by
Group-Males Only

Pattern of Performance on WISC A and WRAT A

Pattern of Cognitive Abilities	WISC A- WRAT A-	WISC A+ WRAT A-	WISC A+ WRAT A+	Total	Percent of Sample
V>S>M	8	22	5	35	34.7
S>V>M	13	17	4	34	33.7
M>S>V	2	0	0	2	2.0
S>M>V	2	1	0	3	3.0
V>M>S	2	4	3	9	8.9
M>V>S	2	3	0	5	5.0
S=M>V	0	0	0	0	0.0
V=S>M	0	3	0	3	3.0
V=M>S	0	0	0	0	0.0
S>M=V	0	3	0	3	3.0
V>S=M	0	4	1	5	5.0
M>V=S	0	2	0	2	2.0

V=Verbal
S=Spatial
M=Memory

TABLE 10

Crosstabulation: Patterns of Cognitive Ability by
Group-Females Only

Pattern of Performance on WISC A and WRAT A

Pattern of Cognitive Abilities	WISC A- WRAT A-	WISC A+ WRAT A-	WISC A+ WRAT A+	Total	Percent of Sample
V>S>M	1	3	1	5	17.2
S>V>M	1	1	2	4	13.8
M>S>V	3	0	0	3	10.3
S>M>V	0	2	1	3	10.3
V>M>S	0	3	2	5	17.2
M>V>S	1	0	0	1	3.4
S=M>V	0	0	0	0	0.0
V=S>M	0	0	0	0	0.0
V=M>S	1	0	1	2	6.9
S>M=V	1	2	0	3	10.3
V>S=M	0	1	1	2	6.9
M>V=S	1	0	0	1	3.4

V=Verbal
S=Spatial
M=Memory

patterns of cognitive abilities has typically gone unreported.

Question 7:

Do children with oral and/or written arithmetic deficits also exhibit other academic deficits?

To examine the coincidence of reading and spelling deficits occurring in conjunction with oral and/or written arithmetic deficits, cut-off scores (see Table 3) were used to define reading and spelling deficits. The frequency of occurrence of reading and/or spelling deficits was then tabulated for each pattern of arithmetic performance. A series of z tests for the difference between two proportions (Perles and Sullivan, 1969) were used to compare the three groups on the occurrence of reading and spelling deficits (see Table 11 and Table 12). In an effort to protect the error rate from being inflated, a significance level of .01 was adopted for these comparisons.

All of the children who were impaired on both arithmetic measures also exhibited reading and spelling deficits. Twenty-nine of these children were male and 9 were female. Of the 71 children who were impaired only on the WFAT A, 90 percent (53 males and 11 females) exhibited reading deficits and 88.7 percent (54 males and 9 females) exhibited spelling

TABLE 11

Summary of Z-tests: Group by Reading Deficit

Sample	Group Comparison	Reading	Total	Z	p	
		Deficit	Group			
		N	N			
Entire Sample	WISC A-; WRAT A-	38	38	4.09	S	
	WISC A+; WRAT A+	13	21			
	WISC A-; WRAT A-	38	38	2.00	NS	
	WISC A+; WRAT A-	64	71			
	WISC A+; WRAT A-	64	71	3.08	S	
	WISC A+; WRAT A+	13	21			
	Males	WISC A-; WRAT A-	29	29	3.56	S
		WISC A+; WRAT A+	8	13		
WISC A-; WRAT A-		29	29	1.78	NS	
WISC A+; WRAT A-		53	59			
WISC A+; WRAT A-		53	59	2.57	NS	
WISC A+; WRAT A+		8	13			
Females		WISC A-; WRAT A-	9	9	2.02	NS
		WISC A+; WRAT A+	5	8		
	WISC A-; WRAT A-	9	9	.89	NS	
	WISC A+; WRAT A-	11	12			
	WISC A+; WRAT A-	11	12	1.60	NS	
	WISC A+; WRAT A+	5	8			

TABLE 12

Summary of Z-tests: Group by Spelling Deficit

Sample	Group Comparison	Spelling	Total	Z	F
		Deficit	Group		
		N	N		
	WISC A-; WRAT A-	38	38	4.09	S
	WISC A+; WRAT A+	13	21		
Entire Sample	WISC A-; WRAT A-	38	38	2.15	NS
	WISC A+; WRAT A-	63	71		
	WISC A+; WRAT A-	63	71	2.85	S
	WISC A+; WRAT A+	13	21		
Males	WISC A-; WRAT A-	29	29	3.14	S
	WISC A+; WRAT A+	9	13		
	WISC A-; WRAT A-	29	29	1.61	NS
	WISC A+; WRAT A-	54	59		
	WISC A+; WRAT A-	54	59	2.20	NS
	WISC A+; WRAT A+	9	13		
Females	WISC A-; WRAT A-	9	9	2.43	NS
	WISC A+; WRAT A+	4	8		
	WISC A-; WRAT A-	9	9	1.62	NS
	WISC A+; WRAT A-	9	12		
	WISC A+; WRAT A-	9	12	1.15	NS
	WISC A+; WRAT A+	4	8		

deficits. Of the 21 children who were not impaired on either measure of arithmetic performance, 61.9 percent (8 males and 5 females) exhibited reading deficits and 61.9 percent (9 males and 4 females) exhibited spelling deficits.

Overall, the two groups impaired on the WRAT A differed in terms of the frequency of occurrence of reading and spelling deficits from the group of children not impaired on the WRAT A. However, there was no difference in the frequency of occurrence of reading and spelling deficits exhibited between the two WRAT A- groups. Generally, the same pattern of results held when males and females were examined separately but the groups differences were not always of sufficient magnitude to reach significance.

These findings support previous research which suggests that most children with arithmetic deficits also exhibit deficits in reading and spelling. The finding that 100 percent of the children who exhibited deficits on both arithmetic measures also exhibited reading and spelling deficits is consonant with the observation of Ackerman, Dykman and Peters (1976) that children with general learning deficits (as measured by the WRAT) exhibit a lower mean score on the WISC A than children with specific deficits. The findings that only 7 of the WRAT A- children (5.38 percent) (6 males and 1 female) performed adequately on the WRAT B and only 8

of the WRAT A- children (6.15 percent) (5 males and 3 females) performed adequately on the WRAT S suggest that the frequency of occurrence of specific arithmetic deficits is quite rare (approx. 6 percent). Learning disabilities affecting only reading and/or spelling appear to occur slightly more frequently (10 percent).

PHASE II

Phase II involved a replication of Phase I on a separate group of clinic-referred children. A replication of Phase I appeared warranted for two reasons:

1) the sample employed in Phase I was a select sample of clinic-referred children. Brain damage was either known or suspected in many cases. Moreover, the learning problems of these children typically have proven to be severe, chronic and resistant to remediation. Any findings derived from Phase I may potentially reflect relationships only representative of this select sample.

2) division of subjects in Phase I into groups with different patterns of arithmetic deficit resulted in small sample sizes necessitating the use of visual inspection and relatively weak statistical procedures for identifying group differences.

In this replication, two questions were addressed:

A) Are the two samples from the same population?

B) Do the same relationships found in Phase I occur for a sample of children referred to an educational clinic?

Method

Subjects:

Files were selected from the Assessment Centre of the Greater Victoria School Board. Criteria for inclusion were

- 1) age between 8 and 14 years at the time of assessment
- 2) no history of psychiatric disturbance
- 3) scores available for the WRAT and the WISC-R³.

Three hundred and fifteen files met these criteria. Scores on the WRAT A were available for 211 males and 98 females and scores on the WISC-R A were available for 215 males and 100 females.

³ The Revised edition of the WISC (WISC-R) rather than the WISC was routinely employed in this setting. The implications of the differences between the WISC and WISC-R will be raised in the discussion section to follow.

Results

The results for each question investigated will be presented. General conclusions, drawn on the basis of the comparison of the two samples, will follow. The Statistical Package for the Social Sciences (SPSS) (Hull and Nie, 1981; Nie, Hull Steinbrenner and Bent, 1975) was used for all analyses. The raw data for all subjects in Sample 2 are presented in Appendix D.

Question A:

Are the two samples from the same population?

To determine if the overall distribution of scores for the two arithmetic measures and the three cognitive measures was the same for the two samples, a multivariate t-test (MANOVA) was performed. Wilks lambda, or the averaged F, was the test statistic employed. If the multivariate test was significant, individual univariate analyses were performed for each dependent variable. This procedure was adopted in an effort to protect the error rate from being inflated by the performance of several individual significance tests (Hummel and Sligo, 1971).

Descriptive statistics for the five variables are presented in Table 13. The MANOVA was significant (approx $F=12.10, 5, 433$ df, $p<.001$) (see Table 14). Inspection of

the univariate F-tests revealed that only two variables, the Verbal cognitive dimension ($F=27.01, 1, 437 \text{ df}, p<.001$) and the dimension of Memory ($F=7.88, 1, 437 \text{ df}, p<.005$), differed for the two samples. Inspection of the means of these variables for the two samples indicated that the performance of the second sample (school board) was inferior to the performance of the first sample (neuropsychology clinic) on both of these measures.

This suggests that the two samples are not from the same population. The significance of this finding will be raised in the discussion section to follow.

TABLE 13

Statistics Table: Means and Standard Deviations

Variable	Sample 1 (N=130)	Sample 2 (N=309)
WISC (R) A	8.16 (2.84)	8.26 (2.80)
WRAT A	83.71 (11.76)	84.35 (12.90)
Verbal	21.03 (5.80)	17.89 (5.76)
Spatial	20.11 (5.59)	19.77 (5.78)
Memory	16.40 (4.29)	15.08 (4.51)

TABLE 14

MANOVA Table: Samples by Cognitive and Arithmetic Variables

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Samples	Wilks	.87	12.10	5.00	433.00	<.001

Univariate F-tests (1,437 df)

Variable	Hypoth. SS	Error SS	Hypoth. MS	Error MS	F	p
WISC A	1.04	3476.31	1.04	7.95	.131	<.71
WRAT A	37.93	69781.59	37.93	159.68	.23	<.62
Verbal	901.48	14580.69	901.48	33.36	27.01	<.001
Spatial	10.49	14350.86	10.49	32.83	.31	<.57
Memory	158.43	8667.01	158.43	19.83	7.98	<.005

Question B:

Do the same relationships found in Phase I occur for a sample of children referred to an educational clinic?

The questions posed in Phase I were addressed for the school board sample. Identical procedures to those employed in Phase I were used to examine the data. The results of this investigation and a comparison of the results for the two samples are presented for each question.

Questions 1 and 2: What is the relative contribution of Verbal, Spatial and Memory abilities to written and oral arithmetic performance? Do the relative contributions of Verbal, Spatial and Memory abilities change as a function of age or sex?

The results of the analyses (see Appendix E) are summarized in Table 15 and Table 16.

The results of the multiple regression analyses for Sample 2 (see Table 15) were similar to those obtained in Phase I (see Table 1) in certain respects. When the WRAT A was used as the criterion variable, the order of entry of the variables differed between the samples (sample 1, Verbal+Memory; sample 2, Memory+Verbal), but the same two vari-

TABLE 15

Summary of Regression Analyses: Entire Sample and by Sex

		Criterion Variable				
		WRAT A		WISC-R A		
Sample	N	Variables Entered Into Equation	Percent Variance Accounted For	N	Variables Entered Into Equation	Percent Variance Accounted For
Entire Sample	309	Verbal	33.81	315	Verbal	37.74
		Memory	3.77		Memory	9.25
					Spatial	3.96
		Total	37.58		Total	50.96
Males	211	Verbal	31.42	215	Verbal	31.80
		Memory	4.20		Memory	10.37
					Spatial	2.49
		Total	35.62			44.66
Females	98	Verbal	38.39	100	Memory	48.40
		Spatial	3.08		Verbal	12.78
					Spatial	3.03
		Total	41.48		Total	65.21

TABLE 16

Summary of Regression Analyses: Males by Age

		Criterion Variables				
		WRAT A		WISC-R A		
Sample	N	Variables Entered Into Equation	Percent Variance Accounted For	N	Variables Entered Into Equation	Percent Variance Accounted For
Males Aged 8 and 9 yrs.	85	Verbal Memory	32.80 9.65	86	Verbal Memory	34.74 7.05
		Total	42.45		Total	41.79
Males Aged 10 and 11 yrs.	59	Verbal Spatial	23.29 6.19	59	Verbal Spatial Memory	33.21 7.53 6.33
			29.48			47.07
Males Aged 12, 13 and 14 yrs.	67	Verbal Memory	26.59 7.08	70	Memory Verbal	40.95 9.90
		Total	33.68		Total	50.85

ables were entered and similar proportions of the variance were accounted for (sample 1 - 36.6 percent; sample 2 - 38 percent).

When the WISC-R A was used as the criterion variable, the Verbal cognitive dimension and the cognitive dimension of Memory were entered into the equation in succession for both samples. However, the Spatial dimension also contributed to the equation for sample 2 and this combination of variables accounted for 16.9 percent more of the variance in the oral arithmetic measure than was explained in sample 1 (sample 1, 34.1 percent; sample 2, 51 percent).

Sex

Males

When only the performance of the males was examined, the results of the multiple regression analyses using the WRAT A as the criterion variable were similar for the two samples (see Table 1 and Table 15). In both samples, the Verbal cognitive dimensions accounted for the majority of the shared variance and the cognitive dimension of Memory added a small increment. Similar proportions of the variance were accounted for in each sample (sample 1, 32 percent; sample 2, 36 percent).

In Sample 1, when the WISC A was used as the criterion variable, the cognitive dimension of Memory accounted for the majority of the shared variance and the Verbal component added a small increment. In Sample 2, the reverse was true. Moreover, the Spatial dimension added a small increment in Sample 2. This combination of variables accounted for 45 percent of the variance, whereas only 30 percent of the variance was accounted for in Sample 1.

Females:

The results of the multiple regression analyses using the WRAT A as the criterion variable, were dissimilar for the two samples (see Table 1 and Table 15). In sample 1, the cognitive dimension of Memory accounted for all of the shared variance with the arithmetic measure (59.16 percent). In sample 2 the Verbal dimension accounted for the majority of the shared variance (38.39 percent) and the Spatial dimension added a small increment. A total of 41.48 percent of the variance was shared by the cognitive dimensions and the arithmetic measure.

When the WISC (R) A was used as the criterion variable, the results of the multiple regression analyses for the two samples were similar only in that the Verbal and Memory cognitive dimensions were entered into the regression equation in each sample (see Table 1 and Table 15). In sample 1, the

Verbal cognitive dimension accounted for the majority of the shared variance with the Memory component adding a small increment. Together they accounted for 47.20 percent of the variance in the oral arithmetic measure. In sample 2, the Memory component accounted for most of the shared variance with the Verbal and Spatial dimensions adding small increments. Together the three variables accounted for 65.21 percent of the variance shared with the oral arithmetic measure.

Age

Age 8 and 9:

When the WRAT A was used as the criterion variable, the results of the multiple regression analyses for the two samples were similar in that the Verbal cognitive dimension accounted for the majority of the shared variance in each sample (see Table 2 and Table 16). However, in sample 2, the cognitive dimension of Memory added a small increment. The amount of variance shared between the arithmetic measure and the cognitive dimensions was similar for the two samples (sample 1, 47 percent; sample 2, 42 percent).

When the WISC(R) A was used as the criterion variable, the results of the multiple regression analyses were similar for the two samples in that the cognitive dimension of Memory contributed to the shared variance in each sample (see

Table 2 and Table 16). However, the Verbal cognitive dimension accounted for more of the shared variance than the cognitive dimension of Memory in Sample 2. The amount of shared variance between the arithmetic measure and the cognitive dimensions was similar for the two samples (sample 1, 46 percent; sample 2, 42 percent).

Ages 10 and 11:

When the WRAT A was used as the criterion variable, the results of the multiple regression analyses were similar for the two samples in that the Verbal dimension accounted for the largest proportion of the shared variance (see Table 2 and Table 16). In sample 2, the Spatial dimension added a small increment. The amount of variance shared by the arithmetic measure and the cognitive dimensions was similar for the two samples (sample 1, 18 percent; sample 2, 29 percent).

When the WISC (R) A was used as the criterion variable, the results of the multiple regression analyses were dissimilar for the two samples (see Table 2 and Table 16). In sample 1, the cognitive dimension of Memory accounted for the largest proportion of the variance and the Verbal dimension added a small increment. A total of 24 percent of the variance was shared between the arithmetic measure and the cognitive dimensions. In sample 2, the Verbal cognitive di-

mension accounted for the largest proportion of the variance, with the Spatial and Memory components adding small increments. A total of 47 percent of the variance was shared by the arithmetic measure and the cognitive dimensions.

Ages 12, 13 and 14:

When the WRAT A was used as the criterion variable, the results of the multiple regression analyses were similar for the two samples. Only the Verbal and Memory dimensions were entered into the regression equation for each sample (see Table 2 and Table 16). However, the relative contribution of each variable was reversed for the two samples (sample 1, Memory+Verbal; sample 2, Verbal+Memory). A similar proportion of the variance was shared by the arithmetic measure and the cognitive dimensions in the two samples (sample 1, 32 percent; sample 2, 33 percent).

When the WISC (R) A was used as the criterion variable, the results of the multiple regression analyses were similar for the two samples in that the cognitive dimension of Memory accounted for the majority of the shared variance in each sample (see Table 2 and Table 16). However, in sample 2, the Verbal dimension added a small increment. Moreover, the total variance shared by the arithmetic measure and the cognitive dimensions differed for the two samples (sample 1, 21 percent; sample 2, 51 percent).

Question 3: What is the relative frequency of occurrence of different patterns of oral and/or written arithmetic performance? More specifically, do some children, like brain-damaged adults, exhibit discrepancies between oral and written arithmetic performance?

To determine the relative frequency of occurrence of patterns of oral and/or written arithmetic performance, the cut-off scores employed in Phase I were used to define group inclusion. This procedure resulted in the formation of four groups (see Table 17). Three children who were impaired on the WISC-R A performed adequately on the WRAT A. Seventy-one children (23 percent) were impaired on both the WISC-R A and the WRAT A. Thirty-eight of the males (18 percent) and 40 of the females (33.7 percent) exhibited this pattern of performance. One hundred and sixty children (53.9 percent) were impaired only on the WRAT A. One hundred and twenty-six (59.7 percent) of the males and forty (40.8 percent) of the females exhibited this pattern of performance. Sixty-nine children (22.3 percent) were not impaired on either the WISC-R A or the WRAT A. Forty-five (21.3 percent) of the males and 24 (24.5 percent) of the females exhibited this pattern of performance.

To compare the relative frequency of occurrence of patterns of arithmetic performance between the two samples, chi

TABLE 17

Crosstabulation: Performance on WISC-R A and WRAT A

Entire Sample
 WISC-R A- WISC-R A+

WRAT A-	71	166

WRAT A+	3	69

	74	235

Males Only
 WISC-R A- WISC-R A+

WRAT A-	38	126

WRAT A+	2	45

	40	171

Females Only
 WISC-R A- WISC-R A+

WRAT A-	33	40

WRAT A+	1	24

	34	64

square tests for independence were employed for the entire sample (see Table 18), for males (see Table 19) and for females (see Table 20). None of the chi square tests were significant indicating that there was no relationship between the sample membership and the frequency of occurrence of patterns of arithmetic performance. However, the chi square test for males only bordered on significance (see Table 19). A smaller percentage of the males in sample 2 were impaired on both measures of arithmetic performance and a larger percentage of the males in sample 2 were not impaired on either measure of arithmetic performance.

Question 4: Can children with different patterns of arithmetic performance be distinguished on the basis of their cognitive abilities?

Profiles of the means of the three cognitive dimensions for the arithmetic groups were plotted for the entire sample (see Figure 4) and for each sex separately (see Figure 5 and Figure 6). Since only three subjects exhibited isolated deficits on the the WISC-R A, the data for this group was considered unreliable. Hence, the means of the cognitive variables for this group of children (see Table 21) were not plotted and they were not included in any of the data analyses.

TABLE 18

Chi Square Table: Comparison of Samples on Groups

		Pattern of Arithmetic Performance				
		WISC-R A-	WISC-R A-	WISC-R A+	WISC-R A+	
		WRAT A+	WRAT A-	WRAT A-	WRAT A+	Total

1	0	38	71	21	130	
Samples		-----				
2	3	71	166	69	309	

Total	3	109	237	90	439	

Chi Square=4.41, 3 df, $p < .22$

TABLE 19

Chi Square Table: Comparison of Samples on Groups-Males Only

	Pattern of Arithmetic Performance				Total
	WISC-R A- WRAT A+	WISC-R A- WRAT A-	WISC-R A+ WRAT A-	WISC-R A+ WRAT A+	
1	0	29	59	13	101
2	2	38	126	45	211
Total	2	67	185	58	312

Chi Square=7.24, 3df, p<.06

TABLE 20

Chi Square Table: Comparison of Samples on Groups-Females
Only

	Pattern of Arithmetic Performance				Total
	WISC-R A- WRAT A+	WISC-R A- WRAT A-	WISC-R A+ WRAT A-	WISC-R A+ WRAT A+	
1	0	9	12	8	29
Samples	-----				
2	1	33	40	24	98
Total	-----				
	1	42	52	32	127

Chi Square=.42, 3df, $p < .93$

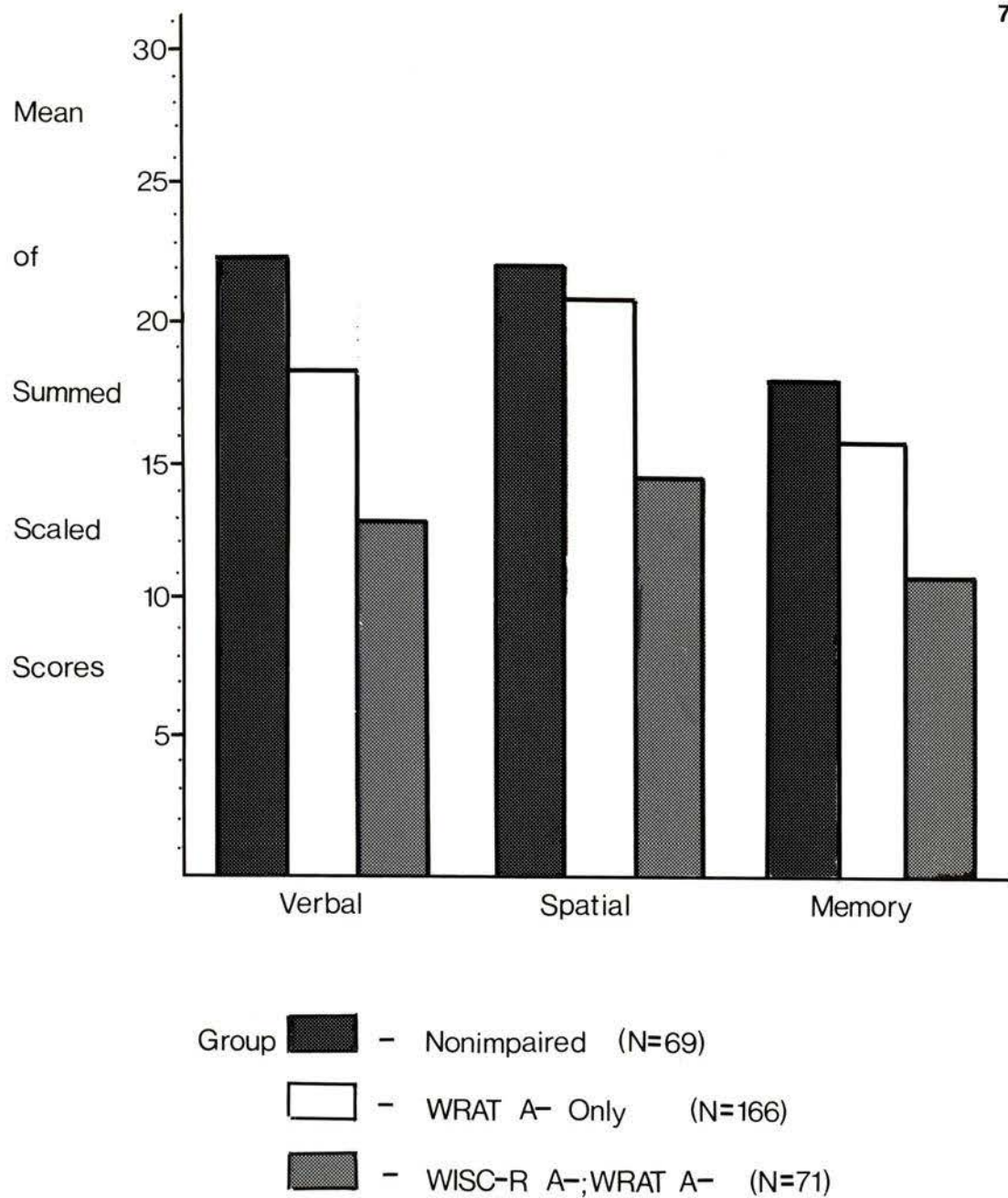


Figure 4: Plot of the Means of the Cognitive Dimensions by Group

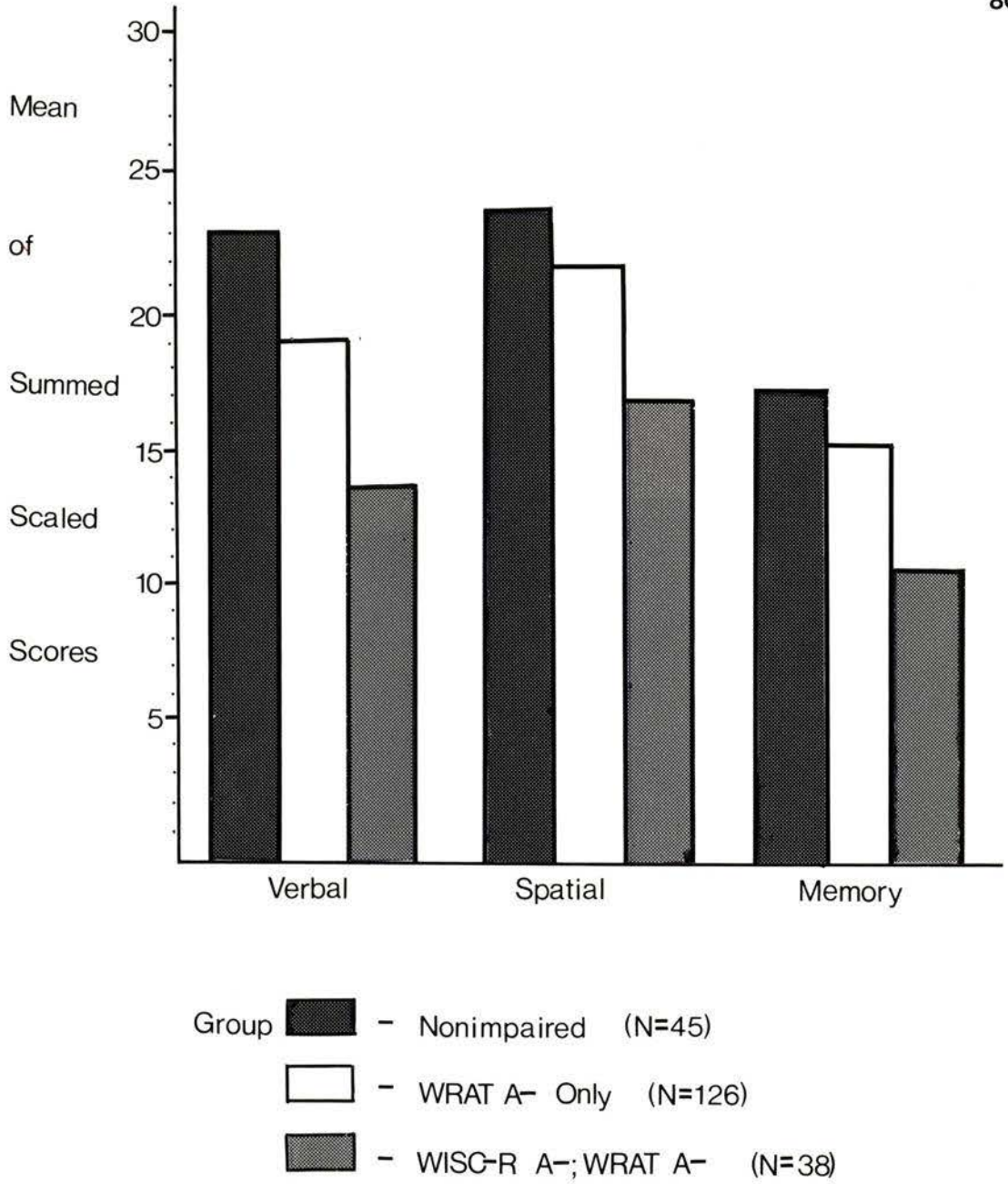
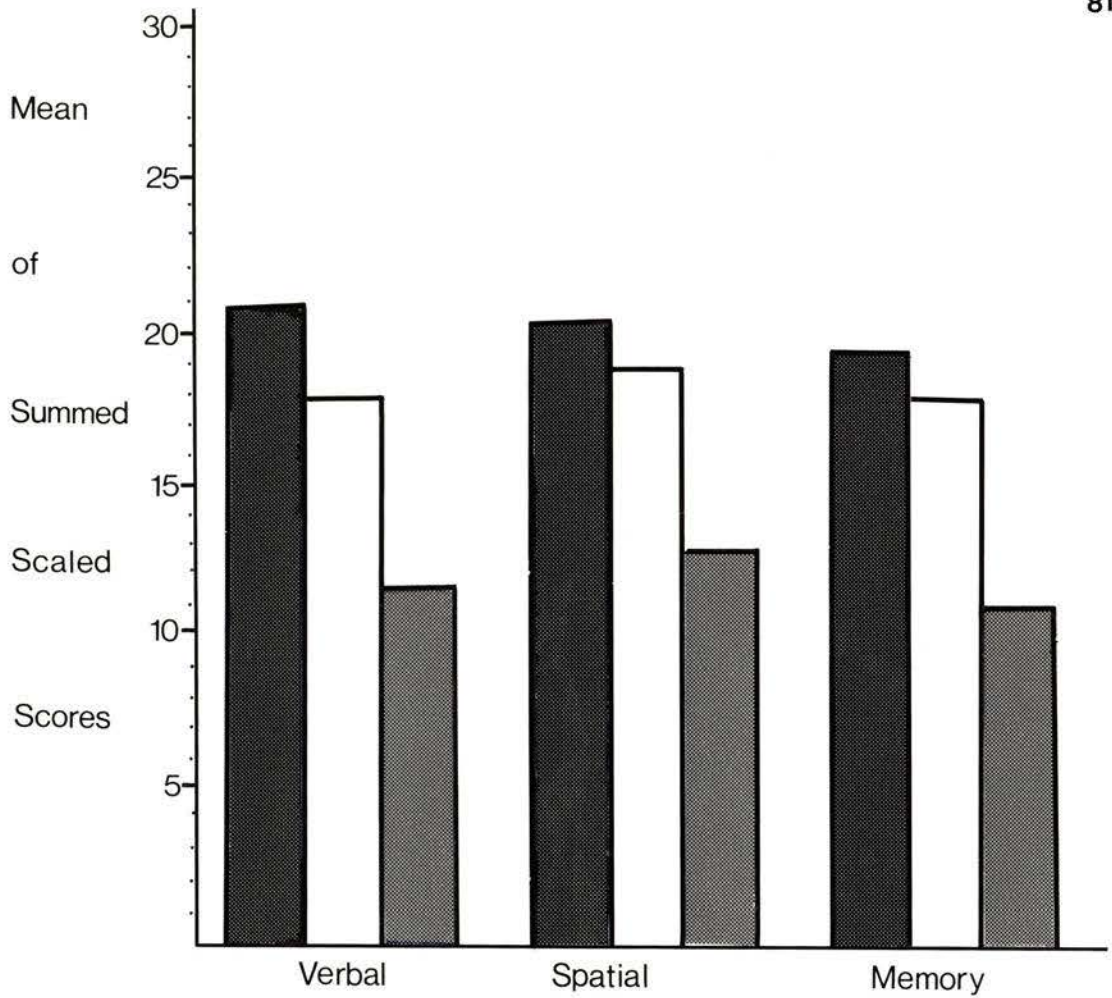


Figure 5: Plot of the Means of the Cognitive Dimensions by Group for Males






Group  - Nonimpaired (N=24)
 - WRAT A- Only (N=40)
 - WISC-R A-; WRAT A- (N=33)

Figure 6: Plot of the Means of the Cognitive Dimensions by Group for Females

TABLE 21

Means of the Cognitive Dimensions for the Isolated WISC-F A-Group

Sample	N	Verbal	Spatial	Memory
Entire Sample	3	22.0	17.0	18.0
Males	2	22.0	17.5	19.0
Females	1	22.0	16.0	16.0

To determine if the arithmetic groups differed on the cognitive dimensions, multivariate analyses of variance (MANOVAs) were performed for the entire sample and for each sex separately. The results of these analyses (see Appendix F) are summarized in Table 22 Table 23 and Table 24.

Overall, each of the groups differed significantly from each other group on the Verbal and Memory dimensions. Although the groups differed on the Spatial dimension overall, the only pairwise group differences were between the group of children impaired on both arithmetic measures and the other two groups of children (WRAT A only and nonimpaired). That is, the WRAT A- only children and the nonimpaired children did not differ on those dimensions.

When only males were examined, the results were identical to those of the entire sample. When females were examined separately, the results were identical to those of the entire sample with the exception that the WRAT A- only group did not differ from the nonimpaired group on any of the cognitive dimensions. However, on inspection of Figure 6 it is apparent that the relative level of performance of the groups is similar to that of the overall sample.

On inspection of Figure 4 and Figure 1, it is apparent that the correspondence between severity of cognitive defi-

TABLE 22

Summary of MANOVAs: Cognitive Dimensions by Group

Group Comparison	N	MANOVA Level of Significance	Univariate ANOVAs Level of Significance		
			Verbal	Spatial	Memory
WISC-R A-; WRAT A-	71				
WISC-R A+; WRAT A-	166	+++	+++	+++	+++
WISC-R A+; WRAT A+	69				
WISC-R A-; WRAT A-	71	+++	+++	+++	+++
WISC-R A+; WRAT A+	69				
WISC-R A-; WRAT A-	71	+++	+++	+++	+++
WISC-R A+; WRAT A-	166				
WISC-R A+; WRAT A-	166	+++	+++		+++
WISC-R A+; WRAT A+	69				

+++ - $p < .001$ ++ - $p < .01$ + - $p < .05$

TABLE 23

Summary of MANOVAs: Cognitive Dimensions by Group-Males Only

Group Comparison	N	MANOVA Level of Significance	Univariate ANOVAs Level of Significance		
			Verbal	Spatial	Memory
WISC-R A-; WRAT A-	38				
WISC-R A+; WRAT A-	126	+++	+++	+++	+++
WISC-R A+; WRAT A+	45				
WISC-R A-; WRAT A-	38	+++	+++	+++	+++
WISC-R A+; WRAT A+	45				
WISC-R A-; WRAT A-	38	+++	+++	+++	+++
WISC-R A+; WRAT A-	126				
WISC-R A+; WRAT A-	126	+++	+++		++
WISC-R A+; WRAT A+	45				

+++ - $p < .001$
 ++ - $p < .01$
 + - $p < .05$

TABLE 24

Summary of MANOVAs: Cognitive Dimensions by Group-Females Only

Group Comparison	N	MANOVA Level of Significance	Univariate ANCVAs Level of Significance		
			Verbal	Spatial	Memory
WISC-R A-; WRAT A-	33				
WISC-R A+; WRAT A-	40	++	+++	+++	+++
WISC-R A+; WRAT A+	24				
WISC-R A-; WRAT A-	33	+++	+++	+++	+++
WISC-R A+; WRAT A+	24				
WISC-R A-; WRAT A-	33	+++	+++	+++	+++
WISC-R A+; WRAT A-	40				
WISC-R A+; WRAT A-	40				
WISC-R A+; WRAT A+	24				

+++ - $p < .001$
 ++ - $p < .01$
 + - $p < .05$

cit and pattern of arithmetic deficit noted in Sample 1 was also evident for Sample 2. No children in Sample 1 exhibited isolated deficits on the WISC A, and only three children exhibited this pattern of performance in Sample 2. The pattern of cognitive abilities exhibited by these children differed from the patterns noted for the other three groups. The means of the Verbal and Memory dimensions for this group did not appear to differ from those of the group with no arithmetic deficits. However, WISC-R A- only children appeared to be more impaired on the Spatial dimension than either the nonimpaired group or the WRAT A- only group. This suggests that children who exhibit WISC-R A deficits show more Spatial impairment and less impairment of the Verbal and Memory dimensions than children who only exhibit WRAT A deficits. This is the reverse of what would be expected on the basis of information derived from the observation of brain-damaged adult populations. However, given the rarity of occurrence of the WISC-R A- only pattern of arithmetic performance (3/439) and the instability of information derived from such a small sample, these results must be viewed with extreme caution.

Question 5 and 6: What is the coincidence of particular patterns of cognitive abilities occurring with and without arithmetic (oral and/or written) deficits?

Tabulation of the frequency of occurrence of the twelve patterns of cognitive abilities is presented in Table 25. The six patterns containing scores of equal magnitude occurred less frequently (18.2 percent of the sample) than the six patterns containing scores of differing magnitude (81.8 percent of the sample). The two hierarchical patterns of cognitive abilities (Verbal>Spatial>Memory and Spatial>Verbal>Memory) that occurred more frequently than any other pattern overall in sample 1 also occurred more frequently than any other pattern in this sample (19.1 and 31.4 percent of the sample, respectively). This was not true for each arithmetic group. However, there was no significant relationship between group membership and the frequency of occurrence of the six hierarchical patterns of cognitive abilities (Chi Square= 23.12, 15 df, $p < .08$).

When only males were examined, the distribution of patterns remained similar to the overall sample (see Table 26) and there was no significant relationship between arithmetic group membership and the frequency of occurrence of the six hierarchical cognitive patterns (Chi square=23.75, 15 df, $p < .07$). When only females were examined, the distribution of patterns of cognitive abilities differed slightly from those of the overall sample and the males (see Table 27). On inspection, it appeared that a smaller percentage of the

TABLE 25

Crosstabulation: Pattern of Cognitive Ability by Group

Pattern of Cognitive Abilities	WISC-R A- WRAT A+	WISC-R A- WRAT A-	WISC-R A+ WRAT A-	WISC-R A+ WRAT A+	Total	Per- Cent of Sam- ple
V>S>M	0	10	33	16	59	19.1
S>V>M	0	21	57	19	97	31.4
M>S>V	0	3	16	3	22	7.1
S>M>V	1	13	24	4	42	13.6
V>M>S	1	7	6	8	22	7.1
M>V>S	0	2	6	3	11	3.6
S=M>V	0	1	5	1	7	2.3
V=S>M	0	3	4	8	15	4.9
V=M>S	0	3	1	1	5	1.6
S>M=V	0	3	10	1	14	4.5
V>S=M	1	3	4	3	11	3.6
M>V=S	0	2	0	2	4	1.3
Total	3	71	166	69	309	

V=Verbal
S=Spatial
M=Memory

females, as compared to the males exhibited patterns with superior Spatial abilities. However, there was no significant relationship between arithmetic group membership and the frequency of occurrence of the six hierarchical patterns of cognitive abilities (Chi Square=14.26, 10 df, $p < .16$) for the females.

These findings were similar to the findings for the Neuropsychology Clinic sample in that, overall, the arithmetic groups did not differ on the frequency of occurrence of the six hierarchical patterns of cognitive abilities. In both samples, this finding held true when each sex was examined separately. The distribution of patterns of cognitive abilities resembled that of the overall sample for males but differed slightly from that of the overall sample for females in each sample.

Although the findings within each sample were similar, there did appear to be a difference between the samples on the frequency of occurrence of the six hierarchical patterns of cognitive abilities (Chi Square= 15.56, 5 df, $p < .008$). From inspection of Table 28, the samples appear to differ most markedly on the frequency of occurrence of the Verbal>Spatial>Memory pattern (30.8 percent of Sample 1 versus 19.1 percent of Sample 2) and the Spatial>Memory>Verbal pattern (4.6 percent of Sample 1 versus 13.6 percent of Sample

TABLE 26

Crosstabulation: Pattern of Cognitive Ability by Group-Males Only

Pattern of Cognitive Abilities	WISC-R A- WRAT A+	WISC-R A- WRAT A-	WISC-R A+ WRAT A-	WISC-R A+ WRAT A+	Total	Per- cent of Sam- ple
V>S>M	0	6	21	13	40	19.0
S>V>M	0	13	53	14	80	37.9
M>S>V	0	0	8	1	9	4.3
S>M>V	1	10	19	3	33	15.6
V>M>S	1	3	5	3	12	5.7
M>V>S	0	0	3	2	5	2.4
S=M>V	0	0	3	0	3	1.4
V=S>M	0	2	4	6	12	5.7
V=M>S	0	2	0	0	2	.9
S>M=V	0	0	7	1	8	3.8
V>S=M	0	1	3	1	5	2.4
M>V=S	0	1	0	1	2	.9

V=Verbal
S=Spacial
M=Memcry

TABLE 27

Crosstabulation: Pattern of Cognitive Ability by
Group-Females Only

Pattern of Cognitive Abilities	WISC-R A- WRAT A+	WISC-R A- WRAT A-	WISC-R A+ WRAT A-	WISC-R A+ WRAT A+	Total	Per- cent of Sam- ple
V>S>M	0	4	12	3	19	19.4
S>V>M	0	8	4	5	17	17.3
M>S>V	0	3	8	2	13	13.3
S>M>V	0	3	5	1	9	9.2
V>M>S	0	4	1	5	10	10.2
M>V>S	0	2	3	1	6	6.1
S=M>V	0	1	2	1	4	4.1
V=S>M	0	1	0	2	3	3.1
V=M>S	0	1	1	1	3	3.1
S>M=V	0	3	3	0	6	6.1
V>S=M	1	2	1	2	6	6.1
M>V=S	0	1	0	1	2	2.0

V=Verbal
S=Spatial
M=Memory

2). The differences in percentage of occurrence of these patterns is consistent with the mean differences between the samples on the Verbal and Memory dimensions.

When only males were examined (see Table 29), the same relationships noted for the entire sample held true (Chi Square=20.09, 5 df, $p < .001$). However, when only females were examined (see Table 30), there was no relationship between sample membership and the frequency of occurrence of the six hierarchical patterns of cognitive abilities (Chi Square=1.64, 5 df, $p < .89$).

Question 7: Do children with oral and/or written arithmetic deficits also exhibit other academic deficits?

The frequency of occurrence of reading and spelling deficits within the four arithmetic groups was tabulated. The results of the comparisons between the arithmetic groups on the frequency of occurrence of reading and spelling deficits are presented in Table 31 and Table 32, respectively. Of the 3 children who were impaired only on the WISC-R A 2 children (1 male and 1 female) exhibited reading deficits and 1 male exhibited a spelling deficit. All of the children (36 males and 31 females) who were impaired on both the WRAT A and WISC-R A also exhibited reading and spelling deficits. Of the one hundred and sixty children who were only

TABLE 28

Crosstabulation: Samples by Pattern of Cognitive Ability

Pattern of Cognitive Abilities	Samples		Samples		Total
	N	Percent of Sample	N	Percent of Sample	
V>S>M	40	30.8	59	19.1	99
S>V>M	38	29.2	97	31.4	135
M>S>V	5	3.8	22	7.1	27
S>M>V	6	4.6	42	13.6	48
V>M>S	14	10.8	22	7.1	36
M>V>S	6	4.6	11	3.6	17
Patterns with two scores of equal magnitude	21	16.1	56	18.2	77

TABLE 29

Chi Square Table: Samples by Pattern of Cognitive Ability-Males Only

Pattern of Cognitive Abilities	Samples				Total
	N	Percent of Sample	N	Percent of Sample	
V>S>M	35	34.7	40	19.0	75
S>V>M	34	33.7	80	37.9	114
M>S>V	2	2.0	9	4.3	11
S>M>V	3	3.0	33	15.6	36
V>M>S	9	8.9	12	5.7	21
M>V>S	5	5.0	5	2.4	10
Patterns with two scores of equal magnitude	13	13.0	32	15.1	45

TABLE 30

Chi Square Table: Samples by Pattern of Cognitive Ability-Females

Pattern of Cognitive Abilities	Samples		N	Percent of Sample	Toa tal
	1	2			
V>S>M	5	19	17.2	19.4	24
S>V>M	4	17	13.8	17.3	21
M>S>V	3	13	10.3	13.3	16
S>M>V	3	9	10.3	9.2	12
V>M>S	5	10	17.2	10.2	15
M>V>S	1	6	3.4	6.1	7
Patterns with two scores of equal magnitude	8	24	30.9	24.5	32

impaired on the WRAT A, 90 percent (110 males and 34 females) exhibited reading deficits and 90 percent (112 males and 32 females) exhibited spelling deficits. Of the sixty-four nonimpaired children 60.9 percent (27 males and 12 females) exhibited reading deficits and 60.9 percent (27 males and 12 females) exhibited spelling deficits.

Overall, each arithmetic group differed from each other arithmetic group on the frequency of occurrence of reading and spelling deficits. When males and females were examined separately, the two groups that were impaired on the WRAT A differed from the nonimpaired group in terms of frequency of occurrence of reading and spelling deficits but did not differ from each other.

These findings are consonant with the findings for the Neuropsychology Clinic sample (see Table 11 and Table 12). The majority (211/227) of the WRAT A- children also exhibited deficits in reading and spelling with 100 percent of the children who exhibited deficits on both the WRAT A and WISC-R A also exhibiting reading and spelling deficits. The occurrence of children exhibiting specific arithmetic deficits (approximately 7 percent) was slightly less frequent than the occurrence of children exhibiting reading and/or spelling deficits in the absence of arithmetic deficits (approximately 8 percent).

TABLE 31

Summary of Z Tests: Group by Reading Deficit

Sample	Group Comparison	Reading Total		Z	p
		Deficit	Group		
		N	N		
	WISC-R A-; WRAT A-	67	67	4.76	S
	WISC-R A+; WRAT A+	39	64		
Entire Sample	WISC-R A-; WRAT A-	67	67	2.68	S
	WISC-R A+; WRAT A-	144	160		
	WISC-R A+; WRAT A-	144	160	5.69	S
	WISC-R A+; WRAT A+	39	64		
	WISC-R A-; WRAT A-	36	36	3.76	S
	WISC-R A+; WRAT A+	27	40		
Males	WISC-R A-; WRAT A-	36	36	1.79	NS
	WISC-R A+; WRAT A-	110	120		
	WISC-R A+; WRAT A-	110	120	3.77	S
	WISC-R A+; WRAT A+	27	40		
	WISC-R A-; WRAT A-	31	31	4.45	S
	WISC-R A+; WRAT A+	12	24		
Females	WISC-R A-; WRAT A-	31	31	2.25	NS
	WISC-R A+; WRAT A-	34	40		
	WISC-R A+; WRAT A-	34	40	3.01	S
	WISC-R A+; WRAT A+	12	24		

TABLE 32

Summary of Z Tests: Groups by Spelling Deficit

Sample	Group Comparison	Spelling Deficit		Z	p
		N	Total Group N		
Entire	WISC-R A-; WRAT A-	67	67	5.69	S
	WISC-R A+; WRAT A+	39	64		
	WISC-R A-; WRAT A-	67	67	2.68	S
	WISC-R A+; WRAT A-	144	160		
WISC-R A+; WRAT A-	144	160	5.08	S	
WISC-R A+; WRAT A+	39	64			
Males	WISC-R A-; WRAT A-	36	36	3.76	S
	WISC-R A+; WRAT A+	27	40		
	WISC-R A-; WRAT A-	36	36	1.59	NS
	WISC-R A+; WRAT A-	112	120		
	WISC-R A+; WRAT A-	112	120	4.19	S
	WISC-R A+; WRAT A+	27	40		
Females	WISC-R A-; WRAT A-	31	31	4.45	S
	WISC-R A+; WRAT A+	12	24		
	WISC-R A-; WRAT A-	31	31	2.45	NS
	WISC-R A+; WRAT A-	32	40		
	WISC-R A+; WRAT A-	32	40	2.76	S
	WISC-R A+; WRAT A+	12	24		

To compare the relative frequency of occurrence of reading and spelling deficits in the two samples, chi square tests of independence were employed (see Table 33 and Table 34). There was no relationship between the samples and the occurrence of reading or spelling deficits overall or for males or females.

TABLE 33

Summary of Chi Squares: Frequency of Reading Deficit by Sample

Sample	Comparison	Reading Deficit N	No Reading Deficit N	Corrected Chi Square	df	p
All	Sample 1	115	15	.26	1	<.60
	Sample 2	266	43			
Males	Sample 1	90	11	.003	1	<.95
	Sample 2	186	25			
Females	Sample 1	25	4	.08	1	<.76
	Sample 2	80	18			

Discussion

It appears that the two samples of children investigated in this study were not drawn from the same population of learning disabled children. Theoretically, these samples may be expected to differ since one sample was drawn from a primary referral source within the school system (sample 2) and the other was drawn from a secondary referral source outside the school system (sample 1). Referrals within the school system would be expected to include a full range of learning problems, from mild to severe, whereas this secondary referral service would deal primarily with children whose learning problems have proven severe, chronic and resistant to remediation or in whom the presence of brain damage is either known or suspected.

The results of this study suggest that the frequency of occurrence of academic deficits (reading, spelling and arithmetic) in these samples does not differ. However, there do appear to be mean differences on the Verbal and Memory dimensions which are reflected in differences in the frequency of occurrence of patterns of cognitive abilities. The school system sample had lower mean scores on the Verbal and Memory dimensions than the Neuropsychology Clinic sample. This may suggest that more children with severe lan-

guage and Memory (verbal learning) problems, which would be expected to be related to academic achievement deficits, are referred within the school system than are referred to external secondary agencies.

In the alternative, these apparent population differences may have resulted as a function of the test instruments employed for each sample (i.e., WISC versus WISC-R) and may not reflect actual differences between the two populations per se. Although the WISC and WISC-R were designed to measure the same abilities and share many of the same items, a number of studies have shown that the WISC-R typically yields lower IQ scores than does the WISC (e.g., Doppelt and Kaufman, 1977; Swerdlik, 1977). This is thought to primarily reflect changes in the normative populations over the course of a generation with the WISC-R raw scores inclining at a steeper rate across age than the WISC raw scores (Kaufman, 1979). If this was the only difference between the measures and it held true for each subtest, it would be expected that the rank ordering of the scores would remain identical thus not affecting correlations with other measures. However, the magnitude of the discrepancies between the WISC and WISC-R Verbal, Performance and Full Scale IQ scores tend to vary (Kaufman, 1979) suggesting that the magnitude of discrepancy for individual subtests may also vary and may af-

fect the rank ordering of scores. These differences between the individual subtest scores could potentially result in the differences between the samples observed here.

Despite the observed differences between the two samples, a number of general conclusions can be drawn from the results of Phases I and II of this research.

1:

It appears that the Verbal and/or Memory cognitive dimensions contribute consistently to both written and oral arithmetic performance, and account for approximately 40 percent of the variance in these measures. This finding supports previous research in which both Verbal and Memory abilities have consistently been found to be related to arithmetic performance. The Spatial cognitive dimension did not contribute to the variance accounted for in either the WRAT A or WISC A in the Neuropsychology Clinic sample but did share variance with the WISC-R A in the School Board sample. This suggests that Spatial ability does not play as important a role in written arithmetic performance for learning disabled children as may be inferred from the clinical evaluation of brain damaged adults and the studies by Rourke and his associates (1978). In addition, these results suggest that some visual-spatial abilities (perhaps

visual imagery as suggested by Clements (1980)) may play an important role in the solving of arithmetic story problems. The finding that approximately 60 percent of the variance remained unaccounted for suggests that other factors are influencing arithmetic performance.

2:

Dividing the overall samples by age and sex resulted in the formation of small groups. These small sample sizes would be expected to affect the reliability of the analyses. However, some general consistencies were noted across the two samples.

A). The results for males only were very similar to the results for the entire sample. This would be expected since males made up the bulk of each sample (sample 1: 101/130; sample 2: 211/309).

B). When only females were examined, the cognitive dimensions accounted for more of the shared variance with the arithmetic measures than was accounted for when only males were examined. This suggests that arithmetic performance may be more dependent on these cognitive dimensions in females than males.

C). The cognitive dimensions accounted for less of the variance shared with the WRAT A for males aged 10-11 years than for younger (age 8-9) or older (12-14 years) males. This suggests that performance on the WRAT A may be less dependent on these cognitive dimensions at this age than before or after.

D). Only the Verbal cognitive dimension and/or the cognitive dimension of Memory shared variance with the arithmetic measures for younger (age 8-9 years) and older (12-14 years) males.

3:

It appeared that very few children impaired on the WISC(R) A (orally presented story problems) performed adequately on the WRAT A (written calculations). However, the majority of children in each sample (i.e., sample 1 - 54.6 percent; sample 2 - 53.9 percent) exhibited discrepant performance on these measures favouring performance on the WISC(R) A.

Since both of these subtests are standardized by age, such a discrepancy may not be expected. However, as noted by Ackerman, Dykman and Peters (1976), the level of operations involved differs between the two measures. On the Arithmetic subtest of the WISC-R, any child who is able to perform rudimentary addition and subtraction problems can attain a raw score of 9 (mean for 8 years 0 months). The

ability to perform simple multiplication and division problems would result in a raw score of 13 (a standard score of 9 for a 14 year old). The items on the WRAT A increase in difficulty much more quickly. To perform at grade level an eight year old would need to be able to perform addition and subtraction of one and two digit whole numbers. A 14 year old would not only need to be able to perform multidigit addition, subtraction, multiplication (with and without borrowing/carrying) and long division (with and without remainder) but also apply these operations to like and unlike fractions and demonstrate a knowledge of measurement concepts.

Thus, it appears that the pattern of deficit on the two measures may reflect a severity of arithmetic deficit dimension. That is, children who are impaired on both measures may be exhibiting a more severe arithmetic disorder than those only impaired on one measure.

4:
It appears that groups of children with different patterns of arithmetic performance can be distinguished on the basis of their cognitive abilities. In both samples, each of the groups differed from each other group on the Verbal and Memory dimensions and the groups differed on the Spatial di-

mension overall. However, in the Neuropsychology Clinic sample, no two groups differed significantly on this dimension whereas in the School Board sample, the only two groups which did not differ significantly on this dimension were the unimpaired group and the WRAT A- only group. Although the overall patterns of cognitive abilities of the groups differed slightly for the two samples, the relationship between the groups on the level of performance remained constant. In both samples, it was apparent that the group impaired on both arithmetic measures exhibited the poorest performance on the cognitive dimensions and the unimpaired group exhibited the best performance on the cognitive dimensions. The performance of the group impaired only on the WRAT A fell in between. This suggests a correspondence between severity of cognitive deficit and severity of arithmetic deficit.

The overall pattern of performance on the cognitive dimensions exhibited by the three children who were impaired only on WISC (R) A subtest differed from the patterns of the other three groups and was the opposite of what would be expected from information derived from the clinical evaluation of brain-damaged adults. That is, this group was less impaired on the Verbal and Memory dimensions and more impaired on the Spatial dimensions than the group of children exhi-

biting isolated WRAT A deficits. However, given the rarity of occurrence of the WISC (R) A- only pattern these results must be viewed with extreme caution.

5:

There did not appear to be a relationship between specific hierarchical patterns of cognitive abilities and patterns of arithmetic performance. In the Neuropsychology Clinic sample, the Verbal>Spatial>Memory and Spatial>Verbal>Memory patterns occurred more frequently than any other hierarchical pattern in each group but there was no relationship between group membership and the frequency of occurrence of the six hierarchical patterns of cognitive abilities. In the School Board sample, the Verbal>Spatial>Memory and Spatial>Verbal>Memory patterns occurred more frequently than any other hierarchical pattern overall and for the unimpaired and the WRAT A- only groups but were not the most frequently occurring patterns for the other two groups. However, there did not appear to be any significant relationship between group membership and the frequency of occurrence of the six hierarchical patterns of cognitive abilities.

These results, taken in conjunction with previous findings, suggest that pattern of cognitive abilities was not as

strongly related to arithmetic deficit as the level of cognitive ability was.

6:

It appears that most children with written arithmetic deficits also exhibit deficits in reading and/or spelling (sample 1 - 102/108; sample 2 - 211/227). In both samples, all children who were impaired on both arithmetic measures also exhibited reading and spelling deficits on the WRAT. This partially supports the observation of Ackerman, Dykman and Peters (1976) that children with general learning deficits (as measured by the WRAT) exhibit a lower mean score on the WISC A than children with specific deficits. However, approximately 90 percent of the children who exhibited isolated deficits on the WRAT A also exhibited reading and/or spelling deficits. Of the children who did not exhibit arithmetic deficits on either measure, approximately 60 percent exhibited reading and/or spelling deficits.

These results suggest that the majority of clinic referred children exhibit generalized learning disabilities and that specific deficits in reading and/or spelling occur slightly more frequently (approximately 9 percent) than do specific arithmetic deficits (approximately 7 percent).

PHASE III

The findings in Phases I and II of this research have provided some general information concerning the cognitive correlates of arithmetic performance in heterogeneous groups of clinic-referred children and have provided the basis for the generation of some tentative hypotheses concerning the relationships observed. However, this information is necessarily limited. The arithmetic measures employed in Phases I and II, although varying in terms of mode of presentation and response, appeared to differ in terms of level of complexity. In addition, these measures assessed only a narrow sampling of a broad range of arithmetic tasks. Thus, it was not possible to systematically examine the areas of arithmetic deficit or types of calculation errors made in relation to pattern of cognitive functioning.

In this investigation of children with arithmetic deficits, a case study approach was adopted and was oriented toward investigating further some of the relationships observed in Phases I and II. In addition, the possibility that types of arithmetic deficit may be related to cognitive functioning was examined.

Specific Questions to be Investigated

Question 1: Does the pattern of performance on the Arithmetic subtests of the WISC (R) and WRAT represent a severity dimension?

Question 2: Does the pattern of performance on the Arithmetic subtests of the WISC and WRAT correspond to a severity of cognitive deficit dimension involving Verbal and Memory abilities?

Question 3: In some cases, does poor performance on the Arithmetic subtest of the WISC (R) result as a function of task demands (most notably verbal memory), as has been suggested in brain damaged adults, rather than as a function of inadequate arithmetic knowledge?

Question 4: Do the types of errors made by children on arithmetic and arithmetic-related tasks correspond to general cognitive deficits?

Method

Subjects:

The learning assistance and learning disability class teachers at two schools in the Greater Victoria School District (No. 61) were asked to identify children who were experiencing difficulty learning arithmetic. A letter describing the

nature of the study was sent to the parents of each child asking permission to administer a variety of cognitive and arithmetic tests to their child. In exchange for their participation, a report on the child's performance on these measures was forwarded to the classroom teacher.

Eighteen (15 males and 3 females) children ranging in age from 9 to 13 years took part.

Procedure:

Each child was administered a battery of cognitive and arithmetic tests (see Table 35) in the order indicated. Additional cognitive measures (see Table 36) were selectively administered following administration of the initial battery to amplify the nature of the cognitive functioning of these children. In addition, informal assessment of arithmetic-related tasks (see Table 37) was carried out with the children from the second school.

The assessments took place in the schools during school hours. Each child was seen individually for two to three hours in an unused school room (e.g., nursing room, science room). Care was taken to try to provide an optimal testing situation. In some cases, this resulted in minor deviations in the testing procedures between children (e.g., allowing extra break time).

TABLE 35

List of Cognitive and Arithmetic Tests

1. WISC-R - Similarities
2. WISC-R - Arithmetic
3. WISC-R - Block Design
4. WISC-R - Vocabulary
5. WISC-R - Object Assembly
6. WISC-R - Coding
7. WISC-R - Digit Span
8. WRAT - Reading
9. WRAT - Spelling
10. WRAT - Arithmetic
11. Token Test for Children (DiSimoni, 1978)
12. Spatial Reasoning subtest of the Hiskey-Nebraska
Test of Learning Aptitude (Hiskey, 1966)
13. Revised Visual Retention Test (Benton, 1974)
14. Rey Auditory Verbal Learning Test (Taylor, 1959)
15. Keymath Diagnostic Arithmetic Test
(Connolly, Nachtman and Pritchett, 1977)
 - Numeration
 - Geometry and Symbols
 - Addition
 - Subtraction
 - Multiplication
 - Word Problems
16. - Numeration
17. - Addition
18. - Subtraction
19. - Multiplication
20. - Word Problems
21. WISC-R Arithmetic (with paper and pencil as
aids)

TABLE 36

List of Additional Cognitive Tests

1. Auditory Discrimination Test (Wepman, 1958)
2. Sentence Repetition Test (Gaddes and Crockett, 1973)
3. Controlled Word Association Test (Gaddes and Crockett,
1973)
4. Auditory Association subtest of the Illinois Test of
Psycholinguistic Abilities (ITPA)
(Kirk, McCarthy and Kirk, 1968)
5. Embedded Figures Test (Spreeen and Gaddes, 1969)
6. Visual Sequential Memory subtest of the ITPA
7. Right-Left Orientation Test (Spreeen and Gaddes, 1969)
8. Visual Association subtest of the ITPA
9. Coloured Progressive Matrices (Raven, 1977)
10. Picture Arrangement subtest of the WISC-R

TABLE 37

Informal Arithmetic Assessment Items

1. **WRITING NUMBERS***
Write down the numbers I say.
A) 7,9,3; 3,5,7 (10 sec. per number group)
B) 17 and 71; 69 and 96 (10 sec. per number group)
C) 27,34,158,396,9845 (10 sec. per number)

2. **READING NUMBERS***
Read these numbers.
A) (CARD A) 7,9,3,,; 3,5,7 (10 sec. per group)
B) (CARD B) 17,71,69,96 (10 sec. per number)
C) (CARD C) 27,34,158,396,9845 (10 sec. per number)
D) There are 3 numbers on this card (CARD D) arranged from top to bottom.
Read each number as a whole number.
(If, on 158, the child says 1-5-8, say I want you to read this as if it were just one number)
(allow 20 sec. per item).

158 ;396 ;1023 .

3. **NUMBER STRUCTURE***
Tell me which number is larger (bigger).
(Allow 10 sec. per item)
17 or 68; 23 or 56; 189 or 201
Look at this card (CARD E) and show me, by pointing, which of the top two numbers is the larger.
Which of the bottom two?
(Allow 10 sec. per item).
189-201 1967-3002

4. **PLACE VALUE CONCEPT (CARD C)**
Look at this number (indicate 27). Which digit is in the ones place?
Look at this number (indicate 34). Which digit is in the tens place?
Look at this number (indicate 396). How many hundreds are there?
Look at this number (indicate 9845). How many thousands are there in this number?
Look at his number (indicate 158). The 5 is in which place?
The 8 is in which place? The 1 is in which place?
(Present all of the numbers on CARD C). Which number has a 5 in the ones place?
Which number has an 8 in the hundreds place?

5. NUMBER SEQUENCES

- A) (Present CARD F) Which number goes in the blue box?
2, 4, 8, 10
- B) (Present CARD G) Which number goes in the blue box?
6, 9, 12, 18
- C) (Present CARD H) Which number goes in the blue box?
4, 8, 12, 20
- D) (Present CARD I) Which number goes in the blue box?
5, 10, 15, 25
- E) (Present CARD J) Which number goes in the blue box?
30, 50, 60, 70
- F) (Present CARD K) Which number goes in the blue box?
750, 760, 770, 790
- G) (Present CARD L) Which number goes in the blue box?
9, 8, 7, 5
- H) (Present CARD M) Which number goes in the blue box?
22, 21, 19, 18
- I) (Present CARD N) Which number goes in the blue box?
20, 16, 14, 12
- J) (Present CARD O) Which number goes in the blue box?
95, 85, 80, 75
- K) I want you to count by 2s like this, 2, 4, 6, and so on. Start from 2 and add 2 each time. If the child makes an error say, "No, it is not What is (give the previous correct response) plus 2. Stop at 20.
- L) Repeat the above (K) instructions for 5s, 10s, 3s.
- M)* I want you to count backward from 50 by 3s like this, 50, 47, 44 and so on. Start from 50 and subtract 3 each time. (If the child makes an error say, "No, it is not What is (give the previous correct response) minus 3?") (Allow 60 seconds).

*Adapted from the Luria-Nebraska Children's Battery,
C. J. Golden University of Nebraska Medical Centre,
Omaha, Nebraska.

Results

The subjects were grouped according to pattern of arithmetic deficit and pattern of cognitive abilities as defined in Phases I and II of this research (see Table 38). Eight (44.44 percent) of the children were impaired on both arithmetic measures and eight (44.44 percent) of the children were impaired only on the WRAT A. Two (11.11 percent) of the children did not show arithmetic deficits on either of these measures.

Question 1: To investigate the possibility that the pattern of performance on the two arithmetic measures represents a severity dimension, two approaches were taken. First, the grade scores attained by each subject on the six subtests of the Keymath Diagnostic Arithmetic Test (KDAT) were subtracted from the expected grade score (based on age) for the subject. The raw grade scores employed are presented in Appendix G. The difference scores for each subtest were then averaged for each of the three arithmetic groups (see Table 39). The second approach taken was to tabulate the frequency of occurrence of calculation errors made on the KDAT problems involving addition, subtraction and multiplication of whole numbers. Tabulations of the frequency of

TABLE 38

Patterns of Performance on WISC-R A, WRAT A and Cognitive Dimensions

Pattern of Cognitive Abilities	WISC-R A-;WRAT A-	
	Age	Sex
1. S>V>M	13	M
2. S>V>M	12	M
3. V=S>M	10	M
4. S>M>V	12	M
5. S>M>V	13	M
6. S>M>V	13	M
7. V>M>S	11	M
8. S>V>M	11	M
	WISC-R A+;WRAT A-	
9. S>V=M	13	M
10. S>V>M	11	M
11. S>V>M	9	M
12. S>V=M	11	M
13. S>V>M	9	M
14. S>V>M	10	M
15. S>V=M	10	M
16. V>S>M	10	F
	WISC-R A+;WRAT A+	
17. S>V>M	11	F
18. V>M>S	11	F

occurrence of errors made by each subject are presented in Appendix H.

On inspection of Table 39, it appeared that the pattern of performance on the WRAT A and WISC-R A does represent a severity of deficit dimension. On each subtest of the KDAT, the children who were impaired on both the WISC-R A and WRAT A were achieving farther below their expected grade level than the children who were only impaired on the WRAT A. On the average, the children who were impaired on both arithmetic subtests were performing approximately 4.5 years below expected grade level whereas the children who were impaired only on the WRAT A were performing approximately 2.5 years below expected grade level. The children in the nonimpaired group performed near or above grade level on all of the subtests. In addition, the children who were impaired on both Arithmetic subtests made more calculation errors overall (72 vs. 61) and attempted fewer problems (22 vs. 17) than the children who were only impaired on the Arithmetic subtest of the WRAT. In turn, the children who were impaired only on the WRAT A made more errors (61 errors made by eight children vs. six errors made by two children) and attempted fewer problems (17 problems not attempted by 8 children vs. 0 problems not attempted by two children) than the nonimpaired children.

TABLE 39

Mean Difference Scores on KDAT Subtests by Group

Difference score=expected grade score based on age-obtained grade score on individual subtests of the Keymath Diagnostic Arithmetic Test.

KDAT Subtests	Pattern of Performance on the WRAT A and WISC-R A		
	WISC-R A-	WISC-R A+	WISC-R A+
	WRAT A- N=8	WRAT A- N=8	WRAT A+ N=2
Numeration	5.1	2.9	2.1
Geometry and Symbols	4.6	3.2	-.5
Addition	4.1	2.4	-.2
Subtraction	4.4	1.9	-.1
Multiplication	4.1	2.0	.5
Word Problems	4.9	1.7	-.8

Question 2: To investigate the possibility that the proposed severity of arithmetic deficit dimension corresponds to a severity of cognitive deficit dimension, the number of children in each arithmetic group who exhibited impaired performance on the cognitive measures was tabulated (see Table 40). This approach was adopted because norms for all of the cognitive measures employed were not available in equivalent standard score format. Appendix I contains a description of the criteria for score classification and score classification for each subject.

On inspection of Table 40, there did appear to be a correspondence between frequency of cognitive impairments and pattern of arithmetic deficit. More of the children who were impaired on both arithmetic subtests than were impaired on the WRAT A only exhibited impaired performances on all of the cognitive measures except the Token Test for Children and the Digit Span subtest of the WISC-R. The groups differed most markedly on the frequency of occurrence of deficits on the Rey Auditory-Verbal Learning Test, the Sentence Repetition test, the Controlled Word Association Test and the Revised Visual Retention Test (all measures of aspects of memory), the Similarities and Vocabulary subtests of the WISC-R (both measures of verbal conceptualization) and the Spatial Reasoning subtest of the Hiskey-Nebraska Test of

Learning Aptitude. Neither of the two unimpaired children exhibited impaired performances on any of the cognitive measures except the Revised Visual Retention Test.

Question 3: To investigate whether poor performance on the WISC-R A may result as a function of task demands rather than as a function of inadequate arithmetic knowledge per se, the scaled scores attained on WISC-R A were compared with the scaled scores attained when the same test items were readministered allowing the child to use a pencil and paper as aids. The scaled scores attained by each child on the initial and aided administrations are presented in Appendix G and J, respectively.

Of the 11 children who were readministered the WISC-R items, 5 children, all of whom were impaired on both arithmetic subtests, were able to improve their scores. The scores for two of these children (case 1 and case 5) were raised into the normal range (scaled score > 7). This suggests that, in some instances, poor performance on the Arithmetic subtest of the WISC-R may not reflect the severity of arithmetic deficit but occur as a function of other task demands.

Question 4: To investigate whether types of errors made on arithmetic and arithmetic-related tasks may correspond to

TABLE 40

Summary Table: Frequency of Deficits on Cognitive Measures

Measure	Pattern of Performance on the WRAT A and WISC-R A		
	WISC-R A- WRAT A- N=8	WISC-R A+ WRAT A- N=8	WISC-R A+ WRAT A+ N=2
WISC-R Similarities	5/8	2/8	0/2
WISC-R Vocabulary	5/8	1/8	0/2
Token Test	0/8	1/8	0/2
WISC-R Block Design	2/8	0/8	0/2
WISC-R Object Assembly	2/8	1/8	0/2
Spatial Reasoning	5/8	0/8	0/2
Coloured Progressive Matrices	1/8	0/6	
WISC-R Coding	4/8	2/8	0/2
Visual Retention Test	3/8	0/8	1/2
WISC-R Digit Span	5/8	6/8	0/2
Rey Auditory Verbal Learning Test	6/8	1/8	0/2
Sentence Repetition	5/8	0/8	
Controlled Word Association Test	4/8	0/7	

general cognitive deficits, two approaches were taken. The first approach was to examine the frequency of specific errors made by groups of children differing on the frequency of Verbal and/or Memory impairments. The second approach was to examine the errors on arithmetic and arithmetic-related tasks made by individual children exhibiting deficits on visual-spatial tasks.

Approach 1:

On investigation of Questions 1 and 2, it was noted that the group of children who were impaired on both arithmetic measures and the group of children impaired only on the WCAT A differed on the total number of calculation errors made as well as on the frequency of occurrence of children exhibiting Verbal and/or Memory cognitive impairments. The present investigation was to examine whether or not differences in the types of errors manifested by these groups of children may be related to these differences in cognitive deficits.

The frequency of specific errors made by the children on the KDAT problems involving addition, subtraction and multiplication of whole numbers were tabulated (see Table 41). Scoring criteria for error types and tabulations of the frequency of occurrence of errors made by each child are presented in Appendix H.

TABLE 41

Summary of Calculation Errors

Error Type	Pattern of Performance on the WRAT A and WISC-R A		
	WISC-R A- WRAT A- N=8	WISC-R A+ WRAT A- N=8	WISC-R A+ WRAT A+ N=2
Basic Fact Error	23	8	1
Incorrect			
Carry/Borrow	14	15	3
No Concept of			
Carry/Borrow	23	15	0
Incorrect Operation	0	2	1
Neglect dollar sign			
or Decimal	10	16	0
Misalignment	0	0	0
Bizarre Error	2	5	1
Number of Problems			
Not Attempted	22	17	0
Total	72	61	6

On inspection of Table 41, it appeared that only two types of errors were made substantially more often by the children who were impaired on both Arithmetic subtests. These were errors which involved the recollection of basic facts and errors which indicated a faulty acquisition of the concepts of borrowing and/or carrying. Broadly speaking, these error types would appear to correspond to the more general cognitive deficits of Verbal conceptualization and Memory exhibited by the children with dual Arithmetic deficits.

Approach 2:

Since visual-spatial abilities have often been implicated as influencing arithmetic performance, errors made on arithmetic and arithmetic-related tasks by children who performed poorly on visual-spatial tasks were examined in relation to the errors made by the other children in the sample.

Tabulation of the frequency of occurrence of errors made by each child on the KDAT problems involving addition, subtraction, and multiplication of whole numbers are presented in Appendix H. Tabulation of the frequency of occurrence of errors made by each child on the items of the informal arithmetic assessment are presented in Appendix J.

Only three children (case numbers 2, 3, and 7), all of whom were impaired on both Arithmetic subtests, scored below

the mean on the visual-spatial tasks from the WISC-R. Two of these children (cases 3 and 7) also performed poorly on the Spatial Reasoning subtest of the Hiskey-Nebraska Test of Learning Aptitude. Many of the calculation errors made by these three children were similar to errors made by the other children. However, these three children did appear to make more errors that were "spatial" in nature. The only two children in the sample who made number order reversals when writing numbers from dictation were cases 2 and 7. Case 2 had great difficulty reading numbers placed in a vertical orientation. All three of these children had more difficulty completing number sequences than any of the other children. None of these three children performed calculation in the wrong order (left to right) or made errors of alignment when setting numerals in their proper spatial relationships for calculation. However, the only items on the KDAT which required such alignment (i.e., those involving two digit multipliers) were not attempted by any of these children. In addition, the only child in the sample who did not use concrete aids (e.g., counting fingers, making tally marks) when performing calculations was case 7. Even when encouraged to do so, he did not.

CONCLUSIONS

In this research, both quantitative and qualitative approaches to the investigation of cognitive correlates of arithmetic performance were assumed. Quantitative comparisons involved the examination of the performance of a heterogeneous group of clinic referred children on the WISC (R) A and WRAT A in relation to three cognitive dimensions that have been commonly associated with arithmetic performance in the literature (Verbal, Spatial and Memory abilities). Two complementary procedures were used to examine the relationships between these measures. Multiple correlations were used to examine the relative contributions of each cognitive dimension to each arithmetic measure to determine if the arithmetic measures placed different demands on cognitive abilities. A subtyping approach was used to examine whether the pattern of performance on the arithmetic measures was related to pattern of cognitive abilities. Evidence from the clinical evaluation of brain-damaged adults has suggested that differential arithmetic deficits may occur in conjunction with different patterns of cognitive abilities. These investigations were then repeated on a larger sample of children, from a different referral source to examine the

robustness of the initial findings. To amplify the nature of the relationships observed, a series of case studies were undertaken. Qualitative analysis of errors made on arithmetic and arithmetic-related tasks provided further information concerning the correspondence between cognitive functioning and arithmetic performance.

From the results of the quantitative comparisons, it appeared that the Verbal and/or Memory cognitive dimensions consistently contributed to both WISC(R) A and WRAT A although the relative contributions of each varied with sex, age and across samples. This finding is consistent with factor analytic studies and with research examining the simple correlations between the WISC(R) and the WRAT. Sattler and Ryan (1981) noted that individual Verbal subtests of the WISC-R were better predictors of performance on the WRAT A than were individual Performance subtests for children referred for psychological testing because of poor academic achievement. Factor analytic studies of the WISC and WISC-R have typically yielded the same three factors with the third factor being comprised of the Arithmetic, Digit Span and Coding subtests (Cohen, 1959; Kaufman, 1975). This finding is also consistent with other research investigating the relationship between cognitive abilities and arithmetic performance (e.g., Whyte, 1978; Moroz, 1978; Webster, 1979) but

suggests that Spatial ability may not play as important a role in arithmetic processes as has been suggested in the literature.

However, some evidence for Spatial involvement in arithmetic ability was noted in the sample of children referred to an educational clinic. In this sample, the Spatial dimension contributed to the variance accounted for in the WISC-R A. The Spatial dimension accounted for 3.96 percent of the variance in the WISC-R A for the entire sample, 2.49 percent of the variance for males and 3.03 percent for females. However, on inspection of the relative contribution of the cognitive dimensions to the WISC-R A for males by age, it appeared that the Spatial dimension only accounted for variance in the Arithmetic subtest for 10 and 11 year olds (7.53 percent). These findings support the proposition that relative contributions to arithmetic performance may differ at different age levels and suggest that some visuospatial abilities (perhaps spatial visualization or visual imagery as suggested by Clements (1980)) may play a role in solving arithmetic story problems.

The results of the subtyping procedure indicated that children do exhibit discrepancies on the performance of the WISC(R) A and WRAT A. However, only three of the two hundred and forty children exhibiting discrepancies performed

poorly on the WISC(R) A but adequately on the WRAT A. As a group, these three children performed well on the Verbal and Memory dimensions but performed poorly on the Spatial dimension. The two hundred and thirty-seven children exhibiting discrepant performances on the WISC(R) A and WRAT A in the opposite direction could only be distinguished from children who performed adequately or inadequately on both Arithmetic subtests by the level of Verbal and Memory abilities. That is, for these three groups of children, it appeared that the pattern of cognitive ability had no relationship to the pattern of arithmetic performance but the level of specific cognitive abilities (i.e., Verbal and Memory abilities) did differ in relation to the pattern of arithmetic performance.

From inspection of the items on each Arithmetic subtest, it appeared that pattern of performance on the two arithmetic subtests may represent a severity dimension. That is, children who were impaired on both arithmetic subtests appeared to exhibit a more severe arithmetic deficit than those impaired only on one measure. This suggests that a correspondence exists between severity of cognitive deficits (i.e., Verbal and Memory deficits) and severity of arithmetic disorder.

The finding that, generally, the level of Verbal and Memory abilities appears to dictate the level of attainment in

calculation ability may be expected since achieving proficiency in computation involves the memorization of basic facts and requires the retention and comprehension of mathematical terms and relations. Indeed, on qualitative analysis of error types, the group of children who exhibited more severely impaired Verbal and Memory abilities made more errors reflecting impaired recollection of basic facts and faulty acquisition of certain arithmetic concepts (e.g., the concepts of carrying and borrowing). However, these findings did not rule out the possibility that, in some cases, poor performance on the WISC(R) A occurred as a function of other task demands (as has been suggested for brain-damaged adults) rather than reflecting severe deficits in Arithmetic knowledge per se. Thus, when task demands were altered for the children in Phase III to reduce the memory and mental manipulation aspects, some children were able to substantially improve their performance.

The finding that groups impaired and unimpaired on the WRAT A did not differ on the Spatial dimension, taken in conjunction with the finding that the Spatial dimension did not predict WRAT A performance suggests that Spatial abilities do not play a particularly important role in written arithmetic performance. However, this finding does not imply that in some, albeit rare, cases a Spatial deficit may not

affect arithmetic performance. Indeed, in Phase III, the children with Spatial deficits did appear to make more errors on certain arithmetic-related tasks reflecting perceptual disturbances (e.g., number order reversals) and a lack of understanding of numeration. Even though no differences in written calculation error types were evident, these findings appear consistent with the description of arithmetic deficits given by Rourke and Strang (1981) of children with spatial disorders who did not exhibit Reading and Spelling deficits. That is, there were indications that the basic concepts underlying number relations were not well understood. This correspondence with the findings of Rourke and Strang (1981) suggests that an impoverished understanding of basic number relations or the "numberness of number" may be characteristic of children with spatial deficits regardless of achievement in other academic areas. Moreover, the proposition that Spatial abilities are related to the understanding of more basic arithmetic concepts such as the structure of the number system may be raised as an alternative explanation for the observed relationship between Spatial abilities and the WISC-R A. That is, Spatial abilities may be related to the performance of fairly elementary calculation tasks when an appreciation of number relations (number reasoning) is required for solution.

Whether a Spatial deficit, in and of itself, may be reflected in calculation tasks remains an issue since, in Phase III of this research, the three children with Spatial deficits also exhibited Verbal and/or Memory deficits. Many developmental theories concerning the acquisition of mathematical ability maintain that for a child to achieve proficiency in number, he will first need to be conversant with elementary spatial relationships which include recognition of forms (perceptual space), the use of visual imagery and the interpretation of space (representational space) (Choat, 1978). However, other theorists, most notably Drummond (1922), emphasize the role of memory and contend that some children are able to perform arithmetic tasks without dependence upon prior spatial experiences. Choat (1978) suggests that the ability to memorize may influence early number development (i.e., rote calculations) but that subsequent mathematical development is restricted until the geometry (i.e., coordination of spatial relationships) provides the necessary understanding for the progression to take place.

Rourke and Strang (1981), examined the arithmetic deficits of children with isolated spatial, as opposed to verbal, deficits. Their findings suggest that children with spatial deficits exhibit an impoverished understanding of fairly routine mathematical concepts, whereas it was su-

spected that many of the children with verbal deficits had difficulty with the implementation of correct procedures because of a (verbal) memory impairment. The verbally impaired children appeared to have an adequate appreciation of the conceptual underpinnings of mathematical operations. The results of the present research concur with Fourke and Strang's (1981) findings in that the children with spatial deficits did appear to exhibit an impoverished understanding of basic number relations but suggested that children with severe Verbal and Memory deficits exhibit, not only errors in recalling basic facts but, errors reflecting a lack of acquisition of the concepts of borrowing/carrying. That is, children with Verbal and Memory deficits did appear to have an understanding of basic number relations but exhibited difficulty with more abstract arithmetic concepts such as regrouping. It has been suggested here that deficits in Verbal ability (i.e., concept acquisition expressed verbally) are related to arithmetic deficits in concept acquisition. Thus, the degree of conceptualization attained by the child limits the level of mathematical experiences he can grasp. The development and use of the awareness of spatial relationships is necessary to acquire an appreciation of the structure and meaning of numeration or the "numbness of number" and serves as a basis for the development of mathematical abilities. Beyond this basis, the degree to which

an individual acquires the ability to abstract appears to play a role in arithmetic performance.

Implications and Suggestions for Future Research:

It should be noted that the above speculations as to the underlying correspondence between cognitive and arithmetic disorders are based on observations of the performance of a small number of cases. Thus, there is a need for more thorough examination of areas of weakness in understanding exhibited by children with different patterns of cognitive abilities to clarify the nature of the observed relationships. As was evident in this research, discrepancies in performance on the WISC(R) A and WRAT A did not prove useful as indices of differential cognitive impairment and should not be considered as such by clinicians. However, by examining performance on a broad range of arithmetic and arithmetic-related tasks and quantifying qualitative error types the information necessary to determine whether deficits cluster in cognitively meaningful ways may be provided. Within this context, examination of differences in performance between males and females and between children with various patterns of academic achievement may lead to a clearer understanding of the roles these factors play.

The results of this research suggest that many children who are experiencing difficulty learning arithmetic exhibit conceptual deficits at various levels of attainment. In terms of remediation of arithmetic disabilities, this suggests that the major emphasis in the curriculum should be on concept attainment. However, the results of this research also suggest that different modes of educational remediation may be in order for children with different patterns of cognitive strengths and weaknesses. For example, access to times tables may assist in alleviating some of the difficulty experienced by children with memory deficits but may be of little use to a child with visual-spatial deficits.

The efficacy of remedial programs designed on the basis of cognitive strengths and weaknesses can only be determined by future research. However, it is important to note that, in this research, the cognitive abilities examined accounted for only a modest proportion of the variance in arithmetic performance. This suggests that other factors (cognitive and noncognitive) may be of equal or greater importance to predicting arithmetic achievement. Thus, future research may not only be directed toward determining the efficacy of cognitively based remedial programs and examining relationships of other more specific cognitive abilities (e.g., spatial visualization) to arithmetic functioning but toward

identifying other factors which may be important to consider when designing remedial strategies for children who have difficulty learning arithmetic.

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Appendix A

RAW DATA-SAMPLE 1

Variable list subnum, sex, age, sim, arith, vocab, bldes,
 obass, digsp, cod, verb, spat, mem, stscr,
 stscs, stsca

Input format (F5.0, 1X, F1.0, 1X, F2.0, 1X, 10 (F2.0, 1X),
 3 (F3.0, 1X))

Variable labels subnum, subject number/
 age, age in years/
 sex, sex/
 sim, Similarities subtest of the WISC-
 scaled score/
 arith, Arithmetic subtest of the WISC-
 scaled score/
 vocab, Vocabulary subtest of the WISC-
 scaled score/
 bldes, Block Design subtest of the WISC-
 scaled score/
 obass, Object Assembly subtest of the WISC-
 scaled score/
 digsp, Digit Span subtest of the WISC-
 scaled score/
 cod, Coding subtest of the WISC-
 scaled score/
 verb, Verbal=sim+vocab/
 spat, Spatial=bldes+obass/
 mem, Memory=digsp+cod/
 stscr, Reading subtest of the WRAT-
 standard score/
 stscs, Spelling subtest of the WRAT-
 standard score/
 stsca, Arithmetic subtest of the WRAT-
 standard score/

Value labels sex (1) Male (0) Female/
 all other variables (-1) Missing data/

269	0	12	7	7	9	2	9	5	4	16	11	9	83	83	71
2481	1	10	9	5	8	6	10	6	5	17	16	11	76	84	77
2529	1	14	11	7	8	6	6	2	6	19	12	8	87	78	68
2099	1	10	8	5	11	10	7	5	4	19	17	9	67	78	69
1875	1	13	11	9	8	7	11	7	8	19	18	15	94	85	71
34	1	10	10	10	10	7	6	6	5	20	13	11	97	92	86

2554	1	12	12	4	8	7	11	7	7	20	18	14	74	70	69
2489	1	10	10	4	10	9	9	8	8	20	18	16	98	56	88
1900	1	10	10	11	11	7	6	6	4	21	13	10	73	65	77
2600	0	10	9	7	12	9	8	8	8	21	17	16	110	112	78
1879	1	14	8	6	13	7	12	8	8	21	19	16	86	74	73
2616	1	10	9	8	12	9	11	8	5	21	20	13	73	74	73
31	1	10	12	10	9	4	16	8	10	21	20	18	90	85	86
2526	1	11	11	7	11	9	8	9	5	22	17	14	91	85	86
124	1	10	13	4	9	8	11	5	4	22	19	9	69	70	75
240	1	12	12	9	10	10	9	10	7	22	19	17	80	68	78
136	1	10	11	8	11	11	9	6	9	22	20	15	90	82	92
29	1	10	12	12	11	12	5	6	6	23	17	12	92	89	96
2021	1	14	12	7	11	9	9	6	10	23	18	16	94	81	66
199	0	12	13	6	10	7	12	5	9	23	19	14	92	89	76
163	1	13	14	14	9	11	10	10	9	23	21	19	80	77	108
2704	1	8	14	9	9	10	12	6	7	23	22	13	77	68	86
2611	1	11	11	7	13	12	10	8	9	24	22	17	82	81	79
238	1	11	12	11	13	11	12	8	6	25	23	14	104	97	81
144	1	10	12	10	14	14	10	12	5	26	24	17	98	96	95
2495	1	8	11	6	15	11	14	7	11	26	25	18	82	82	77
39	1	11	13	9	13	16	9	14	10	26	25	24	122	99	82
260	0	9	15	7	12	11	10	5	10	27	21	15	69	75	84
2478	1	13	16	8	11	12	9	12	5	27	21	17	106	99	103
1903	1	10	14	6	13	12	13	4	11	27	25	15	67	75	89
2570	1	9	13	9	14	12	13	9	7	27	25	16	120	104	90
44	1	12	15	10	13	10	15	9	5	28	25	14	111	103	80
1877	1	9	16	7	15	10	9	8	8	31	19	16	120	121	93
1869	1	10	14	7	17	13	10	6	4	31	23	10	130	131	96
108	1	8	16	-1	15	14	10	15	7	31	24	22	-1	-1	-1
244	1	13	15	10	16	15	14	10	8	31	29	18	106	83	77
1895	1	10	14	10	18	12	13	6	10	32	25	16	84	84	92
105	1	8	14	11	18	12	13	13	10	32	25	23	103	95	91
1896	0	10	16	18	16	15	14	15	11	32	29	26	133	119	106
2482	1	11	16	7	17	10	11	8	4	33	21	12	114	97	83
121	1	9	16	9	18	14	12	14	10	34	26	24	124	113	99
215	1	8	8	5	3	7	10	4	6	11	17	10	82	82	70
1887	1	8	6	4	6	11	9	4	5	12	20	9	68	64	63
23	1	10	4	5	8	12	9	6	4	12	21	10	86	84	89
122	1	9	6	2	6	9	12	5	6	12	21	11	78	75	68
2658	1	13	5	10	7	9	14	5	6	12	23	11	73	75	83
109	1	9	8	5	5	9	14	2	10	13	23	12	71	79	78
2100	1	9	10	5	6	10	7	5	3	16	17	8	85	71	64
2530	1	8	7	5	9	12	10	6	6	16	22	12	68	76	79
2609	1	14	9	8	7	11	12	7	5	16	23	12	72	73	75
2538	1	11	9	6	8	11	9	5	8	17	20	13	99	103	76
33	1	10	11	8	6	10	11	8	5	17	21	13	65	65	71
249	1	14	8	8	9	11	10	8	8	17	21	16	83	80	82
271	0	14	11	4	7	7	12	5	9	18	19	14	74	68	73
2714	1	9	9	7	10	10	10	5	5	19	20	10	92	94	93
2610	1	9	10	7	9	13	10	8	8	19	23	16	94	90	87
126	1	10	9	13	10	13	13	6	11	19	26	17	97	107	95

123	1	9	8	7	11	12	15	6	9	19	27	15	83	86	87
2536	1	13	9	5	11	10	11	7	6	20	21	13	91	75	68
2568	1	10	10	5	10	12	13	8	7	20	25	15	108	92	86
228	1	9	10	6	11	8	15	6	12	21	23	18	104	96	68
2618	1	10	10	4	11	13	13	6	9	21	26	15	55	56	57
79	0	11	10	10	12	12	11	9	9	22	23	18	91	91	86
232	1	10	14	10	10	12	13	12	11	24	25	23	95	75	95
2551	1	12	12	9	12	14	12	6	9	24	26	15	84	65	73
1897	1	10	13	8	11	12	14	8	9	24	26	17	69	71	86
1891	1	13	13	13	11	12	14	8	10	24	26	18	80	78	90
2557	1	11	9	7	15	12	15	5	4	24	27	9	67	66	76
2505	1	13	13	10	11	12	15	7	9	24	27	16	73	65	80
2667	1	10	12	6	13	12	14	6	6	25	26	12	90	86	95
38	1	11	15	13	10	14	13	10	8	25	27	18	122	-1	-1
2485	1	10	12	10	13	15	13	6	10	25	28	16	93	92	92
2565	1	11	13	11	13	14	13	11	11	26	27	22	83	85	91
183	0	10	14	13	12	14	13	11	14	26	27	25	96	101	109
2602	1	13	13	9	14	13	15	5	8	27	28	13	80	72	70
154	1	12	17	11	10	13	15	10	8	27	28	18	106	99	105
120	1	9	15	9	13	13	17	12	12	28	30	24	97	96	96
2544	1	11	12	11	16	16	16	10	13	28	32	23	122	131	113
261	0	9	15	10	14	14	16	12	11	29	30	23	92	94	99
247	1	14	16	11	15	18	15	8	8	31	33	16	82	69	107
268	0	12	4	4	5	9	8	7	12	9	17	19	88	89	80
2500	0	13	6	4	5	9	7	7	4	11	16	11	77	83	65
2082	1	8	7	6	5	6	3	11	6	12	9	17	78	52	60
24	1	10	4	4	8	5	5	6	5	12	10	11	90	89	75
53	1	13	5	9	7	6	4	10	10	12	10	20	81	88	83
178	0	9	5	5	7	9	5	7	10	12	14	17	101	102	89
46	1	12	6	7	7	6	7	10	9	13	13	19	78	75	74
2527	1	10	4	4	9	6	8	8	9	13	14	17	92	87	78
1991	1	8	6	10	7	8	8	7	6	13	16	13	82	90	89
2595	1	9	6	5	7	10	10	8	6	13	20	14	83	78	74
176	0	8	7	9	6	11	11	9	8	13	22	17	78	88	88
204	0	13	6	6	8	6	5	5	13	14	11	18	80	73	80
201	0	13	5	8	9	6	7	8	5	14	13	13	95	88	70
71	0	8	9	3	5	7	7	4	16	14	14	20	72	92	73
196	0	11	6	7	8	6	9	8	6	14	15	14	100	101	81
187	0	10	6	4	8	7	9	8	14	14	16	22	97	98	92
41	1	11	6	9	8	8	11	8	6	14	19	14	76	79	81
2541	1	10	6	7	8	10	10	6	9	14	20	15	83	71	86
2517	1	10	4	6	10	12	13	8	8	14	25	16	65	60	60
30	1	10	6	9	9	7	2	14	8	15	9	22	97	101	93
2077	1	9	5	6	10	6	6	7	9	15	12	16	78	87	74
2521	1	14	8	6	8	10	9	9	11	16	19	20	79	75	70
2624	0	13	10	4	7	3	9	5	12	17	12	17	74	79	70
2490	0	11	9	8	8	9	10	9	8	17	19	17	73	75	79
224	1	9	11	7	6	11	15	8	9	17	26	17	102	96	78
1904	1	14	10	12	8	7	5	12	8	18	12	20	105	104	89
174	0	8	9	10	10	7	3	9	10	19	10	19	109	107	98
11	1	8	9	8	10	6	8	7	9	19	14	16	120	109	98

2559	1	13	9	9	10	9	10	10	8	19	19	18	78	68	78
179	0	9	11	15	8	10	12	12	9	19	22	21	105	96	102
2601	1	13	11	9	9	2	5	5	7	20	7	12	67	70	73
45	1	12	11	13	9	9	5	12	7	20	14	19	98	103	87
221	1	8	10	8	10	11	9	10	11	20	20	21	112	113	95
2079	1	12	11	7	10	12	9	5	5	21	21	10	78	65	71
73	0	9	9	2	13	11	11	10	8	22	22	18	-1	-1	-1
3	1	8	10	11	12	10	12	7	12	22	22	19	85	92	95
272	0	14	13	9	9	16	17	12	12	22	33	24	81	81	84
37	1	11	10	9	13	5	2	6	5	23	7	11	-1	-1	-1
82	0	12	12	5	11	7	4	7	8	23	11	15	-1	-1	-1
2499	1	10	12	5	11	7	4	7	8	23	11	15	89	88	86
147	1	11	13	12	10	10	8	12	6	23	18	18	106	101	93
1955	1	8	14	9	9	12	6	11	10	23	18	21	98	85	88
2553	1	14	14	10	9	9	11	12	9	23	20	21	99	77	75
103	1	8	11	12	13	11	8	8	13	24	19	21	112	94	98
195	0	11	13	12	12	9	7	12	12	25	16	24	112	122	109
259	0	8	15	10	10	9	12	10	11	25	21	21	97	90	102
137	1	10	14	11	12	10	8	9	9	26	18	18	83	72	91
2621	0	10	13	10	13	8	10	12	8	26	18	20	100	108	80
1979	0	8	13	8	13	10	8	11	10	26	18	21	87	107	98
7	1	9	13	9	13	11	9	9	11	26	20	20	104	94	96
264	0	10	13	12	14	9	8	10	12	27	17	22	95	92	83
2606	1	13	14	15	14	4	2	14	7	28	6	21	88	92	103
84	0	13	17	11	12	9	5	14	4	29	14	18	108	110	74
152	1	11	16	12	13	13	12	15	10	29	25	25	105	97	87
151	1	11	15	7	14	13	13	15	11	29	26	26	100	93	87

Appendix B
REGRESSION TABLES-SAMPLE 1

Table B1

Total sample (N=130): WRAT A by Verbal, Spatial
and Memory Dimensions

Step 1:	Multiple R		.5223
	R Square		.2728
	Adjusted R Square		.2671
	F=48.02, 1,128 df, p<.001		
	Variables in the Equation		
	Variable	B	Beta
	-----	-	-----
	Memory	1.43	.52
Step 2:	Multiple R		.6051
	R Square		.3662
	Adjusted R Square		.3562
	F=36.69, 2,127 df, p<.001		
	Variables in the Equation		
	Variable	B	Beta
	-----	-	-----
	Memory	1.08	.39
	Verbal	.67	.33

Table E2

Total Sample (N=134): WISC A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .4964
R Square .2464
Adjusted R Square .2407
F=43.16, 1,132 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Verbal	.25	.49

Step 2: Multiple R .5834
R Square .3403
Adjusted R Square .3303
F=33.79, 2,131 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Verbal	.18	.37
Memory	.22	.33

Table E3

Males only (N=101): WRAT A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .4968
R Square .2468
Adjusted R Square .2392
F=32.45, 1, 99 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Verbal	1.01	.49

Step 2: Multiple R .5659
R Square .3202
Adjusted R Square .3064
F=23.09, 2, 98 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Verbal	.77	.38
Memory	.81	.29

Table B4

Males Only (N=103): WISC A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .4720
R Square .2227
Adjusted R Square .2150
F=28.95, 1,101 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	.30	.47

Step 2: Multiple R .5513
R Square .3039
Adjusted R Square .2900
F=21.83, 2,100 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	.22	.35
Verbal	.14	.30

Table E5

Females Only (N=29): WRAT A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .7691
 R Square .5916
 Adjusted R Square .5764
 F=39.11, 1, 27 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	2.32	.76

Table B6

Females Only (N=31): WISC A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .6194
 R Square .3836
 Adjusted R Square .3624
 F=18.05, 1, 29 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Verbal	.37	.61

Step 2: Multiple R .6870
 R Square .4720
 Adjusted R Square .4343
 F=12.51, 2, 28 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Verbal	.26	.44
Memory	.31	.34

Table B7

Males 8 and 9 yrs. (N=28): WRAT A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .6867
 R Square .4715
 Adjusted R Square .4512
 F=23.20, 1, 26 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Verbal	1.25	.68

Table B8

Males 8 and 9 yrs. (N=28): WISC A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .6774
 R Square .4589
 Adjusted R Square .4381
 F=22.05, 1, 26 df, p<.001

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	.35	.67

Table E9

Males 10 and 11 yrs. (N=43): WRAT A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .4285
 R Square .1836
 Adjusted R Square .1637
 F= 9.22, 1, 41 df, p<.004

Variables in the Equation		
Variable	B	Beta
-----	-	-----
Verbal	.82	.42

Table E10

Males 10 and 11 yrs. (N=45): WISC A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .4098
R Square .1680
Adjusted R Square .1486
F= 8.60, 1, 43 df, p<.005

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	.24	.40

Step 2: Multiple R .4929
R Square .2430
Adjusted R Square .2069
F= 6.74, 2, 42 df, p<.002

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	.19	.32
Verbal	.14	.28

Table B11

Males 12, 13, 14 yrs. (N=30): WRAT A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .4469
R Square .1997
Adjusted R Square .1711
F= 6.98, 1, 28 df, p<.01

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	1.68	.44

Step 2: Multiple R .5683
R Square .3230
Adjusted R Square .2728
F= 6.44, 2, 27 df, p<.005

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	1.53	.40
Verbal	.87	.49

Table B12

Males 12, 13, and 14 yrs. (N=30): WISC A by Verbal,
Spatial and Memory Dimensions

Step 1: Multiple R .4608
 R Square .2123
 Adjusted R Square .1842
 F= 7.50, 1, 28 df, p<.01

Variables in the Equation

Variable	B	Beta
-----	-	-----
Memory	.35	.46

Appendix C
MANOVA TABLES-SAMPLE 1

Table C1

Total Sample (N=130): Groups by Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Group	Wilks	.64	10.41	6	250	<.001

Univariate F-Tests (2, 127 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	1283.42	3063.38	641.71	24.12	26.60	<.001
Spatial	208.01	3835.25	104.00	30.19	3.44	<.035
Memory	444.57	1936.62	222.28	15.24	14.57	<.001

Table C2

Total Sample: WISC A-;WFAT A- (N=38) vs.
 WISC A+;WRAT A+ (N=21) on
 Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Group	Wilks	.39	27.70	3	55	<.001

Univariate F-Tests (2, 57 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	1195.36	1149.55	1195.36	20.16	59.27	<.001
Spatial	185.71	1841.50	185.71	32.30	5.74	<.02
Memory	444.36	797.16	444.36	13.98	31.77	<.001

Table C3

Total Sample: WISC A-;WRAT A- (N=38) VS.
 WISC A+;WRAT A- (N=71) on
 Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypcth. df	Error df	p
Group	Wilks	.79	8.95	3	103	<.001

Univariate F-Tests (2, 107 df)

Variable	Hypoth SS	Error SS	Hypcth MS	Error MS	F	p
Verbal	618.62	2720.14	618.62	25.42	24.33	<.001
Spatial	114.50	2802.29	114.50	26.18	4.37	<.039
Memory	111.33	1593.67	111.33	14.89	7.47	<.007

Table C4

Total Sample: WISC A+;WRAT A- (N=71) VS.
 WISC A+;WRAT A+ (N=21) cn
 Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypth. df	Error df	p
Group	Wilks	.81	6.83	3	88	<.001

Univariate F-Tests (2, 90 df)

Variable	Hypoth SS	Error SS	Hypth MS	Error MS	F	p
Verbal	314.00	2257.06	314.00	25.07	12.52	<.001
Spatial	39.17	3026.69	39.17	33.62	1.16	<.283
Memory	211.32	1482.41	221.32	16.47	12.82	<.001

Table C5

Males Only (N=101): Groups by Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypcth. df	Error df	p
Group	Wilks	.68	6.78	6	192	<.001

Univariate F-Tests (2, df)

Variable	Hypoth SS	Error SS	Hypcth MS	Error MS	F	p
Verbal	860.37	2333.84	430.18	23.81	18.06	<.001
Spatial	93.42	2902.73	46.71	29.61	1.57	<.212
Memory	265.73	1465.69	132.86	14.95	8.88	<.001

Table C6

Males Only: WISC A-;WRAT A- (N=29) VS WISC A+;WRAT A+
(N=13) on Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypcth. df	Error df	p
Group	Wilks	.45	15.40	3	38	<.001

Univariate F-Tests (2, 40 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	792.77	802.86	792.77	20.07	39.49	<.001
Spatial	82.50	1334.56	82.50	33.36	2.47	<.124
Memory	226.31	508.47	266.31	12.71	17.80	<.001

Table C7

Males Only: WISC A-;WRAT A- (N=29) VS.
 WISC A+;WRAT (N=59)
 on Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Group	Wilks	.79	7.21	3	84	<.001

Univariate F-Tests (2, 86 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	405.83	2144.15	405.83	24.93	16.27	<.001
Spatial	50.11	2205.96	50.11	25.65	1.95	<.166
Memory	154.81	1240.46	154.81	14.42	10.73	<.002

Table C8

Males Only: WISC A+;WRAT A- (N=29) VS.
 WISC A+;WRAT A+ (N=13)
 on Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Group	Wilks	.85	3.87	3	68	<.01

Univariate F-Tests (2, 70 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	248.43	1720.67	248.43	24.58	10.10	<.002
Spatial	21.67	2264.93	21.67	32.35	.66	<.416
Memory	51.53	1182.45	51.53	16.89	3.05	<.085

Table C9

Females Only (N=29): Groups by Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Group	Wilks	.42	4.26	6	48	<.002

Univariate F-Tests (2, 26 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	471.42	643.45	235.71	24.75	9.52	<.001
Spatial	168.24	770.79	84.12	29.64	2.83	<.077
Memory	181.36	311.80	90.68	11.99	7.56	<.033

Table C10

Females Only: WISC A-;WRAT A- (N=9) VS.
 WISC A+;WRAT A+ (N=8) on
 Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Group	Wilks	.29	10.41	3	13	<.001

Univariate F-Tests (2, 15 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	463.24	278.87	463.24	18.59	24.91	<.001
Spatial	167.65	397.87	167.65	26.52	6.32	<.024
Memory	133.34	132.88	133.34	8.85	15.05	<.001

Table C11

Females Only: WISC A-;WRAT A- (N=9) VS.
 WISC A+;WRAT A- (N=12) on
 Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Group	Wilks	.65	2.96	3	17	<.06

Univariate F-Tests (2, 19 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	185.14	504.66	185.14	26.56	6.97	<.016
Spatial	54.32	436.91	54.32	22.99	2.36	<.141
Memory	.003	271.80	.003	14.30	.00	<.987

Table C12

Females Only: WISC A+;WRAT A- (N=12) VS.
 WISC A+;WRAT A+ (N=8) on
 Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx. F	Hypoth. df	Error df	p
Group	Wilks	.53	4.56	3	16	<.017

Univariate F-Tests (2, 18 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	95.40	503.54	95.40	27.97	3.41	<.081
Spatial	44.40	706.79	44.40	39.26	1.13	<.302
Memory	149.63	218.91	149.63	12.16	12.30	<.003

Appendix D

RAW DATA-SAMPLE 2

Variable list	sbid,sex,agey,sim,arith,vocab,bd,oa, ds,cod,verb,spat,mem,crss,csss,cass
Input format	(F5.0,1X,F1.0,1X,F2.0,1X,10(F2.0,1X), 3(F3.0,1X))
Variable labels	sbid, subject number/ agey, age in years/ sex,sex/ sim, Similarities subtest of the WISC-R scaled score/ arith, Arithmetic subtest of the WISC-R scaled score/ vocab, Vocabulary subtest of the WISC-R scaled score/ bd, Block design subtest of the WISC-R scaled score/ ca, Object assembly subtest of the WISC-R scaled score/ ds, Digit Span subtest of the WISC-R- scaled score/ cod, Coding subtest of the WISC-R- scaled score/ verb, Verbal=sim+vocab/ spat, Spatial=bd+ca mem, Memory=ds+cod crss, Reading subtest of the WRAT- standard score/ csss, Spelling subtest of the WRAT- standard score/ cass, Arithmetic subtest of the WRAT- standard score/
Value labels	sex (1)Male (0)Female/ all other variables (0) Missing data

232	1	11	10	10	7	10	9	10	5	20	19	15	81	80	76
217	1	10	11	10	10	12	13	7	5	21	25	12	112	110	100
130	1	9	12	12	12	11	12	10	7	24	23	17	113	102	99
131	1	9	9	11	6	10	10	8	10	20	20	18	78	90	78
133	1	9	11	9	13	8	9	5	11	20	17	16	83	84	89
153	0	8	11	10	10	15	12	8	8	21	27	16	96	95	101
156	1	8	8	9	9	8	8	5	5	17	16	10	90	97	94

192	1	10	8	12	10	12	13	10	13	20	25	23	96	92	85
196	0	11	8	6	8	7	13	10	11	14	20	21	118	112	101
4	0	11	4	7	8	6	8	9	7	11	14	16	101	104	74
21	1	8	13	12	12	8	12	8	9	25	20	17	108	100	94
23	1	11	18	11	15	16	18	5	10	29	34	15	106	95	111
36	0	8	4	10	9	9	11	8	9	14	20	17	98	95	98
44	0	12	6	9	7	8	10	8	12	15	18	20	107	90	69
87	1	12	8	9	5	7	7	3	4	17	14	7	55	56	59
4109	0	10	13	11	13	11	11	10	13	24	22	23	124	114	101
4098	1	12	12	9	14	13	15	9	9	21	28	18	80	78	82
4088	1	8	11	14	12	13	15	7	6	25	28	13	93	0	104
4087	0	9	9	9	6	7	9	9	7	18	16	16	82	79	86
4177	1	13	10	10	7	14	12	9	8	20	26	17	86	79	80
4121	0	10	3	2	1	1	1	2	4	5	2	6	56	0	48
4114	1	9	9	10	10	7	9	9	7	19	16	16	116	111	87
4180	1	9	10	8	13	14	9	11	12	18	23	23	84	80	95
649	1	8	9	8	12	8	10	6	8	17	18	14	93	95	94
802	0	11	9	8	5	6	4	7	9	17	10	16	88	99	82
794	1	12	11	10	10	10	14	8	8	21	24	16	91	88	73
789	0	11	7	7	6	7	6	5	1	14	13	6	91	89	72
765	1	12	9	9	9	6	9	3	7	18	15	10	102	73	74
763	1	10	7	4	5	11	11	6	11	11	22	17	80	72	83
757	1	8	11	15	9	10	11	7	12	26	21	19	0	83	99
733	1	12	10	9	7	13	13	5	5	19	26	10	80	80	73
339	0	10	1	3	1	3	4	2	5	4	7	7	55	49	48
337	1	13	8	9	8	8	6	9	3	17	14	12	97	68	87
301	1	12	10	12	10	11	13	11	5	22	24	16	92	81	73
297	1	10	6	8	5	8	4	6	8	14	12	14	99	97	86
283	1	10	9	10	9	12	14	7	8	19	26	15	110	93	91
282	1	10	16	13	10	14	19	6	10	29	33	16	83	83	88
510	1	11	7	9	7	7	7	10	9	16	14	19	94	85	79
509	1	10	7	12	9	10	9	6	7	19	19	13	85	84	88
486	1	9	4	10	5	7	7	8	8	14	14	16	90	84	71
466	1	9	7	9	5	10	9	5	13	16	19	18	91	84	100
460	1	11	7	10	6	12	12	10	4	17	24	14	0	0	73
393	1	11	8	8	12	9	10	6	6	16	19	12	100	89	84
523	1	11	13	11	11	11	12	10	5	24	23	15	106	101	80
516	1	9	6	10	5	12	11	3	8	16	23	11	64	71	81
264	1	8	10	13	9	12	10	10	8	23	22	18	78	89	86
266	0	11	5	8	4	11	9	5	9	13	20	14	91	87	79
890	1	9	9	11	6	6	9	5	11	20	15	16	86	75	0
883	1	13	5	5	2	1	6	1	5	10	7	6	72	68	65
871	1	14	8	7	10	10	10	7	2	15	20	9	102	92	82
858	1	9	9	10	8	14	11	7	11	19	25	18	102	96	96
822	1	14	12	10	11	10	10	14	11	22	20	25	97	92	98
1028	0	10	12	11	9	10	8	12	10	23	18	22	97	97	100
1004	0	12	7	4	5	4	10	6	4	11	14	10	76	65	69
962	1	9	4	5	2	2	7	3	2	9	9	5	52	61	56
945	1	10	3	5	7	8	7	7	6	8	15	13	78	79	86
904	0	11	10	10	7	11	12	4	12	20	23	16	94	89	75
1098	0	9	12	9	8	11	7	5	6	21	18	11	86	88	84

1082	1	13	8	9	7	13	9	3	7	17	22	10	75	70	66
1079	0	11	8	9	6	8	6	5	10	17	14	15	93	80	76
1076	1	8	10	14	12	8	9	6	5	24	17	11	116	114	105
1057	0	10	9	8	6	8	8	10	3	17	16	13	97	95	86
1042	1	13	6	3	9	5	10	8	8	9	15	16	81	89	80
627	1	10	14	11	13	14	15	9	7	25	29	16	82	74	101
613	1	11	6	9	7	9	10	12	8	15	19	20	105	101	79
581	1	12	10	9	8	8	7	5	6	19	15	11	106	88	82
710	0	12	10	8	8	8	6	7	11	18	14	18	102	102	85
706	1	8	15	14	12	2	9	9	9	29	11	18	93	107	98
701	0	11	5	1	4	11	7	2	1	6	18	3	75	66	58
672	1	9	10	10	11	13	12	10	11	20	25	21	108	96	90
1383	1	12	6	8	7	9	7	6	8	14	16	14	93	78	80
1360	1	10	13	14	9	17	18	10	6	27	35	16	101	97	88
1354	0	9	7	7	7	10	10	8	12	14	20	20	101	102	97
1460	1	10	14	12	7	13	15	7	7	26	28	14	109	83	83
1451	0	13	7	6	8	9	10	9	11	13	19	20	90	75	70
1442	1	8	7	8	8	9	9	6	7	15	18	13	109	0	94
1434	0	8	8	8	6	8	10	7	6	16	18	13	81	87	80
1629	0	14	10	8	7	9	7	6	6	18	16	12	72	68	73
1627	1	14	9	10	9	12	13	8	9	19	25	17	94	76	77
1621	0	8	12	10	9	10	10	8	9	22	20	17	90	97	98
1616	1	8	13	12	9	14	9	7	6	25	23	13	109	88	107
1580	0	10	3	2	5	3	8	2	8	5	11	10	86	91	80
1572	1	8	12	9	11	10	11	10	6	21	21	16	117	112	108
1513	1	12	7	10	7	8	6	7	7	17	14	14	101	93	71
1105	0	9	5	8	7	9	8	9	12	13	17	21	103	100	97
1106	1	10	8	7	12	13	13	7	9	15	26	16	94	83	91
1121	1	13	10	8	11	13	14	4	12	18	27	16	0	0	95
1277	1	11	6	8	8	7	8	7	10	14	15	17	85	70	74
1259	1	9	16	14	13	8	12	8	8	30	20	16	120	98	97
1155	1	10	9	9	5	9	10	5	4	18	19	9	97	0	80
1136	0	13	9	8	8	7	8	13	11	17	15	24	62	69	56
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1130	0	12	10	9	9	10	10	11	8	19	20	19	86	78	81
1341	0	10	5	4	6	5	5	5	4	9	10	9	89	87	78
1308	1	13	5	6	7	4	2	3	5	11	6	8	85	66	74
2053	0	13	7	7	5	7	4	8	14	14	11	22	99	88	67
2070	1	12	8	8	9	9	9	12	7	16	18	19	82	90	78
2072	1	10	10	11	12	17	13	11	8	21	30	19	109	106	101
2196	1	13	10	10	8	10	13	9	8	20	23	17	0	0	80
2187	1	13	5	5	8	11	17	6	8	10	28	14	74	74	63
2166	0	8	10	12	6	8	8	8	8	22	16	16	104	104	99
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1675	1	9	8	9	5	4	9	3	8	17	13	11	69	77	74
1755	0	9	12	10	5	8	7	5	6	22	15	11	0	94	80
1747	1	9	19	16	14	15	18	10	7	35	33	17	0	119	99
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1792	1	9	7	9	10	4	9	6	13	16	13	19	80	80	77
1786	0	9	6	7	6	4	8	6	7	13	12	13	93	92	83
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1885	1	8	12	11	8	10	9	9	9	23	19	18	0	97	104
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1872	1	10	8	8	13	12	15	3	2	16	27	5	71	66	93
1870	0	14	9	9	9	9	8	7	6	18	17	13	97	71	63
1852	1	13	7	8	6	7	15	5	3	15	22	8	78	70	68
1845	1	10	11	13	12	10	11	7	11	24	21	18	98	55	91
1820	1	9	13	10	9	11	17	8	8	23	28	16	97	96	102
1414	0	12	10	7	10	11	12	12	11	17	23	23	87	88	77
1405	1	8	14	14	6	7	9	12	8	28	16	20	127	116	105
2609	1	8	11	12	7	13	16	2	5	23	29	7	78	85	77
2592	0	13	10	8	8	10	10	10	8	18	20	18	76	72	73
2587	0	13	4	9	5	5	8	4	1	13	13	5	81	74	63
2218	1	11	8	7	6	5	9	7	8	15	14	15	87	79	82
2230	1	9	7	7	8	8	7	6	6	14	15	12	86	94	78
2236	0	10	3	5	5	5	4	7	5	8	9	12	97	91	88
2290	0	13	4	6	7	9	6	3	10	10	15	13	72	70	73
2303	1	10	7	6	7	5	13	5	9	13	18	14	78	70	80
2285	1	8	11	11	7	12	10	6	10	22	22	16	106	50	99
2281	0	8	5	4	5	6	5	5	5	9	11	10	81	73	82
2341	1	12	15	10	10	10	10	6	8	25	20	14	115	117	88
2320	1	9	7	6	6	5	7	2	4	13	12	6	67	77	78
2316	1	8	9	7	7	11	11	7	9	16	22	16	85	88	91
2447	1	13	8	6	8	12	8	9	7	14	20	16	76	72	74
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2433	1	8	14	17	13	13	11	7	10	31	24	17	100	102	91
2421	1	9	13	8	17	13	9	9	11	21	22	20	113	113	93
2408	1	10	7	9	7	12	8	5	8	16	20	13	96	93	80
2390	1	13	11	8	9	12	14	9	10	19	26	19	99	89	84
2044	1	11	6	1	5	8	11	8	3	7	19	11	80	76	62
2027	1	11	8	9	5	11	14	6	3	17	25	9	91	87	67
2009	1	14	8	7	8	11	15	8	6	15	26	14	71	66	68
1970	1	8	7	9	12	6	13	8	14	16	19	22	85	79	99
1902	0	8	7	7	6	5	4	7	6	14	9	13	95	87	77
2976	0	14	9	7	8	10	7	12	11	16	17	23	95	97	84
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2959	0	8	8	6	7	7	4	9	7	14	11	16	95	96	83
2957	1	11	7	12	7	12	9	5	6	19	21	11	87	83	81
2956	1	12	12	11	9	8	12	7	6	23	20	13	97	75	77
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2939	1	14	3	2	3	4	5	4	2	5	9	6	84	73	73
2928	1	12	14	8	7	10	12	11	7	22	22	18	88	68	71
2866	0	8	9	12	7	12	9	8	11	21	21	19	102	110	99
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2820	0	13	6	6	5	7	11	4	8	12	18	12	74	74	73
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2559	1	13	8	11	9	11	14	7	4	19	25	11	77	74	78
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2516	0	11	5	3	5	4	4	7	9	8	8	16	86	89	73
2514	1	8	8	9	7	10	9	8	6	17	19	14	81	91	89
2487	0	9	9	12	7	10	9	10	9	21	19	19	123	107	109
2483	0	8	6	2	5	5	8	10	5	8	13	15	78	91	71

2474	1	13	8	9	9	7	14	9	13	17	21	22	0	0	0
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2717	C	10	9	8	9	13	11	6	10	17	24	16	90	57	91
2715	1	11	7	3	8	7	6	5	4	10	13	9	45	77	75
2688	0	13	5	4	3	4	7	3	2	9	11	5	67	68	68
2678	1	9	15	13	7	13	16	6	9	28	29	15	104	111	92
2652	1	8	8	10	9	10	12	3	4	18	22	7	72	83	80
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3661	1	13	9	8	7	9	4	9	6	17	13	15	80	88	73
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3681	1	14	8	7	8	9	12	9	8	15	21	17	87	64	73
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3392	1	9	1	2	2	5	8	2	5	3	13	7	75	73	68
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3390	1	9	1	4	3	10	11	3	5	5	21	8	69	75	78
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3457	1	9	10	8	12	16	12	8	10	18	28	18	73	77	90
3458	1	13	6	3	7	12	12	5	8	9	24	13	77	65	73
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3165	0	9	8	11	12	10	10	7	11	19	20	18	118	115	99
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3161	1	8	7	6	9	4	10	9	5	13	14	14	93	100	92
3132	1	11	10	12	15	16	11	9	6	22	27	15	130	131	148
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3197	1	9	12	13	8	11	7	9	8	25	18	17	76	80	92
3195	1	8	13	13	12	14	7	7	11	26	21	18	108	102	101
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3176	1	9	12	13	10	12	12	4	9	25	24	13	95	82	97
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2818	1	14	5	5	3	1	2	3	5	10	3	8	74	76	59
2812	1	9	8	12	9	6	11	8	10	20	17	18	102	96	102

2784	1	10	13	11	9	9	8	10	9	24	17	19	112	108	88
2730	1	8	12	14	9	12	12	7	11	26	24	18	95	98	92
3280	0	11	13	10	9	14	10	10	10	23	24	20	121	114	84
3278	0	10	7	4	5	8	7	6	4	11	15	10	73	72	78
3276	1	8	12	16	7	14	14	15	9	28	28	24	100	108	96
3275	0	12	10	9	9	10	8	9	8	19	18	17	109	108	84
3322	1	11	14	10	10	8	12	11	6	24	20	17	102	95	76
3316	1	8	7	8	9	10	10	6	7	15	20	13	74	73	91
3314	0	9	4	4	3	6	5	4	9	8	11	13	67	67	66
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3036	1	13	8	9	11	15	12	7	12	17	27	19	88	75	80
3009	1	14	12	8	12	6	11	5	7	20	17	12	104	0	96
2990	1	12	7	7	7	9	11	7	8	14	20	15	76	65	66
3735	0	9	15	12	10	12	11	10	9	27	23	19	85	82	92
3740	0	12	6	5	7	7	6	7	9	11	13	16	88	88	72
3779	0	10	10	8	7	13	12	6	10	18	25	16	0	98	0
3788	0	8	7	5	5	5	8	5	6	12	13	11	76	84	68
3790	0	11	10	9	8	7	8	6	5	19	15	11	115	126	80
3798	0	9	10	8	7	6	5	5	7	18	11	12	92	92	82
3801	1	8	11	10	9	8	11	8	10	21	19	18	92	104	101
3806	1	11	15	12	11	8	11	12	7	27	19	19	109	120	82
3814	0	14	6	8	7	3	10	4	8	14	13	12	90	99	68
3816	0	9	11	9	8	10	7	8	5	20	17	13	93	88	95
3826	1	12	11	7	7	10	15	5	7	18	25	12	100	90	67
3847	1	10	7	8	10	9	15	4	7	15	24	11	96	0	85
3725	1	12	11	8	8	6	10	7	7	19	16	14	92	82	68
3730	0	11	7	11	8	7	8	8	7	18	15	15	121	126	90
3724	1	10	10	10	9	11	8	11	11	20	19	22	109	108	91
3721	1	9	14	10	10	8	14	7	8	24	22	15	103	99	94
3723	1	8	12	12	9	11	11	10	4	24	22	14	91	85	88
3712	1	11	5	4	7	7	11	10	6	9	18	16	88	80	67
3716	1	11	8	5	5	7	9	10	5	13	16	15	80	72	59
3718	1	8	8	7	1	9	9	5	5	15	18	10	108	100	79
3698	0	10	11	8	13	14	15	5	10	19	29	15	99	99	98
3908	1	10	7	14	5	3	7	6	5	21	10	11	66	70	76
3529	1	13	12	13	10	11	15	11	5	25	26	16	110	99	88
3510	1	8	12	8	9	14	15	7	9	20	29	16	81	87	89
3493	1	10	18	19	18	10	8	15	11	37	18	26	146	133	124
3492	1	9	6	5	5	12	10	6	2	11	22	8	63	78	74

3491	1	8	12	14	12	18	13	10	4	26	31	14	122	114	104
3225	0	13	9	8	9	12	10	9	9	17	22	18	91	81	80
3224	1	14	12	10	11	15	14	9	9	22	29	18	112	112	0
3222	0	11	9	9	8	9	12	12	6	18	21	18	108	97	73
3220	1	11	4	5	5	11	16	7	5	9	27	12	68	64	73
3219	1	9	9	6	5	12	10	6	4	15	22	10	80	77	84
3216	1	8	15	12	13	13	14	8	8	27	27	16	114	106	96
3212	0	9	4	7	6	4	6	4	6	11	10	10	78	78	77
3210	1	9	10	5	8	9	11	10	7	15	20	17	94	92	99
3237	1	11	2	3	12	13	10	10	10	5	23	20	74	76	98
3231	1	10	8	8	6	11	14	6	4	16	25	10	78	79	81
3230	0	8	11	11	10	11	6	10	12	22	17	22	112	110	105
3229	1	9	9	9	10	10	12	12	7	18	22	19	99	98	89
3226	1	11	11	10	9	10	13	8	6	21	23	14	103	83	71
3272	0	10	12	9	7	10	9	11	6	21	19	17	88	83	73
3271	1	11	6	8	8	9	14	5	10	14	23	15	75	74	78
3266	1	13	8	7	8	15	14	8	6	15	29	14	77	74	75
3264	0	13	10	9	13	6	10	11	11	19	16	22	127	108	98
3261	1	12	11	11	9	12	12	5	6	22	24	11	96	85	93
3247	0	10	13	13	7	10	10	7	11	26	20	18	114	108	83
3289	1	12	9	8	14	8	9	9	9	17	17	18	90	62	104
3889	1	13	11	11	8	15	14	9	7	22	29	16	91	82	74
3869	0	9	7	13	11	12	9	6	11	20	21	17	100	100	103
3938	0	8	11	10	7	13	12	10	9	21	25	19	81	89	96
3937	1	11	5	6	7	11	11	5	7	11	22	12	79	73	79
3930	1	13	5	7	5	11	10	7	8	12	21	15	88	72	70
3926	1	10	13	10	7	9	10	5	6	23	19	11	96	89	79
3923	0	12	5	6	6	5	5	8	1	11	10	9	0	108	0
3988	1	10	10	16	10	10	12	11	11	26	22	22	91	91	96
3985	1	9	9	12	12	13	14	8	11	21	27	19	92	94	92
3966	1	8	12	12	7	12	11	11	5	24	23	16	0	83	89
3944	1	9	6	6	3	5	5	7	3	12	10	10	96	90	72
4045	1	12	19	16	10	16	14	8	9	35	30	17	0	76	0
4024	1	10	4	7	3	3	5	3	1	11	8	4	84	85	70
4022	0	8	13	17	9	12	9	7	8	30	21	15	114	104	101
4015	1	14	7	8	9	9	7	8	11	15	16	19	99	100	78
3991	1	10	10	9	8	14	11	7	7	19	25	14	97	97	86
3543	1	14	11	9	11	11	8	12	10	20	19	22	108	93	98
3548	1	13	10	6	8	12	11	4	8	16	23	12	87	72	77
3560	1	8	12	14	6	11	12	6	6	26	23	12	73	72	88
3565	1	9	9	8	8	13	10	11	11	17	23	22	66	79	92
3585	1	11	14	9	7	7	8	9	8	23	15	17	100	96	73
3582	1	9	11	9	8	14	15	6	8	20	29	14	94	96	96
3575	0	10	14	14	13	14	12	13	12	28	26	25	97	86	94
4183	0	10	5	6	7	9	8	10	6	11	17	16	92	91	83
4190	1	10	9	12	9	13	13	9	9	21	26	18	120	103	99
4253	1	13	16	14	10	10	10	8	5	30	20	13	92	110	105
4245	1	11	9	11	11	13	9	6	15	20	22	21	98	101	99
4243	1	8	13	15	13	15	13	8	13	28	28	21	103	102	110
4239	0	10	17	12	12	13	9	10	12	29	22	22	112	103	96
4224	0	8	5	4	3	5	3	2	1	9	8	3	68	61	76

4223	0	10	10	10	12	11	9	10	15	20	20	25	118	112	104
4264	0	11	16	12	13	10	8	10	13	28	18	23	116	115	96

Appendix E
REGRESSION TABLES-SAMPLE 2

Table E1

Total Sample (N=309): WRAT A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .5814
R Square .3381
Adjusted R Square .3359
F=156.81, 1, 307 df, $p < .001$

Variables in the Equation

Variable	B	Eta
Verbal	1.30	.58

Step 2: Multiple R .6130
R Square .3758
Adjusted R Square .3717
F=92.14, 2, 306 df, $p < .001$

Variables in the Equation

Variable	B	Beta
Verbal	1.08	.48
Memory	.62	.21

Table E2

Total Sample (N=315): WISC-R A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .6143
R Square .3774
Adjusted R Square .3754
F=189.78, 1, 313 df, $p < .001$

Variables in the Equation

Variable	B	Beta
Verbal	.29	.61

Step 2: Multiple R .6855
R Square .4699
Adjusted R Square .4665
F=138.32, 2, 312 df, $p < .001$

Variables in the Equation

Variable	B	Beta
Verbal	.22	.45
Memory	.21	.34

Step 3: Multiple R .7138
R Square .5096
Adjusted R Square .5049
F=107.73, 1, 311 df, $p < .001$

Variables in the Equation

Variable	B	Beta
Verbal	.161	.34
Memory	.19	.31
Spatial	.11	.23

Table E3

Males Only (N=211): WRAT A by Verbal, Spatial
and Memory Dimensions (N=211)

Step 1: Multiple R .5605
R Square .3142
Adjusted R Square .3109
F= 95.77, 1, 209 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	1.26	.56

Step 2: Multiple R .5968
R Square .3562
Adjusted R Square .3500
F=57.56, 2,208 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	1.04	.46
Memory	.71	.22

Table E4

Males Only (N=215): WISC-R A by Verbal,
Spatial and Memory Dimensions

Step 1: Multiple R .5639
R Square .3180
Adjusted R Square .3148
F= 99.32, 1, 213 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.27	.56

Step 2: Multiple R .6494
R Square .4217
Adjusted R Square .4163
F=77.31, 2, 212 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.20	.41
Memory	.24	.35

Step 3: Multiple R .6683
R Square .4466
Adjusted R Square .4388
F= 56.77, 3, 211 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.16	.33
Memory	.23	.33
Spatial	.08	.17

Table E5

Females Only (N=98): WRAT A by Verbal, Spatial
and Memory Dimensions

Step 1: Multiple R .6196
R Square .3839
Adjusted R Square .3775
F= 59.83, 1, 96 df, p<.001

Variables in the Equation

Variable	B	Eeta
Verbal	1.43	.61

Step 2: Multiple R .6441
R Square .4148
Adjusted R Square .4025
F=33.67, 2, 95 df, p<.001

Variables in the Equation

Variable	B	Eeta
Verbal	1.12	.48
Spatial	.56	.22

Table E6

Females Only (N=100): WISC-R A by Verbal,
Spatial and Memory Dimensions

Step 1: Multiple R .6957
R Square .4840
Adjusted R Square .4787
F= 91.93, 1, 98 df, p<.001

Variables in the Equation

Variable	B	Eeta
Memory	.33	.69

Step 2: Multiple R .7822
R Square .6118
Adjusted R Square .6038
F=76.45, 2, 97 df, p<.001

Variables in the Equation

Variable	B	Beta
Memory	.21	.44
Verbal	.19	.43

Step 3: Multiple R .8075
R Square .6521
Adjusted R Square .6412
F= 59.98, 3, 96 df, p<.001

Variables in the Equation

Variable	B	Eeta
Memory	.17	.36
Verbal	.14	.32
Spatial	.12	.26

Table E7

Males 8 and 9 years (N=85): WRAT A by Verbal,
Spatial and Memory Dimensions

Step 1: Multiple R .5727
R Square .3280
Adjusted R Square .3199
F= 40.51, 1, 83 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	1.07	.57

Step 2: Multiple R .6515
R Square .4245
Adjusted R Square .4105
F=30.24, 2, 82 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.74	.39
Memory	.95	.35

Table F8

Males 8 and 9 years (N=86): WISC-R A by Verbal,
Spatial and Memory Dimensions

Step 1: Multiple R .5894
R Square .3474
Adjusted R Square .3396
F= 44.72, 1, 84 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.31	.58

Step 2: Multiple R .6464
R Square .4179
Adjusted R Square .4039
F=29.79, 2, 83 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.23	.43
Memory	.23	.30

Table F9

Males 10 and 11 years (N=59): WISC-R A by Verbal,
Spatial and Memory Dimensions

Step 1: Multiple R .4826
R Square .2329
Adjusted R Square .2194
F= 17.30, 1, 57 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	1.10	.48

Step 2: Multiple R .5430
R Square .2948
Adjusted R Square .2697
F=11.70, 2, 56 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.86	.38
Spatial	.65	.26

Table E10

ce begin Males 10 and 11 years (N=59): WISC-R A by Verbal,
Spatial and Memory Dimensions

Step 1: Multiple R .5763
R Square .3321
Adjusted R Square .3204
F= 28.34, 1, 57 df, p<.001

Variables in the Equation

Variable	B	Eeta
Verbal	.27	.57

Step 2: Multiple R .6383
R Square .0474
Adjusted R Square .3862
F=19.25, 2, 56 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.22	.46
Spatial	.15	.29

Step 3: Multiple R .6860
R Square .4707
Adjusted R Square .4418
F= 16.30, 3, 55 df, p<.001

Variables in the Equation

Variable	B	Eeta
Verbal	.16	.34
Spatial	.16	.31
Memcry	.19	.27

Table E11

Males 12, 13 and 14 years (N=67): WRAT A by
Verbal, Spatial and Memory
Dimensions

Step 1: Multiple R .5157
R Square .2659
Adjusted R Square .2546
F= 23.55, 1, 65 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	1.10	.65

Step 2: Multiple R .5804
R Square .3368
Adjusted R Square .3161
F=16.25, 2, 64 df, p<.001

Variables in the Equation

Variable	B	Beta
Verbal	.87	.40
Memory	.70	.28

Table E12

Males 12, 13 and 14 years (N=70): WISC-R A by
Verbal, Spatial and Memory Dimensions

Step 1: Multiple R .6399
R Square .4095
Adjusted R Square .4008
F= 47.17, 1, 68 df, p<.001

Variables in the Equation

Variable	B	Beta
Memory	.37	.63

Step 2: Multiple R .7131
R Square .5085
Adjusted R Square .4938
F=34.66, 2, 67 df, p<.001

Variables in the Equation

Variable	B	Beta
Memory	.30	.51
Verbal	.15	.33

Appendix F
MANOVA TABLES-SAMPLE 2

Table F1

Total Sample (N=306): Groups by Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.52	38.08	6	602	<.001

Univariate F-Tests (2,303 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	3258.10	6852.84	1629.05	22.61	72.02	<.001
Spatial	2212.40	8065.82	1106.20	26.61	41.55	<.001
Memory	2003.16	4248.88	1001.58	14.02	71.42	<.001

Table F2

Total Sample: WISC-R A-;WRAT A- (N=71) VS.
 WISC-R A+;WRAT A+ (N=69) on Cognitive
 Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.36	79.44	3	136	<.001

Univariate F-Tests (2,138 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	3205.30	3488.48	3205.30	25.27	126.79	<.001
Spatial	1860.21	3890.20	1860.21	28.18	65.98	<.001
Memory	1832.71	1919.02	1832.71	13.90	131.79	<.001

Table F3

Total Sample: WISC-R A-;WRAT A- (N=71) VS.
 WISC-R A+;WRAT A- (N=166) on Cognitive
 Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.62	47.26	3	233	<.001

Univariate F-Tests (2,235 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	1532.26	5003.54	1532.26	21.29	71.96	<.001
Spatial	1642.42	6498.49	1642.42	27.65	59.39	<.001
Memory	1275.73	3423.41	1275.73	14.56	87.57	<.001

Table F4

Total Sample: WISC-R A+;WRAT A- (N=166) VS.
 WISC-R A+;WRAT A+ (N=69) on Cognitive
 Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.83	15.42	3	231	<.001

Univariate F-Tests (2,233 df)

Variable	Hypcth SS	Error SS	Hypcth MS	Error MS	F	p
Verbal	787.62	5213.66	787.62	22.37	35.19	<.001
Spatial	116.22	5742.95	116.22	24.64	4.71	<.031
Memory	229.95	3155.33	229.95	13.54	16.98	<.001

Table F5

Males Only (N=209): Groups by Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.58	20.71	6	408	<.001

Univariate F-Tests (2,206 df)

Variable	Hypoth SS	Errorr SS	Hypcth MS	Errorr MS	F	p
Verbal	1921.06	4867.12	960.53	23.62	40.65	<.001
Spatial	919.19	5740.99	459.59	27.86	16.49	<.001
Memory	980.90	2518.09	490.45	12.22	40.12	<.001

Table F6

Males Only: WISC-R A-; WRAT A- (N=38) VS.
 WISC-R A+; WRAT A+ (N=45) on Cognitive
 Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypoth df	Error df	F
Group	Wilks	.39	40.06	3	79	<.001

Univariate F-Tests (2, 81 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	F
Verbal	1920.05	2215.81	1920.05	27.35	70.18	<.001
Spatial	864.82	2605.56	864.82	32.16	26.88	<.001
Memory	920.97	1042.59	920.97	12.87	71.55	<.001

Table F7

Males Only: WISC-R A-;WRAT A- (N=38) VS.
WISC-R A+;WRAT A- (N=126) on Cognitive
Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.68	24.26	3	160	<.001

Univariate F-Tests (2,162 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	756.95	3560.14	756.95	21.97	34.44	<.001
Spatial	605.77	4614.19	650.77	28.48	21.26	<.001
Memory	650.22	1964.89	650.22	12.12	53.60	<.001

Table F8

Males Only: WISC-R A+;WRAT A- (N=126) VS.
WISC-R A+;WRAT A+ (N=45) on Cognitive
Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypoth df	Error df	p
Group	Wilks	.82	11.58	3	167	<.001

Univariate F-Tests (2,169 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	690.04	3958.27	690.04	23.42	29.46	<.001
Spatial	122.71	4262.22	122.71	25.22	4.86	<.029
Memory	128.24	2028.70	128.24	12.00	10.68	<.001

Table F9

Females Only (N=97): Groups by Cognitive Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypoth df	Error df	p
Group	Wilks	.43	16.01	6	184	<.001

Univariate F-Tests (2, 94 df)

Variable	Hypoth SS	Error SS	Hypoth MS	Error MS	F	p
Verbal	1189.97	1847.96	594.98	19.65	30.26	<.001
Spatial	931.94	1642.22	465.97	17.47	26.67	<.001
Memory	1208.65	1475.40	604.32	15.69	38.50	<.001

Table F10

Females Only: WISC-R A-;WRAT A- (N=33) VS.
WISC-R A+;WRAT A+ (N=24) on Cognitive
Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.29	41.38	3	53	<.001

Univariate F-Tests (2, 55 df)

Variable	Hypoth SS	Errorr SS	Hypcth MS	Error MS	F	p
Verbal	1106.60	1160.06	1106.60	21.09	52.46	<.001
Spatial	772.13	848.84	772.13	15.43	50.02	<.001
Memory	988.74	793.50	988.74	14.42	68.53	<.001

Table F11

Females Only: WISC-R A-;WRAT A- (N=33) VS.
 WISC-R A+;WRAT A- (N=40) on Cognitive
 Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.53	19.73	3	69	<.001

Univariate F-Tests (2, 71 df)

Variable	Hypoth SS	Error SS	Hypcth MS	Error MS	F	p
Verbal	575.37	1380.62	575.37	19.44	29.58	<.001
Spatial	597.05	1348.89	597.05	18.99	31.42	<.001
Memory	790.19	1281.77	790.19	18.05	43.77	<.001

Table F12

Females Only: WISC-R A+;WRAT A- (N=40) VS.
 WISC-R A+;WRAT A+ (N=24) on Cognitive
 Dimensions

Multivariate Test

Effect	Test Name	Value	Approx F	Hypcth df	Error df	p
Group	Wilks	.85	3.42	3	60	<.001

Univariate F-Tests (1, 62 df)

Variable	Hypoth SS	Error SS	Hypcth MS	Error MS	F	p
Verbal	161.70	1155.23	161.70	18.63	8.67	<.001
Spatial	43.77	1086.70	43.77	17.52	2.49	<.119
Memory	49.95	875.52	49.95	14.12	3.53	<.065

Appendix G
ARITHMETIC GRADE SCORES

Table G1

Obtained Score on the WISC-R A (scaled scores),
WRAT and KDAT (grade scores) and Expected Grade
Scores for Eighteen Cases

Test	Subject Number							
	1	2	3	4	5	6	7	8
WISC-R A	6	4	6	6	5	5	6	5
WRAT A	5.7	3.9	3.7	3.9	4.3	2.7	3.5	2.7
KDAT								
-Numeration	3.4	1.1	1.6	4.0	4.2	1.7	2.0	2.8
-Geometry and Symbols	3.8	3.0	3.2	3.0	3.5	2.6	3.4	2.6
-Addition	6.4	4.0	1.8	4.7	4.4	2.0	2.6	2.8
-Subtraction	4.2	3.2	2.6	5.5	4.7	1.4	2.0	2.0
-Multiplication	5.0	3.8	2.0	5.0	5.6	3.0	2.6	2.0
-Word Problems	3.2	2.5	1.7	2.8	3.2	3.0	3.0	3.4
WRAT Reading	6.2	3.4	4.0	4.5	4.0	4.8	3.6	4.0
WRAT Spelling	3.6	2.4	3.5	3.6	3.0	3.0	3.1	4.3
Expected Grade	8.9	7.9	5.9	7.9	8.9	8.9	6.9	6.9

Table G1 continued

Test	Subject Number									
	9	10	11	12	13	14	15	16	17	18
WISC-R A	9	8	7	7	7	11	7	12	13	11
WRAT A	3.9	4.9	3.7	4.7	3.5	4.5	4.5	4.1	7.5	7.1
KDAT										
-Numeration	4.4	2.5	2.8	2.5	2.6	5.3	3.5	3.5	4.2	5.3
-Geometry and Symbols	3.0	1.8	3.2	3.2	2.6	5.0	3.2	2.6	6.4	8.4
-Addition	4.2	4.2	2.0	3.5	3.5	4.7	3.5	5.0	5.0	8.4
-Subtraction	5.6	5.6	2.8	2.0	1.4	8.4	5.0	3.5	5.6	8.4
-Multiplication	5.3	6.0	2.6	5.3	2.1	5.6	4.0	3.0	6.0	6.0
-Word Problems	8.4	3.8	2.8	8.4	3.0	3.4	3.2	3.2	6.4	6.4
WRAT Reading	4.5	2.8	3.8	4.1	4.0	4.1	4.6	3.4	7.7	7.7
WRAT Spelling	3.0	2.9	2.8	3.7	3.9	3.9	4.1	4.1	5.9	6.8
Expected Grade	8.9	6.9	4.9	6.9	4.9	5.9	5.9	5.9	6.9	6.9

Appendix H
QUALITATIVE ANALYSIS OF ERRORS

Table H1

Scoring Criteria for Types of Errors Made
in Calculation of Whole Numbers on the KDAT

Error Types

1. Basic Fact: Error in combining numbers (e.g., $2+3=7$; $3 \times 5=17$)
2. Incorrect Carry/Borrow: error may include neglecting to combine carried/borrowed number with appropriate column, carrying/borrowing incorrect number, combining carried/borrowed number with incorrect column
3. No Concept of Carry/Borrow: error may include neglecting to carry or borrow (e.g., $66+4=610$; in subtraction, may subtract top number from bottom (e.g., $370-82=312$) or may appear as addition (e.g., $500-94=594$)
4. Incorrect Operation: error is obviously in operation, otherwise solution is correct (e.g., $8-2=10$)
5. Neglect \$ or decimal: no \$ or decimal included in solution when necessary
6. Misalignment: error in aligning rows and columns for solution
7. Bizarre error: unique solution not readily accounted for by other types of error; may include changing operations for each column
8. Problems Not Attempted: number of problems not attempted by child (Addition total=9) (Subtraction total=9), (Multiplication total=8)
9. Incomplete solution: Solution to problem was attempted but not completed
10. Addition error in Multiplication: error occurred in addition of columns to attain final solution

Note: Error types are not mutually exclusive

Table H2
Qualitative Analysis of Errors

Type of Error Made In Calculation	Subject Number							
	1	2	3	4	5	6	7	8
<hr/>								
Addition								
-basic fact		1				3		
-incorrect carry						1	1	1
-no concept of carry			3					
-incorrect operation								
-neglect \$ or decimal	1				1	1		2
-misalignment								
-bizarre error						1		
-problems not attempted			2				2	
<hr/>								
Subtraction								
-basic fact	1		1			2		1
-incorrect borrow	2	1			2			2
-no concept of borrow		1	2			5	6	3
-incorrect operation								
-neglect \$ or decimal		2		1	1			
-misalignment								
-bizarre error								
-problems not attempted			3					
<hr/>								
Multiplication								
-basic fact	1	1	1	3	2	2	2	2
-incorrect carry					1	1	2	
-no concept of carry								3
-incorrect operation								
-neglect \$ or decimal	1							
-misalignment								
-bizarre error							1	
-problems not attempted		3	7				2	3
-solution incomplete						1	1	
-addition error						1		
<hr/>								

Table H2 continued

Type of Error Made In Calculation	Subject Number									
	9	10	11	12	13	14	15	16	17	18

Addition										

-basic fact			1							
-incorrect carry	1		2	1	1				1	
-no concept of carry										
-incorrect operation										
-neglect \$ or decimal		2	1	2	1	1	1			
-misalignment										
-bizarre error							1			
-problems nct attempted			1							

Subtraction										

-basic fact										
-incorrect borrow			2	1	1		1		2	
-no concept of borrow				4	5			4		
-incorrect operation										1
-neglect \$ or decimal	1	1		2			1			
-misalignment										
-bizarre error			1	1	1					
-problems nct attempted			2							

Multiplication										

-basic fact			1	2	2		2			1
-incorrect carry	2			2		1				1
-no concept of carry					2					
-incorrect operation				1	1					
-neglect \$ or decimal	1	1					1			
-misalignment										
-bizarre error							1			1
-problems nct attempted			5		3		1	5		
-solution incomplete				2						
-addition error										

Appendix I
SUMMARY OF COGNITIVE ABILITIES

Table I1

Scoring criteria for Cognitive Measures

1. WISC-R subtests - Similarities (SIM), Vocabulary (VOCAB), Block Design (BD), Object Assembly (OA), Coding (CCD), Digit Span (DS), Picture Arrangement (PA)

Scaled Score	Code
19	= +3
18,17,16	= +2
15,14,13	= +1
12,11	= +
10	= x
9,8	= -
7,6,5	= -1
4,3,2	= -2
1	= -3

2. Auditory Discrimination Test (Aud. Discrim.)

Errors	Code
0-3	= +
4-5	= -
6-7	= -1
8-9	= -2

3. Subtests of the Illinois Test of Psycholinguistic Abilities (ITPA) - Auditory Association (Aud.Assoc.), Visual Association (Vis. Assoc.), Visual Sequential Memory (VSM) and the Hiskey-Nebraska Test of Learning Aptitude (HNTLA) - Spatial Reasoning (Sp. Reas.)

Age Equivalent	Code
age +4.0-6.0 yrs.	= +2
age +2.0-3.9 yrs.	= +1
age +.7-1.9 yrs.	= +
age + or - .6	= x
age -.7- -1.9 yrs.	= -
age -2.0- -3.9 yrs.	= -1
age -4.0- -6.0 yrs.	= -2

4. Benton Visual Retention Test (BVRT)

Normal Range	= +
Below Normal Range	= -

5. Other Tests - Controlled Word Association Test (CWAT), Embedded Figures Test (EFT), Right-Left Orientation Test (R-L), Coloured Progressive Matrices (CPM), Rey Auditory Verbal Learning Test (RAVLT), Sentence Repetition Test (Sen Rep.)
Token Test for Children

Percentile	=	Code
99.9	=	+3
98	=	+2
84	=	+1
50	=	x
16	=	-1
2	=	-2
1	=	-3

Table I2
Summary of Cognitive Abilities for Cases

Verbal-Auditory	Subject Number							
	1	2	3	4	5	6	7	8
SIM (WISC-R)	-1	-1	-1	-1	+	-	-	-1
Vocab (WISC-R)	-1	-	-1	-1	-1	-2	+	x
Token Test for Children	+	x	-	-	-	-	+1	x
Aud. Discrim.	+	-2	+	-1	-	+	+	+
CWAT	-1	-1	-3	-	-1	-1	-	-
Aud. Assoc. (ITPA)				-2	-1	-1	-1	+

Visual-Spatial								

BD (WISC -R)	+	-	-1	+	+	+1	-3	+1
OA (WISC-R)	+1	-	-1	+	+	+	-1	+2
Sp. Reas. (HNTIA)	-2	x	-1	+2	-1	-2	-2	+
PA (WISC-R)					+		x	
EFT				+			-1	x
R-L			-	+2			-	-
CPM	+	x	-	+	x	+	-1	+
Vis. Assoc. (ITPA)	+						-2	+

Memory								

Cod (WISC-R)	-1	-3	-1	x	+	x	-1	-
BVRT	+	-	-	+	+	+	-	+
VSM (ITPA)	-1	-2					-2	-2
DS (WISC-R)	-2	-3	-2	-2	-	-	-2	-
RAVLT	-	-1	-1	-1	-	-1	-3	-3
Sen. Rep.	-1	-1	-	-1	-3	-1	-	-

Table I2 Continued

Verbal-Auditory	Subject Number									
	9	10	11	12	13	14	15	16	17	18
SIM (WISC-R)	-1	+	+1	-1	x	+1	-	x	+2	x
Vocab (WISC-R)	-	+1	+	+	-1	+	+	+	+	+
Token Test for Children	+	+1	+	+1	-1	-	-	+1	+1	x
Aud. Discrim.	-		-		+			+		
CWAT	x		-	+	-	+	x	+		
Aud. Assoc. (ITPA)	-1			+						

Visual-Spatial										

BD (WISC -R)	x	+1	+2	x	+	+1	+2	+	+	+1
OA (WISC-R)	-	+2	+3	+3	-1	+1	+2	-	+1	+1
Sp. Reas. (HNTLA)	-	+2	+2	x	-	+1	x	-	-	-
PA (WISC-R)	+	x								
EFT								+2	-1	
R-L			+		+1					
CPM	x	+3	+1	-	+			+2		
Vis. Assoc. (ITPA)				-1						

Memory										

Cod (WISC-R)	-	-	-	-	-1	-	+1	-1	+1	+1
BVRT	+	+	+	+	+	+	+	+	-	+
VSM (ITPA)			-	-1	-			-1		
DS (WISC-R)	-1	-	-2	-	-2	-1	-1	-1	+	-
RAVLT	-	-	x	-	x	-3	-	x	-	+
Sen. Rep.	+	-	-	-	-	-	-	+2		

Appendix J**ERRORS ON INFORMAL ARITHMETIC TASKS**

Table J1
 Errors (e) on Informal Arithmetic Tasks
 for Cases

Informal Assessment Tasks	Subject Number							
	1	2	3	4	5	6	7	8

Writing Numbers (Items=15)								
-number reversal	0e	0e	0e	0e	0e	0e	0e	0e
-order reversal	0e	1e	0e	0e	0e	0e	1e	0e
-number struc- ture	1e	2e	0e	0e	0e	0e	1e	0e
Reading Numbers (Items=18)								
-number struc- ture	0e	1e	0e	0e	0e	0e	0e	0e
-orientation	0e	3e	0e	0e	0e	0e	0e	0e
Number Relations (Items=5) (larger, smaller)	0e	0e	0e	0e	0e	0e	0e	0e
Place Value Concepts (Item=9)	8e	7e	5e	4e	0e	1e	1e	8e
Number Sequence (Items=10)	0e	3e	5e	0e	1e	1e	8e	2e
Skip Counting								
-2s (Items=10)	0e	4e	0e	0e	0e	4e	1e	2e
-5s (Items=10)	0e	2e	0e	0e	0e	0e	0e	0e
-10s (Items=10)	0e	0e	0e	0e	0e	0e	0e	0e
-3s (Items=10)	0e	3e	2e	0e	2e	3e	2e	1e
-backwards 3s (Items=6)	3e	NA	NA	0e	2e	NA	5e	NA
WISC-R A (scaled score) with pencil and paper	8	4	6	6	9	6	7	6

Table J1 Continued

Informal Assessment Tasks	Subject Number									
	9	10	11	12	13	14	15	16	17	18

Writing Numbers (Items=15)										
-number reversal	0e		0e		0e			0e		
-order reversal	0e		0e		0e			0e		
-number struc- ture	0e		1e		3e			0e		
Reading Numbers (Items=18)										
-number struc- ture	0e		0e		1e			0e		
-orientation	0e		0e		1e			1e		
Number Relaticns (Items=5)										
(larger, smaller)	0e		0e		0e			0e		
Place Value Concepts (Item=9)	6e		0e		2e			2e		
Number Sequence (Items=10)	0e		2e		2e			1e		
Skip Counting										
-2s (Items=10)	0e		0e		0e			0e		
-5s (Items=10)	0e		0e		0e			0e		
-10s (Items=10)	0e		0e		0e			0e		
-3s (Items=10)	0e		3e		3e			1e		
-backwards 3s (Items=6)	0e		4e		6e			2e		
WISC-R A (scaled score) with pencil and paper	9		7		7					

VITA (Continued)

Publications:

Human Developmental Neuropsychology. New York: Oxford

University Press, Book in preparation (1983).

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COGNITIVE CORRELATES OF ARITHMETIC PERFORMANCE
IN CLINIC REFERRED CHILDREN

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