Academic, Visuoconstructional, and Social Performance in Children

by

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B.Sc., University of Alberta, 1983

M.A., University of Victoria, 1986

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in the Department of Psychology

We accept this thesis as conforming to the required standard

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Supervisor: Dr. Ctfried Spreen

ABSTRACT

This study was conducted to evaluate the relationships among academic performance, visuoconstructional strategies, and social competence in children. In accordance with the theory of nonverbal learning disabilities, it was predicted that math disability would be associated with difficulties in social competence and construction of configurations. A total of 229 school children were referred by their teachers to the study. After screening, 79 children aged from 104 to 143 months were included in the analyses. All subjects had scores on the WISC-R Block Design and Vocabulary subtests which were at least average, and were classified as Average Achievers (n=29), Low in Reading (n=14), Low in Math (n=17), or Low Overall (n=19), on the basis of their WRAT-R scores. The groups were compared on measures of visuoconstructional performance and social competence. The results partially supported an association between weak configural performance and math disorders. Social competence was found to be most strongly related to attentional performance/hyperactivity. Components of visuoconstructional performance (configural and detail-oriented) were found to be relevant to learning and memory. The two measures of visuoconstruction used appear to measure different aspects of cognitive performance.

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I thank the children who took part in this study, as well as their parents. I am also grateful to members of the participating school districts, including the superintendents, principals, and particularly the teachers. This study would not have been possible without their involvement.

For their interest, expert guidance, and many helpful suggestions, I would like to thank my supervisory committee, especially my supervisor Dr. O. Spreen, and committee member Dr. R. Graves.

For his unflagging patience and encouragement throughout my years of graduate work, I thank my husband, Kenneth Leason.

This project was supported by a generous research grant from the Sara Spencer Foundation.

Academic, Visuoconstructional, and Social Performance in Children

Introduction

In recent years the heterogeneous nature of learning disabilities has become evident. While there is no consensus on the number or nature of specific subtypes, the general categories of verbal, nonverbal, and mixed learning disabilities are widely acknowledged (for review, see Hooper & Willis, 1989). Verbal learning disabilities are characterized by difficulty in psycholinguistic skills including reading, spelling, and auditory perception, accompanied by average or better visuospatial and nonverbal problem solving skills. In contrast, nonverbal learning disabilities are described as including impairments in at least three areas: arithmetic, visuospatial/visuoconstructional, and social competence, in the presence of average or better auditory-perceptual and verbal skills (Badian, 1983; Denckla, 1983; Rourke, 1987; Rourke & Finlayson, 1978; Rourke & Strang, 1978; Rudel, Teuber, & Twitchell, 1974; Strang & Rourke, 1983; Tranel, Hall, Olson, & Tranel, 1987).

Johnson and Myklebust (1967) have offered a theory of learning disabilities which explains this apparently incongruous triad of nonverbal learning impairments. They postulate that a child's cognitive development progresses along a hierarchy of experience in which basic cognitive levels of sensation, perception, and imagery are succeeded by the higher levels of symbolization and conceptualization. Nonverbal learning disabilities (NLD) are theorized to result from disturbances in perception. Because they occur at such a basic level, perceptual disorders cause a fundamental distortion of all aspects of the child's everyday experience. The effects are particularly devastating in the development of social competence. The nonverbally-disabled child is:

> ...unable to comprehend the significance of many aspects of his environment....He fails to learn the implications of many other actions, e.g., gestures, facial expressions, and caresses....We characterize this child as having a deficiency in <u>social perception</u> meaning that he has an inability which precludes acquiring the significance of basic nonverbal aspects of daily living. (Johnson & Myklebust, 1967, p. 272).

Associated with this syndrome, Johnson & Myklebust list deficits in: learning through pictures, gesture, nonverbal motor learning, body image, spatial orientation, right-left orientation, social imperception, and distractibility, perseveration, and disinhibition.

Arithmetic disability was not included in this original formulation as a component of NLD. However, in their discussion of arithmetic disabilities, the authors note that mathematical thinking is based on the assimilation and integration of nonverbal experiences, including concepts of quantity, space, and order. The cognitive characteristics they describe in the dyscalculic child bear many similarities to those noted in the NLD child, including deficits in: visual-spatial organization and nonverbal integration, body image, visual-motor integration, right-left disorientation, and social perception.

In the formulation described by Johnson and Myklebust, disorders occurring near the top of the hierarchy of experience, such as a deficit in symbolization, result in verbal learning disabilities. Because the basic levels of experience are unaffected, these disorders are expected to have more restricted effects on the overall functioning of the child. In this theory personal-social deficits are characteristic of the NLD child, who has had atypical interactions with the environment almost from the beginning.

Rourke (1987, 1993) has proposed a model of NLD which is similar in principle but which includes a neurological substrate for the disorder. In this model, the NLD child is thought to be deficient in inter-modal integration, because of impaired functioning in the white matter of the brain. Because the right hemisphere is thought to have relatively more white matter than the left, and relatively more inter-regional than intra-regional connections, dysfunction of the right hemisphere is implicated in nonverbal learning disorders (Semrud-Clikeman & Hynd, 1990). This dysfunction results in difficulty processing novel information. The child therefore is forced to rely on routinized and stereotyped responses, and has difficulty benefitting from experiences which do not fit well with existing skills. When these difficulties are present from an early age (i.e. the sensory-motor period), deviant cognitive development ensues. These children show deficits similar to those enumerated by Johnson and Myklebust: difficulty with visuospatial, tactile-perceptual, and psychomotor abilities, poor arithmetic and nonverbal problem-solving skills, difficulty with novelty, and significant deficits in social perception and social interaction in spite of well-developed rote verbal skills (Johnson & Myklebust, 1967).

Kolb (1989) has proposed that deficiencies in right hemisphere functioning may arise from early damage to the _left_ cerebral hemisphere. This damage causes language functions to shift to the right hemisphere, crowding out the later-developing right-hemisphere functions which are necessary for development of social competence.

The NLD model is not universally accepted, particularly the aspect of deficient visuospatial functioning leading to deficient social performance. Some authors who have studied social competence in relation to learning difficulties reject causal models and consider the link as correlational at best (Gresham, 1992). Others have suggested that a language disorder, rather than a visuoperceptual deficit, underlies both learning disabilities and social competence deficits (Conte & Andrews, 1993), and that children are rejected by peers due to inefficient and deficient use of language in social situations (Bryan, 1986). Difficulties with pragmatic language skills such as staying on topic, appreciating the point of jokes, and understanding the point of view of a listener, are commonly seen in children with learning difficulties. Vaughn and her colleagues have proposed a model of social competence as a higher order construct much like intelligence, comprising several interactive components which together lead to effective social behaviour. These components are: positive relationships with others; accurate/age-appropriate social cognition; absence of maladaptive behaviours; and effective social skills (Vaughn, Haager, Hogan, & Kouzekanani, 1992; Vaughn, Zaragoza, Hogan, & Walker, 1993). These various perspectives illustrate the difficulties of conceptualizing and defining a complex behaviour. In 1973, a panel of experts in child development tackled the problem, and their discussion yielded a list of 29 descriptive statements of the components of social competence in young children, ranging from "differentiated self-concept and consolidation of identity" to "enjoyment of humour, play and fantasy" (Anderson & Messick, 1974). The 29 components can be grouped into three categories of skills and abilities: perceptual, cognitive, and motor/language skills.

The NLD model specifies that difficulties in social competence should occur predominantly in those children showing other aspects of NLD: i.e., visuospatial difficulties and weak arithmetic skills. If, however, social competence develops independently as a skill in its own right, and is correlated with learning disabilities through some other mechanism, diverse subgroups of learning disabled children may show similar levels of social competence. Social competence may not be correlated with visuospatial and arithmetic skills, but learning disabled students in general may have weaker social competence than would average achievers.

The prevalence of social skills deficits in different subtypes of learning disabilities, and the relationship between visuoperceptual-visuospatial deficits and social skills, have yet to be established. This study will evaluate the relationships among social competence, visuoconstructional strategies, and academic performance.

Social Competence in Learning Disorders

Learning disabilities and social-emotional difficulties often occur together. This fact is taken into account in the recent definition of learning disabilities offered by the Interagency Committee on Learning Disabilities (Gresham & Elliott, 1989a), which includes not only academic difficulties but also social skills deficits as primary learning disabilities. Research has shown that many learning disabled children are less well-accepted than their average achieving peers, and are more often socially rejected. A meta-analysis of 39 studies published between 1974 and 1990 revealed that only 16% of learning disabled children have the same level of social competence as normal achievers, and only 23% of learning disabled are as well accepted as average achievers (Swanson & Malone, 1992). Large-scale sociometric studies which have included students with and without learning disabilities have found that approximately 30% of learning disabled students experience social rejection (Kistner & Gatlin, 1989; Sater & French, 1989; Wiener, Harris, & Shirer, 1990). Teachers rated 38% of 3863 learning-disabled students as showing deficits in social functioning (Baum, Duffelmeyer, & Geelan, 1988). These percentages are significantly higher than the 6-12% of normally-achieving children who are neglected or rejected by their peers (Sater & French, 1989; Wiener et al., 1990). In a recent study, learning-disabled students from kindergarten to grade three were rated by their teachers as showing lower social competence and more behaviour problems than average or high-achieving students (Vaughn et al., 1993). When subtypes of behaviour problems were examined, it was discovered that the learning disabled children differed from the average and high achievers on only one behaviour: attentional problems.

According to the model proposed by Vaughn and colleagues (1992, 1993) described on page 5, social competence results from interplay among four component skills. It is perhaps the case that only some of these components are associated with learning disabilities. The component which Vaughn's study, among many others, implicates as the most likely to occur in association with learning disability is maladaptive behaviour, specifically weak attentional skills and hyperactivity.

The association between hyperactivity, learning disabilities, and social competence. There is considerable overlap between the populations of learning-disabled children and hyperactive children. In childhood, comorbidity of attention deficit hyperactivity disorder and academic underachievement is common (Biederman & Sprich, 1991; Hinshaw, 1992; McGee & Share, 1988). This finding has been incorporated into the descriptions of attention deficit disorders given in the Diagnostic and Statistical Manual of Mental Disorders (3rd ed., 1980) and (3rd. ed. rev, 1987) of the American Psychiatric Association, as well as the most recent definition of learning disability offered by the U.S. Interagency Committee on Learning Disabilities, which is used for legislative, diagnostic and research purposes. This definition states:

> Learning disabilities is a generic term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities, or of social skills. These disorders are instrinsic to the individual and presumed to be due to central nervous system dysfunction. Even though a learning disability may occur concomitantly with other handicapping conditions . . . and *especially attention deficit disorder* [italics added], all of which may cause learning problems, a learning disability is not the direct result of those conditions or influences. (Gresham & Elliott, 1989a, p. 121)

Typical of the research findings is the results from a survey of teachers of 1593 elementary students, aimed at determining the incidence of learning and behavioural difficulties (Holborow & Berry, 1986). 7.7% of the students were rated as showing significant learning difficulties, while 11.4% showed significant hyperactivity. A significant linkage was found between hyperactivity and learning difficulties: seven times as many hyperactive children as nonhyperactive children, were having serious learning problems. Of those having learning difficulties, fully 41% were also rated as showing hyperactivity. Another study compared a group of 60 children diagnosed with attention deficit hyperactivity disorder (ADHD), with 30 children having academic problems and 30 normal controls, to determine psychometrically the rates of learning disabilities in each group (Semrud-Clikeman, Biederman, Sprich-Buckminster, Lehman, Faraone, & Norman, 1992). Using liberal criteria for learning disability, 38% of the ADHD group had learning disabilities; using more stringent criteria, 17 to 23% of the group were considered learning disabled. A follow-up study of 600 children, aged from one year to sixteen years in the initial phase, showed a strong association between learning disability and ADHD in both the initial and the follow-up phases (Cantwell & Baker, 1991). Forty percent of the learning disabled children in the initial study had ADHD; at follow-up four to five years later, 53% of the learning disabled sample had ADHD. Comparisons between samples of learning disabled and nonlearning disabled children, matched on age and Performance IQ, revealed that 63% of the learning disabled children had ADHD, versus only 30% of the nonlearning disabled children. In a group of seven third-grade children with developmental dyscalculia who did not improve significantly with special remedial education, four were found to have attention deficit disorder without hyperactivity (Shalev & Gross-Tsur, 1993).

Studies of behavioural profiles of learning-disabled children on instruments including the Child Behaviour

Checklist and the Personality Inventory for Children have revealed significant elevations on the Hyperactivity scales among others (McConaughy & Ritter, 1986; Nussbaum & Bigler, 1986). When 64 learning-disabled and 46 low-achieving boys in grades 3 to 6 were compared with 40 average boys on teacher ratings of hyperactivity and self-control, the two groups of boys with learning problems were rated as significantly higher in hyperactivity than were the normal boys (Merrell, 1990). Kindergarten students who were later identified as learning disabled, were rated by teachers as showing significantly greater attentional problems than average achievers or high-achieving students, and they were more frequently rejected by classmates (Vaughn et al., 1993).

It has in fact been shown that difficulties with social competence may be more strongly related to hyperactivity than to learning disabilities. Findings of weak social competence in association with learning disabilities may simply reflect the high base rate of ADHD in learning disabled children, rather than suggesting a causal association between the two. In an interesting study, twenty learning-disabled children were compared with twenty normal seven- to ten-year-olds on cognitive measures, the Conners Teacher Rating Scale, and on affective role-taking skills. Peer-domain social skills were related most consistently to hyperactivity ratings, not to academic standing (Bruck & Hebert, 1982). A group of boys in grades 3 to 6 was divided into those having learning disabilities (n=22), those having both learning disabilities and hyperactivity (n=19), and a comparison group of 157 normal children (Flicek & Landau, 1985). Peer sociometric ratings revealed that even though the learning-disabled group was less popular and more rejected than controls, those who were also hyperactive had the most severe social status problems and the most aversive social behaviours. Children with ADHD are likely to encounter social difficulties, even though the primary symptoms of ADHD do not include difficulties in interpersonal functioning (Landau & Moore, 1991). Peer sociometric ratings gathered on 27 clinic-referred children diagnosed with attention deficit disorders, aged six to thirteen years, were compared with those of 45 normal children. The children with attention deficits received significantly fewer "liked most" nominations, more "liked least" nominations, and had lower social preference scores (Carlson, Lahey, Frame, Walker, & Hynd, 1987).

To summarize, a significant proportion of learning-disabled children have social difficulties. A significant proportion also have attentional difficulties which may be the cause of their social difficulties. Is the incidence of attentional difficulties or hyperactivity, and/or impairment in social skills, greater among those children with NLD than among children with verbal learning disorders?

Unfortunately, the foregoing studies have not classified the learning-disabled children according to subtype and so do not address this issue. However, a number of studies have examined the interrelationships among components of NLD (i.e. arithmetic achievement, visuospatial ability, and social competence). Some of these relationships appear to be quite strongly established (i.e. academic achievement and social skills) while others require further elucidation (i.e. visuospatial ability and social skills; visuospatial ability and arithmetic achievement).

Arithmetic achievement and social competence. Those studies which have looked at social skills in children of varying ability in arithmetic generally support the proposition that arithmetic ability and social skills covary. In a review of studies examining sociability and arithmetic achievement in schoolchildren, a positive correlation between the two stood out clearly (Badian, 1983). Children having specific arithmetic disabilities have been rated as weaker in personal-social behaviour than their peers who had specific reading disabilities (Badian & Ghublikian, 1983; Munson, 1986) or who were normal achievers (Munson, 1986). In a recent study of almost 600 children, including 90 who were learning disabled, the pattern of relationship between peer acceptance ratings and academic achievement was different for arithmetic than it was for reading scores (Wiener et al., 1990). Whereas in both the total sample and in the subgroup of learning-disabled the correlation between peer acceptance and WRAT-R arithmetic score did not reach significance, there was a significant negative correlation between peer acceptance and reading score in the learning-disabled group only, reflecting less effective peer interactions in those learning-disabled children who are better readers. In this study the achievement profile was important: whereas the arithmetic score in itself was not a predictor of social success, those learning-disabled children whose arithmetic performance was weaker than their reading performance were the ones experiencing peer relationship difficulties. Similar findings have been reported by Rourke and his colleagues (Rourke & Finlayson, 1978; Rourke & Strang, 1978, 1983), who found that, of the learning-disabled children who had equally weak performances in WRAT arithmetic, those whose arithmetic scores were weaker than their reading scores had interactional problems with peers.

In contrast to these findings, however, socio-emotional measures including structured interviews and ratings by parents, teachers, and the subjects' own self-ratings, were not correlated with arithmetic scores in a sample of 107 thirteen-year-old learning-disabled children (White, Moffitt, & Silva, 1992). No significant correlations were obtained between any achievement score and peer acceptance ratings in another large-scale study of over 700 children (Kistner & Gatlin, 1989).

While many of the foregoing studies support an association between arithmetic achievement and social competency, it appears that low achievement in arithmetic is not the whole story. Arithmetic achievement is but one of a group of deficits which comprise the NLD syndrome, and poor arithmetic achievement can arise from reasons other than NLD (Badian, 1983; Gordon, 1992; Strang & Rourke, 1985; Tuokko, 1982). Thus, not every child with poor arithmetic achievement can be assumed to have NLD. In the construct of NLD, disabilities in both social skills and arithmetic are present and have their basis in an early perceptual disorder. Thus, both should be associated with atypical visuoperceptual-visuospatial performance. Studies which have investigated these relationships will be reviewed next.

Visuospatial ability and social competence. Vision is generally considered the primary sensory modality for human beings, and an extremely important source of contact with the environment even from earliest infancy (Liebert, Poulos, & Marmor, 1977). Thus, visuoperceptual deficits are likely to have significant impact on development. In particular, development of social skills, which rely heavily on quick interpretation of complex nonverbal situations and interactions, may be compromised.

Visual perception is a complex set of skills and a component of many different cognitive tasks, including visuospatial and visuoconstructional tasks. Authors have often used a composite score to operationalize visuoperceptual and visuospatial ability, such as the Performance IQ score from the Wechsler Intelligence Scale for Children-Revised (WISC-R, Wechsler, 1974). Those whose Performance IQ (PIQ) is weaker than their Verbal IQ (VIQ) are considered to have a deficit in visuoperceptual and/or visuospatial ability. Some authors have found that such deficits are associated with social skill deficits. For example, Strang and Rourke (1985) used the _Personality Inventory for Children_ to assess learning-disabled children who had been classified into subtypes on the basis of WISC IQ profiles. Children having VIQ>PIQ profiles were rated as more withdrawn and having more social skills problems than the other two groups (VIQ<PIQ; VIQ=PIQ). Wiener (1980) used Bannatyne's categorizations of WISC-R scores to classify 60 learning-disabled children attending a remedial summer camp into conceptual, spatial, and sequential disability subtypes. Children with conceptual and spatial disabilities were rated by their peers and by camp counsellors as having more problems developing positive peer relationships than were the children with sequential disabilities.

These results are not obtained consistently, however. In a study in which sociometric ratings were used, 65 learning-disabled and 252 nondisabled classmates were classified according to WISC-R IQ scores (Landau, Milich, & McFarland, 1987). Surprisingly, peer and teacher ratings indicated that the learning-disabled children with VIQ>PIQ scores had relatively intact interpersonal skills, whereas the other two subtypes (VIQ<PIQ, VIQ=PIQ) were less popular with peers. In a sample of 157 learning-disabled and normally-achieving children, correlations among a battery of visuospatial and socioemotional measures failed to reach significance (White et al., 1992).

Some researchers have gone beyond basic visual-perceptual skills to measure perceptual components of social interaction, the presumed intermediary through which weak visuoperceptual ability is translated into social skills deficits. This type of visuoperceptual performance, however, has not been found to correlate with scores on standard visuoperceptual and visuospatial measures, or with social competence ratings. In one study, laboratory tasks designed to measure components of social interaction skills (eg., comprehension of oral stories, ability to select appropriate gestures and facial expressions) were performed equally well by children with language or spatial disorders, and by normal children (Ozols & Rourke, 1985). In another study, teachers' ratings of social adjustment of the learning-disabled and normally-achieving subjects were not correlated with performance on two laboratory tasks of sensitivity to nonverbal communication involving videotapes and cartoon drawings (Munson, 1986).

Arithmetic achievement and visuospatial ability. The final set of relationships included in the NLD model is the association of arithmetic and visuospatial abilities. In samples of average schoolchildren, these abilities appear to be related. For example, in a small sample of 38 normally-achieving fourth- and fifth-grade children, spatial measures were more highly correlated than were verbal measures with arithmetic achievement (Solan, 1987). Similarly, in a sample of 434 unselected first- and second-grade subjects, arithmetic achievement was significantly related to visual perception scores, but not to auditory perception scores (Rosner, 1973).

The relationship between arithmetic achievement and visuospatial ability in samples of children with learning problems is less straightforward. White and her colleagues (1992) classified a group of thirteen-year-old children according to academic profile (arithmetic underachiever, reading underachiever, general underachiever, and normal achiever). The children were assessed on a battery of neuropsychological and socio-emotional measures. Arithmetic achievement and visuospatial performance were most strongly related, followed by arithmetic achievement and visual-motor integration. In another study done with a sample of children who had been referred for psychoeducational assessment by their schools or parents, however, the results were less clear-cut. Relationships among achievement test scores and WISC profiles were examined in 135 clinic-referred and 315 school-referred children (Tuokko, 1982). It was found that spatial ability was necessary for basic development of mathematical ability, including acquisition of numeration, but beyond that, spatial ability was less important than higher-level abstraction ability in arithmetic achievement.

Investigators have also looked at accuracy in processing nonverbal social communication cues (a measure of visuoperceptual ability applied to a social context) in relation to arithmetic achievement. In support of the NLD model, learning-disabled children with specific impairments in arithmetic made more errors in comprehension and production of nonverbal (puppet) scenarios in comparison with verbal (narrative) stories, whereas children with general learning disabilities showed the opposite pattern (Loveland, Fletcher, & Bailey, 1990). In another study, however, there were no differences between learning-disabled children with differing academic achievement profiles in social perception and social reasoning, measured with two laboratory tasks of nonverbal social communication (Munson, 1986). These tasks involved decoding videotaped portrayals of various affective states, and choosing alternative endings for interpersonal situations depicted in cartoon drawings.

Arithmetic achievement, visuospatial ability, and social competence. A few studies have undertaken to assess all three of these components of NLD in the same subjects. Results have been contradictory. In one such study, although arithmetic underachievers had significantly weaker visuospatial and visuomotor integration scores on standardized testing than did normal achievers, there were no differences among the groups of reading-disabled, arithmetic-disabled, generally-disabled, and normal achievers, on any of the 6 socio-emotional measures used (White et al., 1992). In the second study, in contrast, underachievers in arithmetic were rated by their teachers as significantly weaker in social adjustment than the other groups in the study (i.e. reading underachievers, general underachievers, and normal achievers; Munson, 1986). Contrary to expectation, however, this weakness was not associated with impaired ability on an indirect measure of visuoperceptual ability: laboratory tasks of nonverbal communication measuring social perception and social reasoning, involving videotaped presentations and cartoon drawings.

The impression given by the studies reviewed to this point is that relationships among arithmetic achievement, visuoperceptual/visuospatial performance, and social competence require further clarification. While weaknesses in arithmetic performance appear to be fairly firmly linked with social skills impairments, the relationships between social competence and visuospatial ability, and between arithmetic performance and visuospatial ability, are less well-established. The common factor here appears to be visuospatial ability.

One possible reason behind the contradictory findings may be that the term "visuospatial" is being used in an overinclusive and ill-defined way, leading to confusing results. Evidence from clinical investigations of brain-injured populations has suggested that visuospatial and visuoconstructional performance includes at least two dissociable and clinically-relevant subskills: analytical processing, that is, processing of the details of a visual display; and configural processing, or processing of the overall visual gestalt of the display. Often, when performance on a visuospatial task is evaluated, how a subject uses these subskills is ignored, and only accuracy of the final product is evaluated. For example, classification of children on the basis of WISC subscale scores, as has been done in a number of the aforementioned studies, fails to take into account qualitative differences in the way a child solves a task, and thereby runs the risk of including children with qualitatively different cognitive disorders within the same group of "spatially impaired" subjects. Kaplan (1983) has noted that similar accuracy scores on the WISC-R Block Design and Object Assembly subtests can disguise major qualitative differences in error patterns which characterize children with left versus right hemisphere lesions. Qualitative differences in visuospatial performance could be confusing the issue of the relationships between visuospatial skill on the one hand, and arithmetic achievement and social competence on the other.

An alternative explanation for the confusing relationships among academic, visuospatial, and social performance, is that these variables may each be influenced to a greater or lesser degree by another, more pervasive factor. One such all-pervasive factor is hyperactivity. Hyperactivity has been shown to be linked with learning disabilities, visuospatial problems, and social difficulties.

These two alternative solutions to the puzzle of how the NLD triad of difficulties could be related, are discussed in more detail below.

Dissociable Components of Visuospatial Processing

Visuoconstructional performance refers to the ability to manually put the parts of an object together into a whole. Thus, it can be considered a psychomotor expression of visuospatial ability. Visuoconstructional tasks include drawing, putting together sticks, or assembling blocks according to a model (Kritchevsky, 1988). At least two cognitive processes are involved: _detail processing_, that is, the ability to perceive details clearly; and _configural processing_, or the ability to apprehend the relationship among the component parts of the entity to achieve the desired synthesis (DeRenzi, 1982). Dissociations between these two cognitive processes have been observed in studies of brain-damaged and normal subjects.

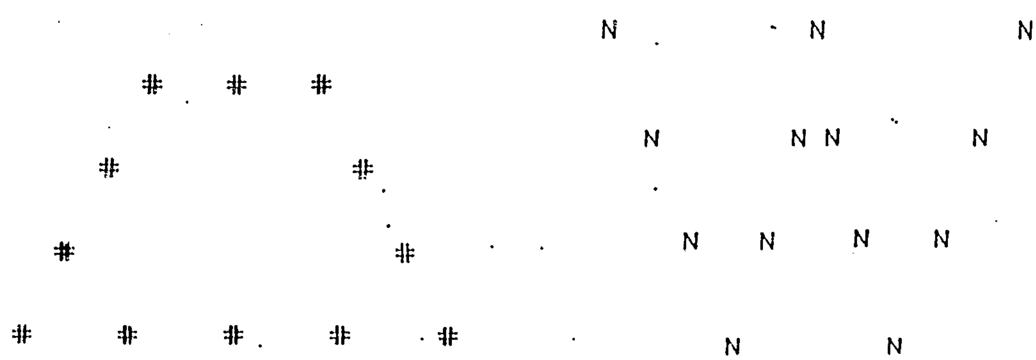
In brain-damaged subjects, lesions in either hemisphere, particularly posterior lesions, can impair visuoconstructional performance. However, on drawing tests, even though accuracy scores of right- and left-hemisphere-lesioned patients may be similar, there are qualitative differences in the performances of the two groups (De Renzi, 1982; Kritchevsky, 1988; Lezak, 1983; McFie & Zangwill, 1960; Warrington, 1969). Drawings of right-hemisphere-lesioned patients tend to be scattered and fragmented, with a loss of spatial relations among the parts of the drawing. There are often serious distortions in proportion or perspective. In contrast, the drawings of left-hemisphere-lesioned patients preserve the spatial relationships and the overall idea of the drawing more accurately, but tend to be oversimplified, with fewer details. In a study of sixteen patients with temporal lobe epilepsy who were candidates for brain surgery, those with a left temporal lobe epileptic focus showed a significant loss of internal detail with preservation of gestalt, on their immediate recall drawings of the Rey-Osterrieth Complex Figure, in comparison with patients who had a right temporal lobe focus (Welch, Deal, & Abou-Khalil, 1991). In normal subjects, a tachistoscopic study of visuospatial processing showed that the left hemisphere is predominant in processing discrete visual details within the stimuli (stylized faces and bugs), whereas the right hemisphere is superior in processing the spatial relationships between the individual details in the same stimuli (Bradshaw & Sherlock, 1982). Similar results were seen when normal subjects were asked to draw geometric designs which had been presented tachistoscopically (Edguer, 1982).

An attempt has been made to characterize these qualitative differences more precisely by using hierarchical stimuli, which lend themselves to processing at different visuospatial levels (Kinchla, 1974). These stimuli consisted of a large ("higher-level", i.e., configural or global-level) letter or shape constructed from numerous smaller ("lower-level", i.e., details or local-level) letters or shapes (see Figure 1). Such stimuli are designed specifically to ensure that the global and local attributes do not differ in complexity, familiarity and recognizability, and that the global and local attributes are independent (i.e. the whole cannot be predicted from the elements, and vice versa; Martin, 1979). These specifications allow direct and fair comparisons between processing of the two levels of stimuli.

These stimuli have been used in a number of studies with various subject populations. The results have shown that the global attributes are more efficiently processed by the right cerebral hemisphere, while local attributes are processed preferentially by the left. For example, in a tachistoscopic task presented to normal adult subjects, a left visual field (right hemisphere) advantage was obtained when decisions were required about global attributes of the stimuli, while a right visual field (left hemisphere) advantage was found when local attributes had to be processed (Sergent, 1982). In an interesting single-case report about the performance of a patient before and after undergoing complete commissurotomy, it was found that the subject could draw both levels of the stimulus accurately

Figure 1

<u>A Sample Hierarchical Stimulus</u>



with either hand before undergoing the surgery. Following commissurotomy, however, the subject was more accurate in drawing and recognizing global forms when responding with the left hand (controlled primarily by the right hemisphere) and showed the opposite pattern when responding with the right hand (controlled primarily by the left hemisphere; Delis, Kramer, & Kiefner, 1988). It has been found also that subjects with right-hemisphere lesions had more difficulty drawing and remembering global leve- forms while those with left-hemisphere damage were more impaired in drawing local-level forms (Delis, Kiefner, & Fridlund, 1988; Delis, Robertson, & Efron, 1986).

A similar dissociation in hierarchical drawing performance has been seen when groups of children with Down Syndrome or Williams Syndrome are compared (Bihrle, Bellugi, Delis, & Marks, 1989). Williams Syndrome is a metabolic disorder resulting in mental retardation. The Down Syndrome subjects were significantly more accurate in drawing and remembering global relative to local forms, while age- and IQ-matched Williams Syndrome subjects showed the opposite pattern. While there is no evidence on MRI scans for unilateral hemisphere lesions in either Williams or Down Syndrome (Jernigan & Bellugi, 1990), it is noteworthy that Williams Syndrome patients are functionally similar to right-hemisphere lesioned adult patients in their neuropsychological profile of relatively intact language skills and local visuospatial processing with impaired global visuospatial processing, whereas Down Syndrome children resemble adults with left-hemisphere lesions, showing relatively impaired language processing and preserved global visuospatial processing (Bihrle et al., 1989).

Thus, studies of both normal and brain-impaired subjects suggest that there are at least two dissociable components in drawing performance: reproduction of detail (local attributes) and reproduction of configuration (global attributes). These two components appear to involve predominantly the cognitive processes of the left and right hemispheres respectively. Analysis of drawing performance can provide useful information about preferred cognitive strategy, and by inference, the integrity of cognitive processing in the hemispheres. There is reason to believe, based on current evidence of hemispheric involvement in learning disability subtypes, that these components of drawing ability may be differentially impaired in different subtypes of learning disability.

Brain Function and Learning Disabilities

Neurologically-impaired adult subjects often experience difficulties with previously-acquired academic skills of reading, writing, and calculation. These impairments are most often seen with left-hemisphere lesions. For children in the process of learning these academic skills, hemispheric specialization is less clear-cut. For example, in learning to read, accumulating evidence suggests that the right hemisphere is more involved in the initial stages, perhaps because of the visuoperceptual demands of beginning reading (Bakker, 1992; Fletcher & Satz, 1980; Hinshaw, Carte, & Morrison, 1986; Licht, Kok, Bakker, & Bouma, 1986), and perhaps because the right hemisphere is better at handling novel, unpracticed tasks (Goldberg & Costa, 1981). As reading skills become more practiced, advancing from decoding to extracting meaning from text, the left hemisphere appears to become predominant (Bakker, 1992). Neuropsychological studies have shown that learning-disabled children whose reading performance is stronger than their arithmetic performance show neuropsychological test profiles indicative of dysfunction in the right cerebral hemisphere, marked by weak visuoperceptual organizational skills, whereas children whose arithmetic performance is stronger than reading have profiles consistent with left cerebral dysfunction, marked by poor verbal and auditory perceptual abilities (Rourke & Finlayson, 1978; Rourke & Strang, 1985). Neuroanatomical studies of children with verbal learning disabilities suggest the left hemisphere may be compromised. Clinical case studies of children with right hemisphere lesions show that nonverbal learning problems predominate.

Verbal learning disabilities. In dyslexic subjects, who have verbal learning disabilities, neuroanatomical abnormalities have been found primarily in the left hemisphere (Duane, 1989; Geschwind & Galaburda, 1985; Hynd, Marshall, & Semrud-Clikeman, 1991). A recent study of 10 severely-dyslexic children used magnetic resonance imaging (MRI) to compare the size and symmetry of their brains to those of normal children and those diagnosed with attention deficit disorder (Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990). The planum temporale, a brain area involved in phonological coding, language comprehension and auditory perception, is larger in the left hemisphere than in the right in approximately 65% of an unselected population (Geschwind & Levitsky, 1968). However, Hynd & colleagues discovered a pattern of reversed asymmetry in 90% of the dyslexics, on MRI scanning. In these children, either the planum temporale was larger in the right hemisphere, or the two plana were symmetrical. Autopsy studies of eight dyslexics revealed symmetry of the planum temporale in all 8, together with other cortical anomalies predominantly in the perisylvian, language-related zones of the left hemisphere (Galaburda, 1989). A similar reversed pattern of asymmetry in this brain region was also seen in 16 of 24 dyslexics who were examined by computed tomography (Hier, LeMay, Rosenberger, & Perlo, 1978). Other abnormalities found in dyslexics have included abnormal cell architecture virtually confined to the left hemisphere, particularly in the temporal areas involved in language (Galaburda, 1983; Kemper, 1984); a shorter insula on both left and right sides and a smaller right anterior region (Hynd et al., 1990), and abnormalities in the grey and white matter of the parietal regions bilaterally, with thinning of the nearby section of the corpus callosum (Drake, 1968).

These anatomical findings indicate that left-hemisphere processing may be compromised in verbal learning disabilities. Theories of cognitive processing have characterized the two hemispheres as having preferred modes of cognition: the left hemisphere being more specialized for analytic, sequential, and verbal processing, and the right hemisphere more adapted for synthetic, simultaneous, and configurational processing (Kolb & Whishaw, 1980; Lezak, 1983). Poor readers, who may have compromised left hemispheres, have been found to overutilize right-hemisphere, simultaneous strategies in tasks such as reading in which a left-hemisphere approach may be more appropriate (Gordon, 1983; Williams & Bologna, 1985). For example, in a study of 160 second- and third-grade schoolchildren, it was found that poor readers preferred a simultaneous processing style, whereas good readers preferred a sequential strategy (Sivan & Carmon, 1986). This dependence on less-efficient right-hemisphere strategies may result from impaired left-hemisphere functioning.

The accumulated evidence shows that left-hemisphere functioning is likely impaired in children with verbal learning disabilities. Since left-hemisphere impairment is associated with difficulty in the processing of detail it could be expected that the visuoconstructional performance of children with verbal learning disorders will show a selective weakness in reproduction of detail.

There is little data to bring to this issue, since very few studies have looked at visuoconstructional strategies in learning-disabled children. Aaron (1978) devised an experimental task which appears to measure detail and configural visuoconstructional strategies. Two letters were placed close together with almost no space between them, e.g. HH or db. These stimuli were shown to reading-disabled children who had been classified into subgroups according to Boder's criteria for dysphonetic and dyseidetic readers. Following offset of the stimuli, the children were asked to draw what they had seen. The dyseidetic group and a control group of normal readers were more likely to draw the stimuli as individual letters (detail strategy), whereas the dysphonetic readers drew them more often as single visual gestalts, leaving out the small space between the two letters (configural strategy). Since the majority of reading-disabled children can be classified as dysphonetic (Boder, 1973), Aaron's data suggests that the majority of reading-disabled children will have difficulty with the detail components of visuoconstructional tasks.

Aaron's task was used again in a battery of experimental and clinical measures to compare reading-disabled children with normal readers (Teeter & Smith, 1989). The reading-disabled group was found to use a configural strategy more often than the normal readers, although this difference disappeared when a general intelligence score was used as a covariate in the statistical calculation. In another comparison between older dyslexic children (11 to 14 years of age) and normal readers, performance on drawing the Rey-Osterrieth Complex Figure was assessed (Klicpera, 1983). Contrary to what may be expected, the dyslexics used a <u>more</u> detail-oriented strategy on this task, reproducing details much sooner than the normals, who in turn tended to draw structural elements earlier. The dyslexics also drew lines in a more segmented manner. Looking more closely at subgroups of dyslexics, however, revealed that those dyslexics whose Verbal IQ was ten points or more higher than their Performance IQ produced less well-organized copies of the figure than those whose Verbal IQ was equal to or lower than their Performance IQ. This latter finding suggests that there may be subgroups of dyslexics who vary in their proclivity to use a detail-oriented versus a configural strategy.

In none of the three studies just described was arithmetic performance taken into consideration. Because many reading-disabled children also have difficulty with arithmetic, it would be expected that at least some of the subjects of the foregoing studies had arithmetic disabilities in addition to their reading disabilities (in fact, such a "combined" learning-disabled subgroup may have a reading-spelling performance pattern which corresponds to Boder's dyseidetic subtype). It may be that, had arithmetic performance been measured, those whose weakest academic performance was in arithmetic would be the group most likely to overutilize detail strategies, whereas those whose weakest scores were in reading would be most likely to overutilize configural strategies. This study remains to be done, and is one aspect of the present study.

Nonverbal learning disabilities. Neuroanatomical studies of children with NLD have yet to be reported. However, children having right-hemisphere and white-matter lesions have been described in clinical case studies as showing the visuospatial, mathematical, and interpersonal difficulties which are characteristic of NLD. This subtype, therefore, may be a manifestation of compromised processing by the right hemisphere.

Neuropsychological profiles were described for fifteen children aged 5 to 13 who had neurological findings consistent with right-hemisphere damage or dysfunction

(Voeller, 1986). Visuospatial performance measured by the WPPSI or WISC-R was significantly weaker than verbal performance. In achievement testing, the subjects scored significantly more poorly on arithmetic than on reading. Most of the children had social difficulties, being either withdrawn and isolated, or overly aggressive and behaving inappropriately. Fourteen of the fifteen subjects had attention deficit disorder. The group as a whole had below-normal scores on two tests of affect recognition, with those children who had right parietal lesions obtaining particularly weak scores. In another series of 14 cases, neurological and neuropsychological signs consistent with right hemisphere dysfunction were associated with poor to severely impaired nonverbal abilities, in contrast to average to superior verbal performance (Weintraub & Mesulam, 1983). Most had weak scores on tests of spelling and arithmetic, but reading was reported by 11 of the 14 subjects to be one of their strengths. The subjects, most of whom were examined as adults, reported lifelong interpersonal problems including shyness, social isolation, and depression. Similar difficulties with social adjustment and nonverbal abilities in the presence of right-hemisphere dysfunction were reported in a further series of 11 adolescent and adult cases referred for neurological work-up (Tranel et al., 1987). Comparing learning-disabled adolescents and control subjects, it was found that interpretation of emotional expression (possibly a component of interpersonal skill) was correlated with visuoconstructional performance on block design and object assembly tests, with the learning-disabled group performing significantly more poorly than the controls (Wiig & Harris, 1974).

These studies have shown many points of similarity in cognitive and interpersonal functioning between children with right hemisphere dysfunction and those with NLD. Disturbance in a specific aspect of visuoconstructional performance, configural processing, has been demonstrated in a group of 14 children who had right-hemisphere dysfunction together with arithmetic and social skills disabilities. These children used an atypical, piecemeal approach to copying a complex figure, and 11 of the 14 had notably impaired immediate recall of the figure, marked by serious distortions and poor configuration of the design (Weintraub & Mesulam, 1983).

Thus, current evidence suggests differential patterns of brain impairment in verbal and NLD, with compromise of the left and right hemispheres respectively. Left and right hemispheric dysfunction has been shown to compromise detail and configural aspects of visuoconstructional performance as well. It follows that children with verbal learning disabilities could be expected to show disrupted detail processing, whereas NLD would be associated with disrupted configural processing.

Summary

A pattern of coexisting arithmetic, visuospatial, and social skills deficits has been predicted by some theorists. The empirical evidence, however, has been equivocal. Several shortcomings in the data are evident, including failure to group learning-disabled children according to subtype, use of vague and overinclusive definitions of visuospatial deficits, and failure to take arithmetic performance into account as a vital component of the achievement profile of learning-disabled children. A study in which arithmetic, visuospatial-visuoconstructional, and social skills performance can be directly compared is needed as one step in evaluating the ecological validity of the nonverbal subtype of learning disability.

Hypotheses

1. In comparison with normally-achieving children, those children with specific arithmetic disorders will have weak configural scores on visuoconstructional tasks.
2. In comparison with normally-achieving children, those children with specific reading disorders will have weak detail scores on visuoconstructional tasks.

3. Children with specific arithmetic disorders will receive weaker social competence ratings than will other children.
4. Difficulty with configural aspects of visuoconstructional tasks will be associated with weak social competence ratings.

Method

Subjects

The three local public school boards (Districts 61, 62, and 63), as well as a number of independent schools, were informed about the study, and permission was received to contact individual principals about conducting the research in the schools. Twenty-seven public and independent elementary and middle schools participated, and are listed in Appendix A, along with the number of students referred from each school. Although demographic data were not collected, the students participating were for the most part Caucasian, and appeared representative of the largely middle-class population of Greater Victoria.

Learning assistance and classroom teachers in participating schools were given a letter which described the study (reproduced in Appendix B). The author then met individually with teachers who had expressed interest in the study, provided them with further information about which students would be suitable and which would not, and asked the teachers to select students from their classes based on the criteria given in the letter. The teachers sent home a letter to the selected children's parents explaining the purpose and procedures of the study, and requesting permission for their child to participate (reproduced in Appendix C). The subjects were not identified to the author until consent forms had been returned from the parents. No school records or documents were reviewed at any time by the author, as the subjects were selected by their teachers according to the criteria already presented.

A total of 229 students were given permission by their parents to participate, and were then referred to the study. Each student was screened at his/her school, by the author, in an individual testing session of approximately 45 minutes. The purpose of the screening was to inform the students about the study, to secure their consent to participate, and to ensure that the subjects who would ultimately be chosen to take part in the study met the criteria described above. Because the school staff and parents preferred that the students miss as little classroom time as possible, it was necessary to limit the testing sessions to the minimum time in which the necessary data could be collected. Thus, only essential measures of mental ability and achievement were included. Two students declined to participate in the study, and the remaining 227 students were administered the following tests: the Wide Range Achievement Test - Revised, Reading and Arithmetic subtests (Jastak & Wilkinson, 1984); and the Wechsler Intelligence Scale for Children - Revised, Vocabulary and Block Design subtests (Wechsler, 1974). The students were also administered the Passage Comprehension subtest from the Woodcock-Johnson Psycho-educational Battery as a measure of reading comprehension. It was discovered, however, that this measure was not a good discriminator as very few students received low scores. It was therefore not included among the screening measures used to differentiate the groups.

The psychometric cutoff scores used to ensure that the subjects met the criteria for mental ability and learning profile are given in Table 1. Of the initial 227 students who were tested, 120 met these criteria, and were administered the experimental tasks. The group composition for these 120 students is given in Table 2. Note that the age range in the Low Reading group is lower than in the other three groups, with the oldest subject being 141 months. To maximize comparability of the groups, it was decided to use an upper age limit of 143 months for all groups, which includes all subjects less than twelve years of age. Using this age restriction, the total number of subjects is 86. This is the subject sample which was used for the analyses.

The subject sample is described psychometrically in Table 3. When the achievement scores on the Wide Range Achievement Test - Revised are translated to grade equivalents, in the Low Reading group fourteen subjects scored two or more years behind their grade placement in reading, while the remaining two subjects scored between 1.5

Table 1

Psychometric Criteria for Inclusion in the Study

	Group			
Measure	Average Achievers	Low Reading	Low Math	Low Overall
Wide Range Achievement Test - Revised				
Math	SS=90-119 (25th to 90th percentile)	SS=at least 15 points (1 SD) above Reading SS	SS=<90 and at least 15 points below Reading SS	SS=<90 and within 15 points of Reading SS
Reading	SS=90-119	SS=<90 and at least 15 points below Math	SS=at least 15 points above Math SS	SS=<90 and within 15 points of Math SS
Wechsler Intelligence Scale for Children - Revised				
Block Design	Scaled Score of at least 7 in all groups			
Vocabulary	Scaled Score of at least 7 in all groups			

Note. SS = Standard Score

Table 2

Description of Subject Sample (N = 120)

Measure	Group: Average Achievers	Low Reading	Low Math	Low Overall
# males	25	13	20	20
# females	19	3	15	5
Total N	44	16	35	25
Age in months				
Mean	132.57	117.13	138.66	131.28
S.D.	17.47	12.89	17.47	19.18
Range	108-172	99-141	111-166	109-173
WRAT-R Math Standard Scores				
Mean	99.75	85.00	77.26	79.16
S.D.	6.24	8.20	7.58	5.40
Range	91-117	68-102	57-88	67-86
WRAT-R Reading Standard Scores				
Mean	102.93	67.25	101.89	79.60
S.D.	6.13	7.56	10.52	5.21
Range	90-117	54-80	81-127	73-88
WISC-R Block Design Scaled Scores				
Mean	10.57	10.81	9.94	11.04
S.D.	2.12	2.90	1.86	2.21
Range	7-15	7-16	7-14	7-15
WISC-R Vocabulary Scaled Scores				
Mean	10.45	9.31	10.09	9.72
S.D.	1.95	1.62	1.85	1.90
Range	7-16	7-12	7-15	7-14

Table 3

Description of Subject Sample used for Analyses. N=86

	Group			
Measure	Average Achievers	Low Reading	Low Math	Low Overall
# males	15	13	13	15
# females	16	3	7	4
Total N	31	16	20	19
Age in months				
Mean	123.19	117.13	125.20	121.79
S.D.	9.90	12.89	8.21	8.12
Range	107-141	104-141	111-143	109-140
WRAT-R Math Standard Scores				
Mean	100.84	85.00	79.40	80.32
S.D.	6.16	8.21	5.34	4.76
Range	91-117	68-102	67-88	71-86
WRAT-R Reading Standard Scores				
Mean	103.61	67.25	103.65	78.79
S.D.	6.46	7.56	7.96	5.62
Range	90-117	54-80	90-114	67-88
WISC-R Block Design Scaled Scores				
Mean	11.00	10.81	9.95	11.26
S.D.	2.08	2.90	2.16	2.21
Range	7-15	7-16	7-14	7-15
WISC-R Vocabulary Scaled Scores				
Mean	10.90	9.31	11.00	10.21
S.D.	2.02	1.62	1.72	1.90
Range	7-16	7-12	9-15	7-14

and two years behind. In the Low Math group, thirteen subjects scored two or more years behind their grade placement in math, five subjects scored between 1.5 and two years behind, and two scored between one and 1.5 years behind. In the Low Overall group, nine subjects scored at least two years behind in both reading and math, six scored at least 1.5 years behind in both, and four scored at least one year behind in both areas.

Some initial descriptive analyses were undertaken to determine how successful the selection process had been in identifying four distinct and differentiable subject groups. All analyses described in this study were carried out using $SPSS^x$.

It was important that the groups be similar in age and mental ability, but differ in their academic achievement profiles. In order to compare the groups on age, a one-way ANOVA was done, using age in months as the dependent measure. The results of the ANOVA revealed no significant age differences between the groups (F (3,82) =2.1646; p=.0984).

Next, a MANOVA was carried out to compare the four subject groups on the mental ability variables of Block Design and Vocabulary performance, and academic achievement variables of Arithmetic and Reading performance. Predictions were as follows:

Prediction 1. Block Design score will be similar in all groups.

Prediction 2. Vocabulary score will be similar in all groups.

Prediction 3. Math scores will be significantly higher in the Average Achievement and the Low Reading groups than in the Low Math and Low Overall groups.

Prediction 4. Reading scores will be significantly higher in the Average Achievement and Low Math groups than in the Low Reading and Low Overall groups.

The results of the MANOVA were highly significant ($p<.001$), indicating that the four groups were easily distinguished from one another using the four variables. The results of univariate F tests on the four variables individually were therefore examined to discover wherein lay the differences between groups.

The results of the univariate F test on the Block Design variable was not significant ($F(3,82) = 1.2453$; $p=.2987$), no two groups being significantly different at the .05 level. Thus, there was no difference among the four groups of subjects in their performance on the Block Design test. This results confirms Prediction 1.

The results of the univariate test of the Vocabulary measure were significant (F (3,82) =3.2946; p=.0246), and examination of the mean scores for the four groups given in Table 4 reveals that the Vocabulary score for the Low Reading group was significantly lower than that obtained by the Average Achievement and the Low Math groups. Thus, Prediction 2 was not confirmed. It should be noted, however, that the mean scores for all groups were well within the Average range, and therefore satisfied the subject selection criterion of average mental ability, as measured by this test. Because the dependent measures in this study are drawing and social skills measures, it is likely that this relatively small difference between the groups on the vocabulary measure will have little bearing on the results of the study.

Very significant group differences were revealed on the Arithmetic measure (F (3,82) =69.2181; p<.0001). The pattern of group differences is shown in Table 5. The mean score of the Average Achievement group was significantly higher than that of all the learning disabled groups, indicating that all of the learning disabled groups obtained relatively low scores on the math measure, relative to age norms. This finding has been noted in other studies of learning disabled groups as well (e.g. Rourke & Finlayson, 1978; Rourke & Strang, 1978; Share, Moffitt, & Silva, 1988; Strang & Rourke, 1985). Although the mean score of the Low

Reading group was weak in comparison with that of the Average Achievement group, in was nevertheless significantly higher than the mean scores of the Low Math group. The mean Math scores of the Low Math and Low Overall groups did not differ. These results confirm Prediction 3.

The Reading measure also yielded very significant group differences ($F(3,82) = 140.7364$; $p < .0001$). Table 6 reveals that the Average Achievement group and the Low Math group had similar Reading scores, which were significantly higher than the scores obtained by the other two groups. The mean score for the Low Reading group was significantly lower than those of all other groups. The Low Overall group fell midway between the Low Reading and the other groups on mean reading score, and was signficantly different from all other groups. These results confirm Prediction 4. The foregoing analyses confirm that the four groups of subjects are similar to one another in age and mental ability, but show profiles of achievement in reading and arithmetic which are unique for each group. The four groups are therefore appropriate samples of the populations of interest for this study.

Table 4

Mean Vocabulary Scaled Scores and Pairs of Groups Significantly Different at the .05 Level

		Group		
Mean Score	Group	Average Achievers	Low Reading	Low Math
10.903	Average Achievers			
9.313	Low Reading	*		
11.000	Low Math		*	
10.211	Low Overall			

Note. * denotes pairs of groups significantly different at the .050 level.

Table 5

Mean Arithmetic Scores and Pairs of Groups Significantly Different at the .05 Level

		Group		
Mean Score	Group	Average Achievers	Low Reading	Low Math
100.839	Average Achievers			
85.000	Low Reading	*		
79.400	Low Math	*	*	
80.316	Low Overall	*		

Note. * denotes pairs of groups significantly different at the .050 level.

Table 6

Mean Reading Scores and Pairs of Groups Significantly Different at the .05 Level

Mean Score	Group	Group: Average Achievers	Low Reading	Low Math
103.613	Average Achievers			
76.250	Low Reading	*		
103.650	Low Math		*	
78.790	Low Overall	*	*	*

Note. * denotes pairs of groups significantly different at the .050 level.

Dependent Measures

The 120 subjects who had met the screening criteria were tested at their schools by the author in a second individual session of about forty-five minutes, during which they were administered the dependent measures of visual learning style and social competence. In addition, their teachers were asked to evaluate each student's social competence and classroom behaviour, using two standardized rating scales. As was explained on page 40, the final subject sample consisted of 86 of these subjects, those aged less than 144 months. The various measures administered during this second session yielded data falling into two categories: visual learning style data and social competence data. The tests and data derived from each test are described below. All scoring was done by the author. The object of using only one rater was to obtain maximum consistency in scoring. This method provided for no external verification of the accuracy of scoring, however, as could have been obtainable through a measure of inter-rater reliability had more than one rater been used.

Visual Learning Style Variables

Two measures of visual learning style were used, the Rey-Osterrieth Complex Figure Test and the California Global-Local Learning Test. The relevant information to be obtained from these drawing tests was the stylistic approach used by the subject in reproducing the stimuli, which can vary along a continuum of a more configural style to a more detail-oriented style. Scoring systems which quantify this aspect of drawing performance, and were used in this study, are described below.

Rey-Osterrieth Complex Figure Test (Rey, 1941; Osterrieth, 1944). This complex geometric figure, illustrated in Figure 2, was copied by the subject using coloured pencils. The sequence of colours used by the subject was noted as a record of the sequence in which the various parts of the figure were copied. After copying the figure, the subject was engaged in other tasks for about five minutes, and then without warning, was asked to draw the design again, from memory. No intimation was given ahead of time that the subject should try to remember the figure. Both the copied and the recalled drawing were scored.

The accuracy of the reproduction in each drawing was scored using the detailed scoring criteria developed by Taylor (published in Spreen & Strauss, 1991). A higher score indicates greater accuracy. A second measure of accuracy was also used, a scoring system which identifies drawing errors which have been shown to occur frequently in patients having right cerebral hemisphere lesions (Loring, Lee & Meador, 1988). A higher score on the Loring scale indicates more inaccuracies.

The stylistic approach taken by the subject in drawing the design was scored using a variety of scoring systems which have been devised by several authors. In general, a more configural style is one in which the major components of the figure, such as the base rectangle, diagonals, and interior box, are drawn as units. This style of drawing is illustrated in Figure 3. A more piecemeal approach is one in which the line segments are drawn individually with

Figure 2

The Rey-Osterrieth Complex Figure

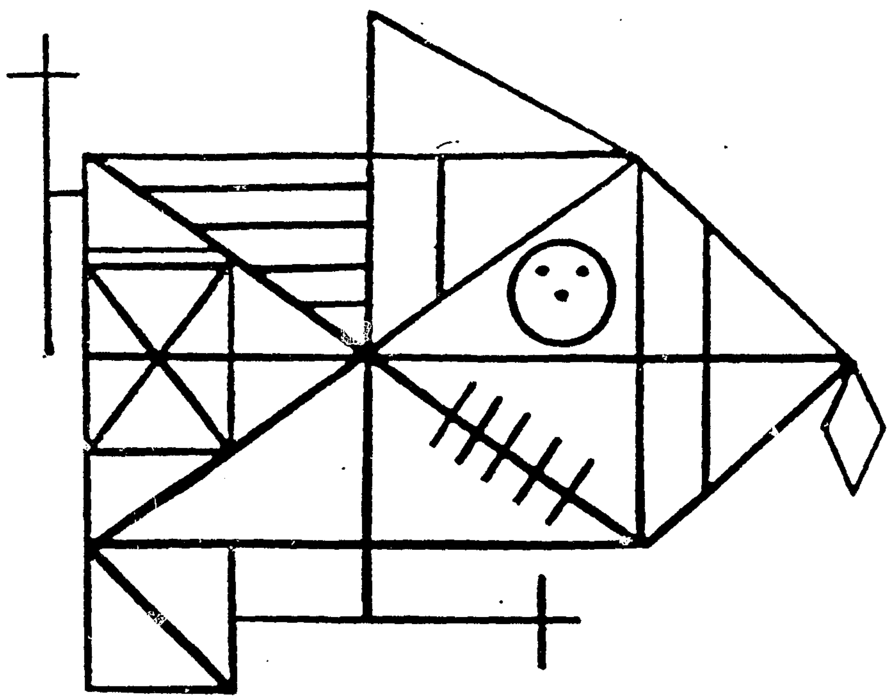
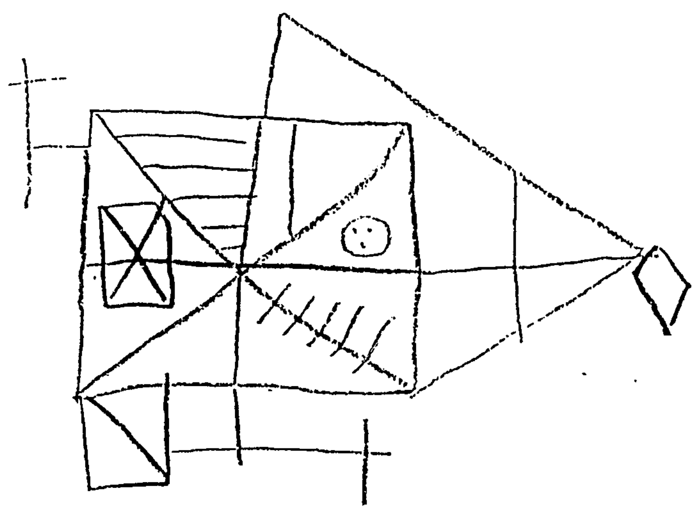


Figure 3

A Configural Approach to Drawing the Rey-Osterrieth Complex Figure



little appreciation for the larger configurations. An example is illustrated in Figure 4, in which it can be seen that line segments of the larger components of the figure do not meet precisely since they were not drawn continuously. Despite the quite different approaches to the drawing task seen in Figures 3 and 4, the drawings received the same score for accuracy.

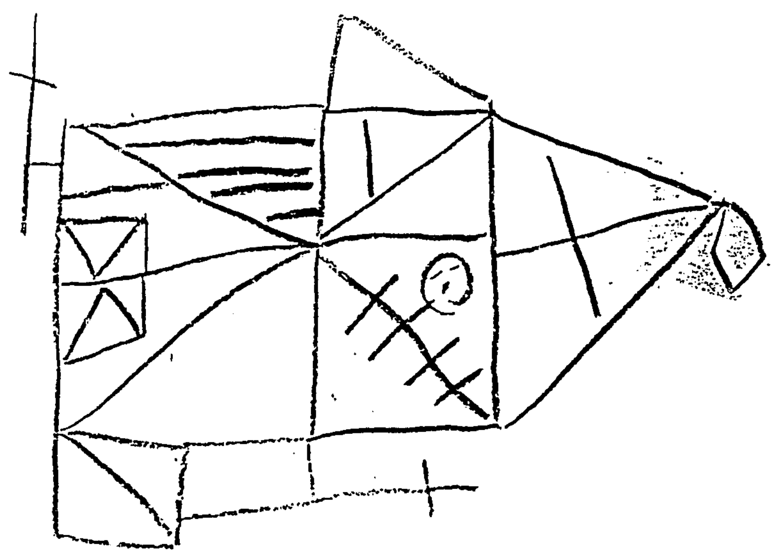
The following scoring systems for quantifying the style used to draw the figure were used in the study.

1. Binder (1982) selected five elements of the figure, comprising the base rectangle with its interior diagonals and bisectors, which could be drawn either as one continuous unit across a juncture (configural style), or could be drawn as a series of line fragments (fragmented style). This scoring system yields three scores, each having a maximum value of five: the Configural score (number of lines drawn in a continuous fashion); the Fragmented score (number of lines drawn in fragmented fashion); and the Missing score (number of lines not drawn). Binder used this scoring system in a study of 42 brain-injured adults and control subjects.

2. Bennett-Levy (1984) developed a scoring system in which two aspects of the drawing are evaluated. First, similarly to Binder's system, Good continuation points are awarded if a line is drawn in a continuous manner across a juncture. Eighteen junctures were scored, including four of the five

Figure 4

A Detail-Oriented Approach to Drawing the Rey-Osterrieth Complex Figure



used by Binder. Secondly, a maximum of eighteen Symmetry points are awarded for the successive drawing of components of symmetrical units. Bennett-Levy validated his scoring system on a sample of 107 adults.

3. Waber and Holmes (1985) developed a technique for scoring organization and production style in drawing the Rey-Osterrieth Complex Figure Test and validated their method on an unselected sample of 454 schoolchildren between the ages of five and fourteen. Each drawing is first given a rating for level of organization, which varied from one (least organized) to five (most organized). Production style is then assessed for the drawing, based on accuracy of the alignment of lines at eighteen juncture points in the figure, four of which were used by Binder and seven by Bennett-Levy in their scoring systems. Different combinations of juncture points are scored, according to the organizational level of the drawing. If adjacent segments of a line on either side of the juncture were drawn in the same colour and were aligned accurately, the line is judged to have been drawn continuously across the juncture, rather than in a segmented manner. One point is awarded for each juncture which was drawn continuously, and the Style score is the cumulative total of all these points.

4. Schorr, Delis, and Massman (1992) developed a perceptual Cluster index. This scoring system is similar in concept to others, in that credit is received toward the

perceptual cluster index for each line which is drawn continuously across a juncture. Twenty juncture points were identified, including all five of Binder's junctures, ten of those used by Bennett-Levy, and twelve used by Waber and Holmes in their scoring systems. Schorr et al.'s system was evaluated on a sample of 50 neuropsychiatric patients.

5. Kirk and Kelly (1986) proposed a scoring system which quantifies the initial approach to copying the figure. The Starting strategy is assigned a value from five points (for most configural, i.e. drawing the base rectangle first) to one point (for most piecemeal, i.e. drawing detail by detail), based on the first features of the figure to be drawn. A separate Progression score is obtained by evaluating the number of lines required to draw specific features of the design. The greater number of discrete lines which were used, the higher the score and the less configural the approach to the drawing.

California Global-Local Learning Test (Delis & Kaplan, 1987). This is a drawing task using specially-designed hierarchical geometric figures in which larger forms (letters and less familiar shapes) are composed of smaller forms. A typical stimulus is illustrated in Figure 1. Each stimulus was exposed for five seconds, and immediately after exposure, the subject drew the design from memory. The drawings were scored for accuracy of reproduction of the large and small forms independently of one another. Global

Accuracy was rated on a five-point scale for accuracy in reproducing the overall global (large) form, independent of the accuracy of reproduction of the smaller forms. A higher score reflects greater accuracy of configuration. Local Accuracy was also rated on a five-point scale for accuracy in reproducing detailed (small) forms, independent of the accuracy of reproduction of the larger forms. A higher score reflects greater accuracy of detail. Figure 5 shows examples of drawings in which the global accuracy score was greater than the detail accuracy score. Figure 6 shows drawings having the opposite pattern. Another score was a count of the number of global forms drawn using a solid line, with no indication of the local forms. This count yielded a score labelled Solid.

Social Competence Variables

Two rating scales for measuring aspects of social competence were used, and yielded a number of variables, described below.

Social Skills Rating System (Gresham & Elliott, 1990). This is a set of questionnaires for students, teachers and parents which evaluate a broad range of social behaviours. The Social Skills Rating System (SSRS) was standardized in 1988 on a stratified sample of 4700 American children and 1300 teachers, yielding standard scores based on age and gender. A three-point scale ("never" / "sometimes" /

Figure 5

Examples of Drawings in which Global Accuracy was Greater than Local Accuracy

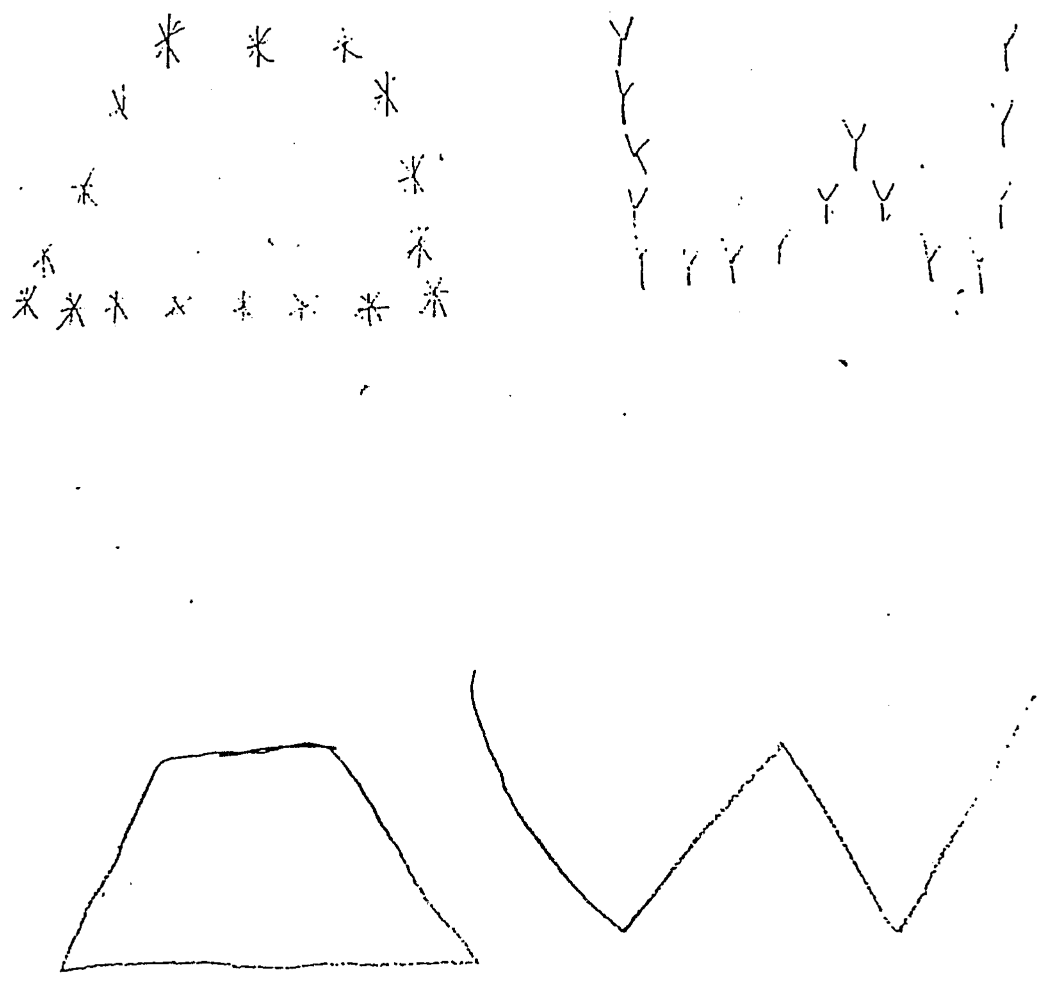
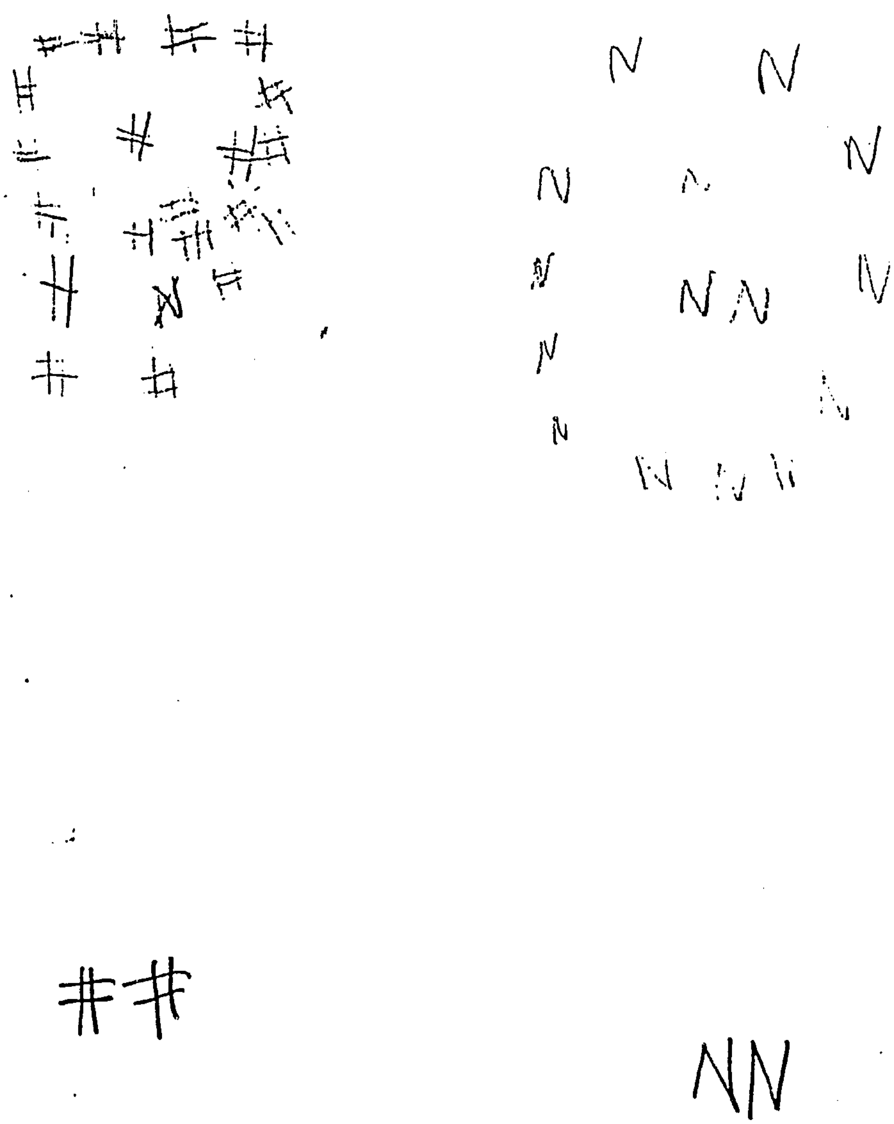


Figure 6

Examples of Drawings in which Local Accuracy was Greater than Global Accuracy



"always") is used to answer questions such as "I make friends easily". A pure factor structure has been demonstrated for this rating scale, and the component factors are internally consistent, with coefficients of congruence exceeding .90 (Gresham, Elliott & Black, 1987). Test-retest reliabilities are reported in the .90's, and interrater reliabilities for the teacher form are in the .70's (Gresham & Elliott, 1989). Construct validity has been demonstrated using other social skills rating scales, peer sociometrics, and direct observation. In the present study, each child directly rated his/her own social skills using the Student Form of the SSRS, yielding a Social Skills standard score. In addition, each subject was rated by his/her teacher on the Teacher Form of the SSRS. This form yields two standard scores: a Social Skills score and a Behaviour Problems score.

Conners' Teacher Rating Scale (Goyette, Conners, & Ulrich, 1978). This rating scale, completed by the teacher, measures a student's attention and activity levels, and is often used in the assessment of attention deficit disorder. The ten-item Hyperactivity Index derived from this instrument was included in the study to provide information about the subjects' attentional abilities, in view of the findings of some authors that inattention and weak self-control characterize those learning disabled children who experience rejection by their peers (Sater & French, 1989) and those who are underachieving specifically in arithmetic (Munson, 1986). The Hyperactivity Index is used with age- and gender-based norms, derived from a sample of 383 children aged from 3 to 17 years (Goyette, Conners, and Ulrich, 1978), to yield a z-score. A higher value denotes greater hyperactivity.

Research indicates that the Hyperactivity Index is a reliable and valid instrument for evaluating attention disorders. Test-retest reliability for the Hyperactivity Index has been measured from .86 to .89 over intervals between tests ranging from two weeks to two months (Epstein & Nieminen, 1983; Zentall & Bartack, 1979). Inter-rater reliability has ranged from .70 to .94 (Epstein & Nieminen, 1983; Homatidis & Konstantareas, 1981). Evidence for validity of the Hyperactivity Index has accumulated from a number of studies described in the test manual (Conners, 1990), including studies of the effects of drug treatment, biofeedback, and relaxation training with hyperactive children. Hyperactivity Index scores have been found to correlate with other established indicators of attention deficit disorder, including established rating scales, physician ratings and neuropsychological test results. Using the Hyperactivity Index, behaviour disordered children have been discriminated from normal and learning disordered peers.

Analysis and Results

The statistical analyses described in this section were carried out using $SPSS^x$ (SPSS Inc., 1896).

The mean scores for each group of subjects on each score used for the analyses are given in Tables 7 (social competence variables), 8 and 9 (drawing style variables).

Table 7

Group Mean Scores and Standard Deviations on Social Competence Variables

		Group			
Variable		Average Achievers	Low Reading	Low Math	Low Overall
Hyperactivity Index	M	0.108	0.904	1.269	0.761
	SD	0.876	0.975	2.361	0.938
SSRS Student Form	M	110.931	98.429	101.118	109.684
	SD	13.164	20.399	18.432	14.633
SSRS Teacher Form					
Social Skills	M	101.586	94.714	92.588	97.053
	SD	10.726	12.009	12.947	9.652
Behaviour Problems	M	101.862	111.357	111.588	108.263
	SD	11.294	17.644	16.229	11.699

Table 8

Group Means and Standard Deviations on Drawing Style Variables (Copy Trial)

Variable		Average Achievers	Low Reading	Low Math	Low Overall
Taylor Accuracy	M	26.603	22.929	24.382	23.974
	SD	4.577	3.931	3.525	3.799
Loring et al. Error Score	M	1.448	2.429	1.824	1.895
	SD	1.502	1.453	1.425	1.100
Bennett-Levy Good Cont'n.	M	10.517	9.786	11.353	11.000
	SD	3.552	2.723	2.572	1.944
Bennett-Levy Symmetry	M	7.069	6.429	7.353	7.000
	SD	2.359	1.604	3.040	2.494
Binder Configural	M	2.655	2.429	2.706	3.368
	SD	1.396	1.555	1.863	1.461
Binder Fragmented	M	2.241	2.571	2.294	1.632
	SD	1.405	1.555	1.863	1.461
Binder Missing	M	0.103	0.000	0.000	0.000
	SD	0.310	0.000	0.000	0.000
Waber & Holmes Level	M	2.655	1.786	2.294	2.474
	SD	1.173	0.802	0.920	0.905
Waber & Holmes Style	M	49.000	48.571	56.235	62.579
	SD	31.429	25.964	32.403	27.553
Kirk & Kelly Starting	M	2.621	2.214	2.529	2.474
	SD	1.781	1.888	2.095	1.954
Kirk & Kelly Progression	M	24.172	23.786	22.941	22.789
	SD	3.974	4.209	3.976	3.155
Schorr et al. Cluster	M	12.586	12.214	13.412	13.474
	SD	3.111	2.887	3.043	2.091
Global-Local Normalized	M	-0.014	-0.452	-0.896	-0.174
	SD	1.055	1.372	1.339	1.291

Table 9

Group Means and Standard Deviations on Drawing Style Variables (Recall Trial)

Variable		Group: Average Achievers	Low Reading	Low Math	Low Overall
Taylor	M	15.121	13.071	14.618	16.711
Accuracy	SD	5.340	5.410	5.249	4.562
Loring et al.	M	3.483	4.357	3.412	3.000
Error Score	SD	1.765	1.865	1.698	1.247
Bennett-Levy	M	6.138	6.643	6.765	8.842
Good Cont'n.	SD	3.420	4.634	4.161	2.950
Bennett-Levy	M	6.483	4.429	5.765	7.263
Symmetry	SD	3.323	3.975	3.437	2.864
Binder	M	2.448	2.000	2.471	3.579
Configural	SD	1.325	1.569	1.586	1.261
Binder	M	1.379	1.571	1.588	0.947
Fragmented	SD	1.115	1.555	1.417	1.079
Binder	M	1.172	1.429	0.941	0.474
Missing	SD	1.167	1.158	1.298	0.618
Waber & Holmes	M	2.069	1.929	1.529	1.842
Level	SD	1.193	1.072	0.717	0.958
Waber & Holmes	M	2.310	2.000	2.294	2.579
Style	SD	0.761	0.784	0.772	0.838
Kirk & Kelly	M	2.966	3.286	3.235	3.263
Starting	SD	1.918	1.684	1.786	1.485
Kirk & Kelly	M	26.207	27.357	25.588	23.684
Progression	SD	3.858	4.651	4.823	2.982

Effects of Age and Gender

The visuospatial and social performance variables used in this analysis are of a type that may be affected by age and gender. Although age and gender distribution were very similar among the four groups of subjects, it remained a possibility that age and gender differences in the variables may have affected the groups differentially. In the case of the social competence variables, this possibility was not considered an important issue because the scores used were standardized with large subject samples stratified according to age and gender. In the case of the Hyperactivity Index, these norms were developed with a Canadian sample, whereas the Social Skills Rating System was developed using an American sample. For the visual learning style variables, however, no standardized scores were available from published reports. To determine whether performance on these tasks varied according to age and gender, the performance of subgroups of Average Achievers varying in age and gender was examined. The 31 subjects in the Average Achievers group, aged from 107 months to 141 months, were split into three subgroups based on age: less than 119 months (nine-year-olds), from 120 to 131 months (ten-year-olds), and from 132 to 143 months (eleven-year-olds). Subjects were also divided according to gender (15 male, 16 female). The subgroup composition is given in Table 10.

Table 10

Composition of Age-Based Subgroups of Average Achievers

Age range	N Males	N Females
Less than 119 months	9	5
120 to 131 months	3	6
132 to 143 months	3	5
Total	15	16

The statistical procedure chosen for comparing the subgroups was MANOVA. With a total of 31 subjects in three subgroups, only one variable could be used and maintain statistical validity. In the case of the Rey-Osterrieth Complex Figure Test, however, there were a large number of scores available from the different scoring methods used. To allow analysis of all this data using only a single statistical test, the scores were combined into one composite variable, called "Drawing". Before the individual scores could be summed, however, transformations of the raw scores were necessary to ensure that the direction of the scores was consistent, and that each received equal weighting in the composite variable.

It was necessary to ensure that the direction of the component scores was consistent, so that in each case a higher value would signify greater configural accuracy. The direction was consistent for all raw scores except the Progression score of Kirk and Kelly (1986), in which a higher score signifies a more piecemeal style. To change the direction of this score, therefore, the raw score was subtracted from a constant (40), yielding an inverted progression score in which a higher value signified greater configural accuracy.

Because different raw scores had different metrics, each was converted to a z-score, based on the mean and standard deviation of the entire group of Average Achievers (given in Table 11). This procedure allowed each score to receive equal weighting in the composite variable. The z-scores for each subject on all these variables were then summed to yield a composite score on the variable labelled "Drawing".

A single variable was also required to capture the subject's performance on the California Global-Local Learning Test. The most important information from the latter test is the relative accuracy of the subject in reproducing global configuration compared to local detail. The difference between these two accuracy scores was therefore considered the most important variable. A simple difference score did not appear adequate, however, because of the wide range of total scores which was observed in the data. To illustrate, compare a subject who had a total

Table 11

Means and Standard Deviations of the Average Achievers Group on Visual Learning Style Scores

Score	Mean	Standard Deviation
Configural (Binder, 1982)	2.60	1.39
Total strategy (Bennett-Levy, 1984)	17.63	4.31
Style (Waber & Holmes, 1985)	48.81	31.92
Cluster Index (Schorr et al., 1992)	12.68	3.07
Starting strategy (Kirk & Kelly, 1986)	2.77	1.70
Inverted progression(Kirk & Kelly,1986)	16.07	4.02

global score of 60 and a local score of 50 (to yield a difference score of 10), with another subject who had a total global score of 20 and a local score of 10 (again yielding a difference score of 10). Although the difference scores received by these subjects are the same, the magnitude of the relative advantage for global over local accuracy is very different in the two cases, and is not captured by the simple difference score. For this reason, it was decided to calculate a score for each subject which would take into account both the difference between the global and local scores, and the relative magnitude of this difference. This was achieved by calculating a normalized score, as follows: (Global Accuracy score <u>minus</u> Local

Accuracy score) divided by (Global Accuracy score _plus_ Local Accuracy score), or symbolically: (G-L)/(G+L). This variable was labelled _"GL Normalized"_.

To determine whether the visual learning style scores varied according to age and gender, MANOVA was carried out using the three subgroups of the Average Achievement group. Using the composite variable _Drawing_ as the dependent variable, the MANOVA revealed no significant main effects for age ($F_{(2,25)} = 1.35$; $p = .278$) or gender ($F_{(1,25)} = 1.15$; $p = .295$), and no significant age x gender interaction ($F_{(2,25)} = 0.12$; $p = .890$). Similar results were obtained when the variable _GL Normalized_ was used as the dependent variable. Again, there were no significant main effects for age ($F_{(2,25)} = .92$; $p = .412$) or gender ($F_{(1,25)} = 0.01$; $p = .930$), and the age x gender interaction was also nonsignificant ($F_{(2,25)} = 0.95$; $p = .401$).

These results indicate that in this sample of schoolchildren of average academic achievement aged from nine to eleven years, age and gender differences have minimal effect on the approach used by the children when drawing the geometric figures used in this study. It therefore is not necessary to stratify the sample according to age and gender in further analyses.

Main Analyses

A series of stepwise discriminant analysis was performed to address the hypotheses of the study. The discriminant analysis procedure allows the use of as many variables as there are subjects, less two (Klecka, 1980). Therefore, all the raw scores available were included in the analysis. The predictor variables were:

1. Scores from the Rey-Osterrieth Complex Figure Test: (Note: Each student made two drawings of the Rey-Osterrieth Complex Figure, one a direct copy and one drawn from memory. Both drawings were scored, and the results were analyzed separately.)

    Taylor: Accuracy score

    Loring et al.: Error score

    Bennett-Levy: Good Continuation, and Symmetry scores

    Binder: Configural, Fragmented, and Missing scores

    Waber & Holmes: Level, and Style scores

    Kirk & Kelly: Starting strategy, and Progression scores

    Schorr et al.: Cluster score

2. Scores from the California Global Local Learning Test:

    GL Normalized, and Solid scores

3. Scores from the Conners Scale:

    Hyperactivity Index

4. Scores from the Social Skills Rating System, Teacher Form: Social Skills, and Behaviour Problems scores
5. Scores from the Social Skills Rating System, Student Form: Social Skills score

Intercorrelations among all variables are given in Appendices D and E.

Two-Group Discriminant Analyses

The first pair of analyses was undertaken to determine whether the Average Achievers could be discriminated from the undifferentiated group of learning-disabled subjects, without considering subgroups of learning disorder. The entire sample of 86 subjects was processed initially. However, because seven subjects had missing data (teacher rating scales), only 79 were included in the analysis, 29 in the Average Achievement group and 50 in the general Learning Disabled group.

Analysis including the copy trial scores from the Rey-Osterrieth Complex Figure Test. The variables included in this analysis were all the social competence variables, the California Global Local Learning Test variables, and the scores from the copy trial of the Rey-Osterrieth Complex Figure Test. The canonical correlation obtained from this analysis was highly significant ($r = .5539$; $x^2 = 27.667$; $p = .0000$), indicating that the General Learning Disabled group is highly discriminable from the Average Achievers using these predictor variables. The structure matrix for this function revealed the highest loading on this function was for the Taylor Accuracy score ($r = .504$). Other scores having moderate loadings were the SSRS - Teacher Form, Behaviour Problems score ($r = -0.450$), the SSRS - Teacher Form, Social Skills score ($r = .424$), and the Loring Error score ($r = -0.422$). Thus, this function appears to measure a combination of drawing accuracy and social competence.

The classification results are presented in Table 12. The correct classification rate was 77.78%, which represents a considerable improvement over the rate which would be expected with random assignment to the two groups. Both groups enjoyed a correct classification rate of approximately 75%.

Table 12

<u>Classification Results of the Two-Group Discriminant Analysis (Copy Trial)</u>

		Predicted Group Membership	
Actual Group	N	Average Achievers	Learning Disabled
Average Achievers	29	22 75.9%	7 24.1%
Learning Disabled	52	11 21.2%	41 78.8%

Percent of Cases Correctly Classified: 77.78%

Univariate F-ratios were calculated for each variable prior to entering the step-wise analysis. These F ratios reveal the relative contribution of each variable, on its own, to the discrimination between the groups. The results are given in Table 13. The best individual discriminator is the Taylor accuracy score, followed in descending importance by the Hyperactivity Index, the SSRS Teacher Form - Behaviour Problems score, the SSRS Teacher Form - Social Skills score, and the Binder Missing score. These results indicate that drawing accuracy and social competence are significant discriminators between the two groups, when the variables are considered in isolation and redundancies in discriminating power are not considered.

Group mean scores on these variables are given in Table 14. These scores reveal that the Average Achievers were more accurate in their copies of the Rey-Osterrieth Complex Figure, were less hyperactive, and had fewer behaviour problems and better social skills, than the Learning Disabled subjects.

A step-wise discriminant analysis was conducted to produce the optimal combination of variables which could be used to discriminate the groups from each other, while reducing redundancy from variables which may have shared discriminating power. A summary of the results is presented in Table 15. The first variable to enter the discriminant

Table 13

Univariate F-ratios for Individual Variables in the Two-Group Discriminant Analysis

Variable Name	F-ratio	p
Taylor Accuracy	8.669	0.0043
Hyperactivity Index	7.500	0.0077
SSRS Teacher Form-Behaviour Probs.	6.913	0.0103
SSRS Teacher Form-Social Skills	6.597	0.0121
Binder Missing	5.623	0.0202

Note. Each F statistic has 1 and 77 degrees of freedom.

Table 14

Group Mean Scores for Significant Discriminators in Univariate F-tests in the Two-Group Analysis

	Group	
Variable	Average Achievers	Learning Disabled
Taylor Accuracy	26.603	23.820
Hyperactivity Index	0.108	0.974
SSRS Teacher Form-Behav. Probs.	101.862	110.260
SSRS Teacher Form-Social Skills	101.586	94.880
Binder Missing	0.310	0.000

function was the Taylor Accuracy score, this being the single most effective discriminator between the Average Achievers and the General Learning Disabled group (F (1,77) = 8.699; p = .0043). The greatest discriminating power can be obtained using the combination of the first two variables which entered the analysis (Taylor Accuracy, and Binder Missing; F (2,76) = 13.390; $p < .0001$), although the F-to-remove ratios for all three variables were much larger than for any other variables (Taylor accuracy F-to-remove = 17.751; Binder Missing F-to-remove = 15.276; and SSRS Teacher Rating of Social Skills F-to-remove = 5.0046; F-to-enter for all other variables is below 1.0). Group means on these two variables are presented in Table 16. Inspection of these means reveals that the Average Achievers were more accurate in their drawings using the Taylor scoring criteria, although they were also more likely to leave lines out (Binder Missing score).

Analysis including the delayed recall scores from the Rey-Osterrieth Complex Figure Test. The canonical correlation obtained from this analysis revealed that, when the delayed recall trial data from the Rey-Osterrieth Complex Figure Test was used in place of the copy trial data, the two groups were again significantly discriminated (r = .4999; x^2 = 21.137; p = .0036), but somewhat less effectively than when using the copy trial data. The structure matrix for this function revealed the highest

Table 15

Summary Table of the Two-Group Step-Wise Discriminant Analysis (Copy Trial)

Step	Variable Entered	Number of Variables In	Wilks Lambda	p
1	Taylor Accuracy	1	.8988	.0043
2	Binder Missing	2	.7395	<.001
3	SSRS Teacher Form - Behaviour Problems	3	.6932	<.001

Table 16

Group Means on the Discriminator Variables in the Two-Group Discriminant Analysis (Copy Trial)

	Variable	
Group	Taylor	Missing
Average Achievers	26.60	0.103
Learning Disabled	23.82	0.000

loadings on the Hyperactivity Index (r = -0.541), the SSRS Teacher Form, Problem Behaviours score (r = -0.519), and the SSRS Teacher Form, Social Skills score (r = .492). Thus, this function clearly appears to measure a lack of hyperactive or problem behaviours, and social competence.

The classification results are presented in Table 17. The correct classification rate was 69.62%, which represents a considerable improvement over the rate which would be expected with random assignment to the two groups, but in the case of the Learning Disabled group, is lower than the correct classification rate obtained using the copy trial data.

Table 17

Classification Results of the Two-Group Discriminant Analysis (Delayed Recall Trial)

		Predicted Group Membership	
Actual Group	N	Average Achievers	Learning Disabled
Average Achievers	29	21 72.4%	8 27.6%
Learning Disabled	50	16 36.4%	34 63.6%

Percent of Cases Correctly Classified: 69.62%

Univariate F-ratios were calculated for each variable prior to entering the step-wise analysis, and the variables which reached significance are reported in Table 18. The best individual discriminator is the Hyperactivity Index, followed in descending importance by the SSRS Teacher Form - Behaviour Problems score, and the SSRS Teacher Form - Social Skills score. Thus, using delayed recall rather than copy trial data from the Rey-Osterrieth Complex Figure, drawing accuracy is no longer a significant discriminator. The two groups differ significantly only in activity level and social competence.

Group mean scores on these variables have been given in Table 14. These scores reveal that the Average Achievers are less hyperactive, and have fewer behaviour problems and better social skills, than the Learning Disabled subjects.

Table 18

Univariate F-ratios for Individual Variables in the Two-Group Discriminant Analysis (Delayed Recall Trial)

Variable Name	F-ratio	p
Hyperactivity Index	7.500	0.0077
SSRS Teacher Form-Behaviour Probs.	6.913	0.0103
SSRS Teacher Form-Social Skills	6.597	0.0121

Note. Each F statistic has 1 and 77 degrees of freedom.

A summary of the results of the step-wise discriminant function is presented in Table 19. The first variable to enter the discriminant function, and the variable which by itself provides the greatest discrimination among the groups, was the Hyperactivity Index ($F\ (1,77) = 7.500$; $p = .0077$). The most effective discrimination was obtained using the first four scores together, that is, the Hyperactivity Index, GL Normalized, Bennett-Levy Good Continuation, and Bennett-Levy Symmetry ($F\ (4,74) = 4.699$; $p = .0020$). The F-to-remove values for all four variables were 3.1233 or greater, while the F-to-enter for all other variables was no greater than 1.6418.

The results of the canonical correlation and the discriminant function analysis indicate that using the Rey-Osterrieth Complex Figure Test delayed recall trial data, the Average Achievers and the General Learning Disabled groups are significantly different in hyperactivity and in stylistic approach in drawing. Group means on the four variables identified as significant in these analyses are presented in Table 20. The most important variable, being by itself the most powerful discriminator among the groups, was the Hyperactivity Index. Inspection of the means reveals that the General Learning Disabled group had a score on this variable which indicated a higher degree of hyperactivity than the Average Achievers. The General Learning Disabled group also had a more piecemeal, detail-

Table 19

Summary Table of the Two-Group Step-Wise Discriminant Analysis (Delayed Recall Trial)

Step	Variable Entered	Number of Variables In	Wilks Lambda	p
1	Hyperactivity Index	1	.9113	.0077
2	Global Local Normalized	2	.8766	.0067
3	Binder Good Continuation	3	.8538	.0076
4	Binder Symmetry	4	.7974	.0020
5	Waber & Holmes Level	5	.7799	.0024
6	SSRS Student Form	6	.7620	.0027
7	SSRS Teacher Form - Behaviour Problems	7	.7501	.0036

oriented approach to drawing the California Global Local Learning Test figures. The scores on stylistic approach to the Rey-Osterrieth Complex Figure were inconsistent. The Average Achievers had a stronger configural score on one variable (Symmetry), while the General Learning Disabled were more configural on the other (Good Continuation).

Four-Group Discriminant Analyses

The foregoing analyses clearly showed that the Average Achievers are different from the undifferentiated learning disabled group on variables measuring drawing accuracy,

Table 20

Group Means on the Discriminator Variables in the Two-Group Discriminant Analysis (Recall Trial)

	Variable			
Group	H-Index[a]	GLNorm[b]	GdCont[c]	Symm[d]
Average Achievers	0.108	-0.014	6.138	6.483
Learning Disabled	0.974	-0.497	7.520	5.960

[a] H-Index = Hyperactivity Index
[b] GL Norm = Global Local Normalized Score
[c] Gd Cont = Bennett-Levy Good Continuation Score
[d] Symm = Bennett-Levy Symmetry Score

activity level, social competence, and drawing style. Another set of analyses was conducted to determine whether subgroups of learning disabled subjects, classified according to their academic achievement profiles, could also be discriminated from the Average Achievers.

The four groups of subjects used in these analyses were:

Group 1 - Average Achievement group (n=29)

Group 2 - Low Reading group (n=14)

Group 3 - Low Math group (n=17)

Group 4 - Low Overall group (n=19)

Analysis including the copy trial scores from the Rey-Osterrieth Complex Figure Test. The canonical correlation obtained from this analysis revealed that one function significantly and substantively discriminated among the groups (r = .5706; x^2 = 45.840; p = .0013). This function accounted for 65.33 percent of the total discriminating power of the canonical correlation. The structure matrix for this function revealed moderate loadings for Taylor accuracy (r = .497) and the Hyperactivity Index (r = -.453), indicating that this function appears to be measuring a combination of drawing accuracy on the Rey-Osterrieth Complex Figure and lack of hyperactive behaviour.

The classification results are presented in Table 21. The correct classification rate was 56.79%, which is a considerable improvement over the rate which would be expected with random assignment to groups. For all groups, more subjects were assigned to the correct group than to any incorrect group. The group having the lowest rate of correct assignment (44.4%) was the Low Math group.

Univariate F-ratios were calculated for each variable prior to entering the step-wise analysis, and those which reached significance are given in Table 22. The best individual discriminator was once again the Taylor accuracy score, followed in descending importance by the Hyperactivity Index, and the SSRS Student Form - Social Skills score. These results indicate that drawing accuracy

Table 21

Classification Results of the Four-Group Discriminant Analysis (Copy Trial)

Actual Group	N	Predicted Group Membership: Average Achievers	Low Reading	Low Math	Low Overall
Average Achievers	30	20 66.7%	2 6.7%	4 13.3%	4 13.3%
Low Reading	14	2 14.3%	7 50.0%	4 28.6%	1 7.1%
Low Math	18	4 22.2%	3 16.7%	8 44.4%	3 16.7%
Low Overall	19	5 26.3%	1 5.3%	2 10.5%	11 57.9%

Percent of Cases Correctly Classified: 56.79%

Table 22

Univariate F-ratios for Individual Variables in the Four -Group Discriminant Analysis (Copy Trial)

Variable Name	F-ratio	p
Taylor Accuracy	3.193	0.0283
Hyperactivity Index	2.911	0.0399
SSRS Student Form-Social Skills	2.767	0.0476

Note. Each F statistic has 3 and 75 degrees of freedom.

and social competence are significant discriminators among the four groups, when the variables are considered in isolation and redundancies in discriminating power are not considered.

Group mean scores on these variables are given in Table 23. These scores reveal that the Average Achievers are more accurate in their copies of the Rey-Osterrieth Complex Figure and are less hyperactive than the three learning disabled groups. Together with the Low Overall group, the Average Achievers share a higher self-rating of their own social competence than the Low Reading and the Low Math groups.

A summary of the results of the step-wise discriminant analysis is presented in Table 24. The first variable to enter the discriminant function was the Taylor Accuracy score, indicating that this variable by itself provides the best discrimination among the groups ($F\ (3,75) = 3.193$; $p = .0283$). The differences between pairs of groups are presented in Table 25, which shows that using this variable alone, the Average Achievers group is significantly different from both the Low Reading group and the Low Overall group. The Low Math group is not significantly different from any other group.

The greatest discriminating power is obtained using the first three variables in combination (Taylor Accuracy, Binder Missing, and SSRS Student Form; $F\ (9,\ 177.8) =$

Table 23

Group Mean Scores for Significant Discriminators in Univariate F-tests in the Four-Group Analysis (Copy Trial)

Variable	Group: Average Achievers	Low Reading	Low Math	Low Overall
Taylor Accuracy	26.603	22.929	24.382	23.974
Hyperactivity Index	0.108	0.904	1.269	0.761
SSRS Student Form	110.931	98.429	101.118	109.684

Table 24

Summary Table of the Four-Group Step-Wise Discriminant Analysis (Copy Trial)

Step	Action: Entered	Removed	Number of Variables In	Wilks Lambda	p
1	Taylor Accuracy		1	.8868	.0283
2	Binder Missing		2	.7266	.0005
3	SSRS Student Form		3	.6643	.0004
4	Global Local Normalized		4	.6290	.0006
5	Binder Fragmented		5	.5928	.0008
6	Hyperactivity Index		6	.5575	.0009
7	Good Continuation		7	.5314	.0014

3.615; p = .0004). The F-to-remove values for these variables are: 6.2900 for Taylor Accuracy; 5.3233 for Binder Missing; and 2.2809 for SSRS Student Form. F-to-enter values for all other variables are not above 1.36 at this step in the analysis. Table 26 displays the differences between pairs of groups at this stage of the discriminant analysis. The Average Achievers group is different from all three Learning Disabled groups, but none of the Learning Disabled groups differ from one another. Group means on the three variables are presented in Table 27. Inspection of these means reveals that the Average Achievers differed from the Learning Disabled groups in having more accurate copies of the Rey-Osterrieth Complex Figure, but more missing lines in their drawings. The Average Achievers shared a higher self-rating of social skills with the Low Overall group, in comparison with the other two groups. These results are similar to the results obtained from the two-group discriminant analysis. It is notable that in neither of these analyses using the copy trial data from the Rey-Osterrieth Complex Figure Test, did the variables quantifying stylistic approach to the drawing tasks contribute significantly to the group discrimination.

Table 25

Univariate F-Statistics and Significances between Pairs of Groups Following the First Step of the Four-Group Discriminant Analysis (Copy Trial)

Group		Average Achievers	Low Reading	Low Math
Low Reading	F	7.6744		
	p	0.0071		
Low Math	F	3.1822	0.9766	
	p	0.0785	0.3262	
Low Overall	F	4.7780	0.5299	0.0902
	p	0.0319	0.4689	0.7648

Note. Each F Statistic has 1 and 75 degrees of freedom.

Table 26

Univariate F-Statistics and Significances between Pairs of Groups Following the Third Step of the Four-Group Discriminant Analysis (Copy Trial)

Group		Average Achievers	Low Reading	Low Math
Low Reading	F	8.0832		
	p	0.0001		
Low Math	F	5.2724	0.4696	
	p	0.0024	0.7044	
Low Overall	F	5.1190	1.4622	0.8745
	p	0.0029	0.2319	0.4584

Note. Each F Statistic has 3 and 73 degrees of freedom.

Table 27

Group Means on the Discriminator Variables in the Four-Group Discriminant Analysis (Copy Trial)

	Variable		
Group	Taylor Accuracy	Binder Missing	SSRS Student
Average Achievers	26.603	0.103	110.931
Low Reading	22.929	0.000	98.429
Low Math	24.382	0.000	101.118
Low Overall	23.974	0.000	109.684

Analysis including the delayed recall scores from the Rey-Osterrieth Complex Figure Test. The canonical correlation obtained from this analysis revealed that, as in the previous analysis, one function significantly and substantively discriminated among the groups ($r = .5527$; $x^2 = 46.284$; $p = .0041$). This function accounted for 59.14 percent of the total discriminating power of the canonical correlation. The structure matrix for this function revealed moderate loadings for the SSRS Student Form ($r = .496$), the Hyperactivity Index ($r = -.448$), and the SSRS Teacher Form, Social Skills score ($r =. 443$). Thus, this function appears to measure social competence and lack of hyperactive behaviour.

The classification results are presented in Table 28. The correct classification rate was 60.49%, which is marginally better than the rate obtained using the copy trial data from the Rey-Osterrieth Complex Figure Test. Once again, this classification rate represents a considerable improvement over the rate which would be expected with random assignment to groups. For all groups, more subjects were assigned to the correct group than to any incorrect group. The group having the lowest rate of correct assignment (44.4%) was again the Low Math group.

Univariate F-ratios were calculated for each variable prior to entering the step-wise analysis and the results are given in Table 29. In this case, the best individual discriminator is the Binder Configural score, followed in descending importance by the Hyperactivity Index and the SSRS Student Form - Social Skills score. Thus, drawing style, hyperactivity, and self-evaluation of social competence are significant discriminators among the groups, when the variables are considered in isolation and redundancies in discriminating power are not considered.

Group mean scores on these variables are given in Table 30. These scores reveal that the Low Reading group used the least configural approach to drawing the Rey-Osterrieth Complex Figure. The Average Achievers were less hyperactive than the three learning disabled groups. Together with the Low Overall group, the Average Achievers shared a higher

Table 28

Classification Results of the Four-Group Discriminant Analysis (Delayed Recall Trial)

Actual Group	N	Predicted Group Membership: Average Achievers	Low Reading	Low Math	Low Overall
Average Achievers	30	22 73.3%	2 6.7%	2 6.7%	4 13.3%
Low Reading	14	3 21.4%	9 64.3%	1 7.1%	1 7.1%
Low Math	18	3 16.7%	3 16.7%	8 44.4%	4 22.2%
Low Overall	19	5 26.3%	1 5.3%	3 15.8%	10 52.6%

Percent of Cases Correctly Classified: 60.49%

Table 29

Univariate F-ratios for Individual Variables in the Four-Group Discriminant Analysis (Recall Trial)

Variable Name	F-ratio	p
Binder Configural	4.005	0.0106
Hyperactivity Index	2.911	0.0399
SSRS Student Form - Social Skills	2.767	0.0476

Note. Each F statistic has 3 and 75 degrees of freedom.

Table 30

Group Mean Scores for Significant Discriminators in Univariate F-tests in the Four-Group Analysis (Delayed Recall)

	Group			
Variable	Average Achievers	Low Reading	Low Math	Low Overall
Binder Configural	2.448	2.000	2.471	3.579
Hyperactivity Index	0.108	0.904	1.269	0.761
SSRS Student Form	110.931	98.429	101.118	109.684

self-rating of their own social competence than the Low Reading and the Low Math groups.

A summary of the results of the step-wise discriminant function is presented in Table 31. The first variable to enter the discriminant function was the Binder Configural score ($F(3,75) = 4.005$; $p = .0106$). Thus, in the case of delayed recall of the Rey-Osterrieth Complex Figure, the best single discriminator among the groups is this measure of drawing style. Table 32 presents the differences among groups using this variable alone as a discriminator, and shows that the Low Overall group is significantly different from every other group. No other group differences are significant.

Table 31

Summary Table of the Four-Group Step-Wise Discriminant Analysis (Delayed Recall Trial)

Step	Variable Entered	Number of Variables In	Wilks Lambda	p
1	Binder Configural	1	.8619	.0106
2	Hyperactivity Index	2	.7644	.0026
3	Global Local Normalized	3	.7044	.0020
4	SSRS Student Form	4	.6531	.0016
5	Good Continuation	5	.6178	.0022
6	Symmetry	6	.5818	.0024
7	Loring Errors	7	.5535	.0033
8	Waber & Holmes Level	8	.5258	.0042

The greatest discriminating power is obtained using a combination of the first four variables to enter the analysis (Binder Configural; Hyperactivity Index; GL Normalized; and SSRS Student Form; $F(12, 190.8) = 2.778$, $p = .0016$). This indicates that the four groups can be discriminated by a combination of stylistic approach to the drawing tasks, hyperactivity level, and self-rating of social skills. The F-to-remove values for these variables are: 3.9410 for Binder Configural; 2.4469 for Hyperactivity Index; 2.0355 for Global Local Normalized; and 1.8844 for SSRS Student Form. There were no F-to-enter values above 1.3531 for any other variables at this step in the analysis. The group differences obtained using these variables are presented in Table 33. All pairs of groups are significantly different from one another, except for the Average Achievers/Low Overall pair, and the Low Math/Low Reading pair.

Group means on the four variables identified as significant in these analyses are presented in Table 34. Inspection of these means reveals that the Average Achievers had a lower level of hyperactivity, a more configural style on the California Global-Local Learning Test, and higher self-ratings of social skills, than did other groups. The Low Reading group had the lowest self-rating of social skills, and the least configural approach to the Rey-

Table 32

Univariate F-Statistics and Significances between Pairs of Groups Following the First Step of the Four-Group Discriminant Analysis (Delayed Recall Trial)

		Group		
Group		Average Achievers	Low Reading	Low Math
Low Reading	F	0.9484		
	p	0.3333		
Low Math	F	0.0027	0.8499	
	p	0.9589	0.3595	
Low Overall	F	7.3357	10.0450	5.5096
	p	0.0084	0.0022	0.0216

Note. Each F Statistic has 1 and 75 degrees of freedom.

Table 33

Univariate F-Statistics and Significances between Pairs of Groups Following the Fourth Step of the Four-Group Discriminant Analysis (Delayed Recall Trial)

		Group		
Group		Average Achievers	Low Reading	Low Math
Low Reading	F	2.7969		
	p	0.0322		
Low Math	F	4.2588	0.6168	
	p	0.0038	0.6520	
Low Overall	F	2.0963	3.7471	3.4068
	p	0.0901	0.0080	0.0131

Note. Each F Statistic has 4 and 72 degrees of freedom.

Table 34

Group Means on the Discriminator Variables in the Four-Group Discriminant Analysis (Delayed Recall Trial)

	Variable			
Group	Config[a]	H-Index[b]	GLNorm[c]	SSK Stud[d]
Average Achievers	2.448	0.108	-0.014	110.931
Low Reading	2.000	0.904	-0.452	98.429
Low Math	2.471	1.269	-0.896	101.118
Low Overall	3.579	0.761	-0.174	109.684

[a] Config = Binder Configural Score
[b] H-Index = Hyperactivity Index
[c] GL Norm = Global Local Normalized Score
[d] SSK Stud = SSRS Student Form

Osterrieth Complex Figure Test. The Low Math group had the highest rating in hyperactivity and the most detail-orientedapproach on the California Global Local Learning Test. The Low Overall group used the most configural approach to drawing the Rey-Osterrieth Complex Figure, and were similar to the Average Achievers in drawing style for the California Global Local Learning Test and in self-ratings of social competence.

Table 35 summarizes the main findings of this study.

Table 35

Summary of Discriminant Analysis Results

Groups Compared	Best Discriminators: Singly	Best Discriminators: Combined	Results
Copy Trial			
Average All LD[1]	Taylor Hyperac. SSRS Prob. SSRS Teach. Errors	Taylor Missing	Avg. grp. more accurate Avg. grp. more missing Avg. grp. less hyperac. Avg. grp. better social skills
Average Low Reading Low Math Low Overall[2]	Taylor Hyperac. SSRS Stud.	Taylor Missing	Avg. grp. most accurate Avg. grp. most missing Low Math most hyperact. Low Read. lowest social
Recall Trial			
Average All LD[3]	Hyperac. SSRS Prob. SSRS Teach.	Hyperac. GL Norm. Good Con. Symmetry	LD grp. most hyperact. Avg. grp. more config. on GL Norm and Symmetry LD grp. more config. on Good Continuation
Average Low Reading Low Math Low Overall[4]	Config. Hyperac. SSRS Stud.	Config. Hyperac. GL Norm. SSRS Stud.	Low Read. least config. on Binder; Low Math on GL Norm. Low Math most hyperac.

1 The two groups are significantly different (p=0.0000)
2 The Average Achievers differ from all other groups (p=0.0004); no differences among the 3 LD groups.
3 The two groups are significantly different (p=0.0020).
4 All pairs of groups differ (p=0.0016), except the pairs of Low Reading/Low Math, and Low Overall/Average.

Post-Hoc Analyses

Low Configural group. A closer look was taken at those subjects who had used a strongly detail-oriented approach to the California Global Local Learning Test, and therefore scored poorly on the configural component. A total of eight subjects of the entire group of 120 (6.67%) scored two or more standard deviations below the mean of the Average Achievers group on the GL Normalized variable, and were grouped together in a "Low Configural" group. This group was slightly younger than the other sample groups (mean age = 116.88 months, standard deviation 12.91; range 99 to 141 months). The distribution of these subjects among the sample groups is as follows: 1 Average Achiever (2.27% of the Average group); 3 Low Reading subjects (18.75% of the Low Reading group); 3 Low Math subjects (8.57% of the Low Math group): and 1 subject from the Low Overall group (4.00% of that group). Thus, 37.5% of the Low Configural group was from the Low Reading group, even though the reading disabled group was the smallest in number in the general sample.

The Low Configural group's mean scores on the variables of significance in this study, and the intercorrelations among those variables in the group, are presented in Table 36. In comparing these mean scores with those of the other groups (Tables 7, 8, and 9), the Low Configural group has a lower rating than any of the learning disabled groups or the Average Achievers on the SSRS Teacher Form -Social Skills, as well as a higher rating on the SSRS Teacher Form - Behaviour Problems. Table 36 also reveals very high correlations among the variables measuring drawing style (GL Norm, Good Continuation, Symmetry, and Configural), and also among those measuring social competence (the SSRS variables, and the Hyperactivity Index). Contrary to what might be expected with such a small group whose range on at least one variable is highly restricted (the GL Norm variable), these intercorrelations are much stronger than those in the sample as a whole, and indicate that this Low Configural group is a highly identifiable group. Using two different sets of social competence measures, this group is consistently rated low in social competence.

Hyperactive group. Since the Hyperactivity Index was identified as a good discriminator among groups in the main analyses, a closer look was taken at the subjects who received a high rating in hyperactivity. A total of 22 subjects of the entire sample of 120 (18.33%) scored two or more standard deviations above the mean of the Average Achievers group on the Hyperactivity Index. This group was older than the other sample groups (mean age = 144.68 months, standard deviation 17.81; range 109 to 173 months). The distribution of these subjects among the sample groups is as follows: 5 Average Achievers (11.36% of the Average group); 3 Low Reading subjects (18.75% of the Low Reading group); 8 Low Math subjects (22.86% of the Low Math group);

Table 36

Mean Scores and Intercorrelations Among Scores Obtained by Low-Configural Subjects

	Variable							
	SSK Teach	SSK Prob	SSK Stud	Hyper Index	GL Norm	Good Cont.	Symm	Config
M	90.00	116.63	105.13	1.02	-2.60	7.00	5.38	2.38
SD	12.46	12.85	26.65	1.09	0.54	3.25	3.54	1.51
Teach	1.000							
Prob	**-0.999**	1.000						
Stud	**0.980**	**-0.972**	1.000					
Hypr	**-0.77[illegible]**	**0.794**	**-0.630**	1.000				
GL	-0.206	0.172	-0.398	-0.462	1.000			
GdCo	-0.300	0.268	-0.486	-0.373	**0.995**	1.000		
Symm	-0.655	0.629	-0.793	0.027	**0.874**	**0.918**	1.000	
Conf	-0.189	0.156	-0.382	-0.477	**0.999**	**0.993**	**0.866**	1.000

and 5 subjects from the Low Overall group (20.00% of that group). Thus, there was a higher proportion of hyperactive children in the learning disabled groups than in the Average Achievers group, and the rates in the various learning disabled groups were comparable. The proportion of Average Achievers who were hyperactive is reflective of the rate in the general population.

The Hyperactive group's mean scores on the variables of significance in this study are presented in Table 37. In comparing these mean scores with those of the other groups (Tables 7, 8, and 9 and 36), the Hyperactive group has the lowest rating of any group in this study on the SSRS Teacher Form -Social Skills and the SSRS Student Form, as well as the highest rating on the SSRS Teacher Form - Behaviour Problems. It is notable but not unexpected that the Hyperactive group has the weakest social performance in this study. The strongest correlations for this group are found among the three variables measuring drawing style on the Rey-Osterrieth Complex Figure (Good Continuation, Symmetry, and Configural), ranging from 0.601 to 0.673. Configural scores are not strongly correlated with hyperactivity or social competence in this group.

Table 37

Mean Scores and Intercorrelations Among Scores Obtained by Hyperactive Subjects

	Variable							
	SSK Teach	SSK Prob	SSK Stud	Hyper Index	GL Norm	Good Cont.	Symm	Config
M	81.29	121.29	91.91	4.24	0.08	8.09	6.82	3.00
SD	9.83	12.42	18.10	2.24	1.31	4.34	4.49	1.48
Teach	1.000							
Prob	-0.437	1.000						
Stud	0.562	-0.245	1.000					
Hypr	-0.309	0.218	-0.053	1.000				
GL	-0.056	-0.049	-0.068	-0.337	1.000			
GdCo	0.262	-0.410	0.024	0.053	0.388	1.000		
Symm	-0.079	-0.238	0.275	0.461	0.152	**0.673**	1.000	
Conf	0.138	-0.287	0.249	-0.221	0.428	**0.632**	**0.601**	1.000

Discussion

The purpose of this study was to determine whether a child's academic achievement profile, social competence, and processing of the details or configuration of a design, are interrelated. The results support a relationship between academic profile and drawing style, and between academic profile and social competence, in that variables which measure drawing style and social competence did vary significantly among the four subject groups (see Tables 22 and 29). Used the variables in combination, however, the Low Math and Low Reading groups were not discriminable. Hyperactivity was repeatedly found to contribute to the group discrimination. These findings are discussed in further detail below, (a) as they relate to the hypotheses of the study, and (b) as they relate to brain-behaviour relationships proposed by other researchers.

Hypothesis 1. In comparison with normally-achieving children, those children with specific arithmetic disorders will have weak configural scores on visuoconstructional tasks.

This hypothesis was not supported using copy trial data from the Rey-Osterrieth Complex Figure Test, since the Low

Math group was not significantly different from the Average Achievers. Partial support for this hypothesis is found in the analysis using recall trial data. The best discrimination among the groups was achieved at the fourth step of the discriminant analysis. The largest difference between groups was between the Low Math group and the Average Achievers (p=.0038, Table 33). This difference arose using a combination of four variables, two of which measure drawing style: the Binder Configural score for the recall trial of the Rey-Osterrieth Complex Figure Test, and the Normalized score from the California Global Local Learning Test. Examination of group means on these two variables (Table 34) reveals that, when drawing from memory, the Low Math group used the least configural approach of all the groups on the California Global Local Learning Test, whereas the Average Achievers used the most configural approach. The two groups were not different on their approach to the Rey-Osterrieth Complex Figure.

This finding of group differences with the California Global Local Learning Test must be tempered by the fact that, standing alone, this measure was not a significant discriminator among the four groups. It reached significance only in combination with other variables in the step-wise discriminant analysis. Thus, at best the first hypothesis received only limited support in the present study.

The relationship between visuospatial ability and math performance has been explored in earlier studies, with varying results. Some studies have found that visuoperceptual and spatial measures are more strongly correlated with math achievement than are other variables such as auditory perceptual or verbal variables (Rosner, 1973; Solan, 1987; White et al., 1992). There are, however, a number of other factors involved in math performance and a variety of ways in which math performance can be disrupted (Badian, 1983; Gordon, 1992; Tuokko, 1982), apart from visuospatial factors. The observation that, in this study, the Low Math group consistently had the lowest classification rates in the discriminant analyses, indicates that this group was the most heterogeneous. Math-disabled subjects may need to be further classified into subgroups according to the types of errors they exhibit, in order to gain a clear idea of how various cognitive factors, including aspects of visuospatial processing, contribute to math achievement.

A premise of this study was that visuospatial processing has in the past often been treated as a unitary factor in research studies. This overinclusiveness has confused the issue of how visuospatial processes contribute to math achievement. The division of visuospatial processing into components (detail-oriented and configural) has been shown to have validity by the results of this study. Further work with well-defined subgroups of math-disabled subjects may further elucidate the role of these components in math achievement.

The results further suggest that the Rey-Osterrieth Complex Figure Test and the California Global Local Learning Test cannot be used interchangeably as measures of components of visuospatial processing. In fact, the correlation between the variables from each test which were found to be significant discriminators (the Binder Configural score and the GL Normalized score) is very low (r=0.0119). Since the California Global Local Learning Test was specifically designed to assess configural versus detail processing, while the Binder Configural score was devised post-hoc based on clinical experience with the Rey-Osterrieth Complex Figure Test, the California Global Local Learning Test may be the more valid instrument for this purpose. Validity studies done to date with clinical populations support its usefulness in discriminating groups based on cognitive processing style (Bihrle et al., 1989; Delis, Kramer, & Kiefner, 1988; Delis, Kiefner, & Fridlund, 1988; Delis et al., 1986). Further information on convergent and divergent validity of the instrument would also help to validate it. In the present study, the GL Normalized score provides the only support for the hypothesis that children with specific arithmetic disorders are less likely to use a configural approach to visuoconstructional tasks than average achieving children.

Hypothesis 2. In comparison with normally-achieving children, those children with specific reading disorders will have weak detail scores on visuoconstructional tasks.

This hypothesis was not supported by the results of the analysis using copy trial data from the Rey-Osterrieth Complex Figure Test. Although the Low Reading group was significantly different from the Average Achievers, none of the variables measuring drawing style contributed significantly to the discrimination.

Using the delayed recall trial data from the Rey-Osterrieth Complex Figure Test, this hypothesis was again not supported. At the fourth step of the discriminant analysis, when the best discrimination among the groups occurred, the Low Reading group was significantly different from the Average Achievers ($p=.0322$, Table 33). On the two variables entered in the discriminant analysis at this step which measured drawing style, however, the Low Reading group used a <u>more</u> detail-oriented style than did the Average Achievers. This result is similar to the findings of Klicpera (1983) using the Rey-Osterrieth Complex Figure.

It is of interest to note that of the eight subjects from the entire sample who had used a strongly detail-oriented approach to the California Global Local Learning Test, three subjects (37.5%) were from the Low Reading group, even though the reading disabled group made up only 13.3% of the sample of 120 subjects. Thus, a small subgroup of reading-disabled subjects showed a very strong detail-oriented approach to the task. These subjects may be similar to those described by Bakker (1992) as L-type dyslexics, who show a reliance on what is described as left-hemisphere processing in reading. These stand in contrast to P-type dyslexics, who are postulated to rely on right-hemisphere reading strategies. Although Bakker's model of dyslexia subtypes has not yet been independently validated (Hynd, 1992), the present findings, which show that at least some reading-disabled subjects are strongly detail-oriented, appear to be consistent with it. Further study of visuospatial processing in subgroups of dyslexics, grouped according to Bakker's criteria, would be warranted.

Hypothesis 3. Children with specific arithmetic disorders will receive weaker social competence ratings than will other children.

This hypothesis is partially supported, in that the Low Math group received a lower mean score on the teacher rating of social skills, and a higher mean score on behaviour problems, than other groups. These variables, however, were not significant discriminators among the learning disabled groups.

A social competence variable which was found to have significance was the student's own self-rating of social skills. The mean score of the Low Math group was similar to that of the Low Readers, and lower than that of the Average Achievers and the Low Overall groups. This variable entered the discriminant analysis, in combination with the Hyperactivity Index and two drawing style variables, when the recall trial data was used. Using all four variables, the Low Math group was significantly different from the Average Achievers and the Low Overall groups, but once again was not discriminable from the Low Reading group (Table 33). In another recent study of self-acceptance ratings by learning disabled and average or high achieving students, those who were low achievers in both reading and math, and those who were particularly low in reading, had lower self-ratings than did the average or high achievers, but the two low-achieving groups did not differ significantly from one another (Vaughn et al., 1992). These results indicate that weak social competence is not limited to those with specific arithmetic disorders, but occurs in other learning disorders as well.

The most consistently effective variable in discriminating the four groups, both standing alone and in combination with other variables, was the Hyperactivity Index. The Low Math group had the highest rating on this variable (indicating greatest attentional difficulties) followed by the Low Reading and Low Overall groups. The Average Achievers had the lowest score. If the behaviours associated with an attention deficit can be considered socially maladaptive, then the Low Math group is showing weak social competence in at least one component of the multidimensional model proposed by Vaughn and colleagues (1992, 1993). There is general agreement across a number of studies that children with attention deficits are at risk for peer relationship problems (Cantwell & Baker, 1992). Other research has shown that social difficulties are more strongly associated with hyperactivity than with learning disability (Bruck & Hebert, 1982). In the present study, the subgroup of subjects who had the highest ratings in hyperactivity, also received the lowest ratings in social competence of any group (Table 37).

An association between nonverbal learning disorder and distractibility and disinhibition, was noted early by Johnson and Myklebust (1967). According to the nonverbal learning disability model, social difficulties arise from early visuoperceptual problems. In the present study, social difficulties were found in conjunction with a high rating on the Hyperactivity Index in the Low Math group, but this group was not found to have striking visuoperceptual difficulties. Contrary to the mechanism suggested by the NLD model, the social difficulties noted in the Low Math group may be largely due to higher hyperactivity and/or impaired attentional skills, rather than visuoperceptual problems.

Hypothesis 4. Difficulty with configural aspects of visuoconstructional tasks will be associated with weak social competence ratings.

This hypothesis is not supported in the subject sample as a whole. Table 38 gives the correlations obtained among the variables measuring visuoconstructional performance on the one hand and social performance on the other. Only those variables which were found to be significant discriminators in any analysis are given. None of the variables given are significantly correlated.

There was some support for this hypothesis in the post-hoc analysis of the results for the Low Configural group, who had a lower mean score than the main four groups on the Teacher ratings of social performance, and a higher mean score on the Teacher rating of behaviour problems, reflecting an overall level of social competence which was lower than the sample as a whole.

Table 38

Intercorrelations Among Visuoconstructional and Social Competence Variables

Drawing Variables	Social Competence Variables H-Index	SSK-Stud	SSK-Teach	SSK-Prob
Configural	0.2264	-0.0383	-0.0343	0.0309
GL Normalized	0.0862	-0.0380	0.0856	0.1521
Good Contin'n	0.1408	0.0058	-0.0460	0.0245
Symmetry	0.2213	0.0433	0.0027	-0.0020

This hypothesis therefore received support only in a specific subgroup of learning disabled children: those who used an extremely detail-oriented approach to drawing the figures of the California Global Local Learning Test. This group of subjects may best represent the NLD subjects described by Myklebust, Rourke, and others, who show a deficiency in right-hemisphere processing resulting in difficulties with both constructional tasks and social perception.

Brain-Behaviour Relationships

Researchers have observed similarities between some symptoms exhibited by patients having documented cerebral lesions, and characteristics of children with learning disabilities. This has led to the speculation that learning disabilities may reflect cerebral dysfunction similar to that seen in the neurological patients. As Reschly and Gresham (1989) have pointed out, however, in the vast majority of learning disabled children, there is no neurological evidence of any cerebral disease or dysfunction and, overall, a connection between learning disorders and brain dysfunction remains a "leap of faith". Do the results of the present study support this connection?

Left hemisphere dysfunction in verbal learning disorders. As has been outlined in the introduction, brain abnormalities in reading disordered subjects have been found to occur primarily in the left cerebral hemisphere (Drake, 1968; Duane, 1989; Galaburda, 1983; Geschwind & Galaburda, 1985; Hier et al., 1978; Hynd et al., 1990; Kemper, 1984). Although these studies are consistent with one another, the number of subjects involved is small, and in most cases there was no control group with whom the index cases were compared. Thus, while the data are suggestive, they do not provide definitive evidence that left hemisphere dysfunction is more prevalent in verbal learning disorders than in other types of learning disorder, other types of handicapping conditions, or perhaps even compared to normal children.

Another line of research has looked at information processing patterns in the cerebral hemispheres, and has uncovered evidence that the left hemisphere predominates in the processing of visuospatial detail (Bihrle et al., 1989; Bradshaw & Sherlock, 1982; Delis, Kramer, & Kiefner, 1988; Delis, Kiefner, & Fridlund, 1988; Delis et al., 1986; Edguer, 1982; Sergent, 1982). Combining these two lines of evidence leads to the inference that reading-disabled subjects would have difficulty with processing of visuospatial detail, and if this inference were confirmed, it would strengthen the argument that left hemisphere dysfunction is the primary factor in verbal learning disorders. In the present study, and in Klicpera's study using the Rey-Osterrieth Complex Figure (1983), however, the Low Reading group was more accurate in processing of details than of configurations. These findings provide no support for the theory of a left hemisphere substrate in verbal learning disabilities.

Right hemisphere dysfunction in nonverbal learning disorders. Several authors have provided neurological evidence of morphological anomalies or dysfunction in the right hemisphere in children having nonverbal learning disorders, and/or attention deficit disorders. Nonverbal learning disorders were associated early on with distractibility and disinhibition (Johnson and Myklebust, 1967). An anatomical link between the two disorders has been proposed: both NLD and attentional deficits are speculated to arise from dysfunction in the right cerebral hemisphere.

Tucker and Williamson (1984) have proposed a model of attention which postulates two separate attentional control systems in the brain: 1) an arousal system which controls perceptual receptivity to stimuli; and 2) an activating system controlling readiness to respond motorically. Results of research including animal studies, human brain lesion studies, and evoked potential studies, support a model in which the arousal (perceptual sensitivity) system is localized in the right posterior region of the brain. The activation or motor readiness system is modulated through the left anterior systems of the brain (Schaughency & Hynd, 1989). After reviewing numerous studies of brain structures subserving attention and motor control, Voeller (1991) proposed three neuroanatomically-based subtypes of attentional disorders. The first two, a sensory-attentional subtype and a motor-intentional subtype, are similar to those proposed by Tucker and Williamson, and are associated with dysfunctions in the right posterior and right anterior areas of the brain respectively. The third subtype, the arousal-activation subtype, is characterized by a high level of restlessness and locomotor activity, and dysfunction in the ventral limbic/nucleus accumbens systems.

These theories link attentional deficits with right hemispheric dysfunction. Deficits in visuospatial processing, especially processing of configuration, and with difficulty with some aspects of mathematics, have also been inferred to results from right hemisphere dysfunction. Impaired performance in simultaneous processing of visual sensory stimuli has been linked with deficits in right posterior hemispheric functions, and has been found to occur in children with attention deficit without hyperactivity (Shaughency, 1986).

The right hemisphere is speculated to play a leading role in those aspects of mathematical calculation which involve visuospatial organization and integration, across all school grades (Gordon, 1992). For example, in a study of first grade children, who were administered measures of auditory and visual perceptual ability, arithmetic computation was found to correlate significantly only with the visual perceptual test, which draws on right hemisphere functions (Rosner, 1973). First- to fifth-grade children who had math disabilities were tested on measures of math achievement, visual, and auditory abilities. High to moderate correlations were obtained between mathematics achievement variables, spatial relations, and orientation variables (McLeod & Crump, 1978). In a factor analysis of abilities contributing to math achievement in high school students, a spatial/mechanical factor was found to account for a portion of the variance (McCallum, Smith, & Eliot, 1979). A right hemisphere superiority in calculation (addition and subtraction) has been reported for normal university undergraduates in a divided visual field study (Dimond & Beaumont, 1972).

Taken together, these models link right hemisphere dysfunction with weak math skills, difficulty processing visuospatial configuration, and attentional deficits. Attentional deficits have also been associated with impaired social competence. This list of deficits comprise the major characteristics of nonverbal learning disorder. The finding in the present study that the Low Math group used the least configural approach for drawing the figures of the California Global Local Learning Test, and had the weakest attentional performance, is consistent with these models, and thus supports the conjecture of a right-hemisphere substrate for nonverbal learning disorders. Nevertheless, this model must remain a conjecture at present, as there are many gaps in the neurological data currently available, and a definitive link between nonverbal learning disorders and right hemisphere dysfunction has yet to be established. Children with known dysfunction in the right hemisphere show nonverbal learning disorders (Voeller, 1986; Weintraub &

Mesulam, 1983), but studies of brain function and morphology have not been carried out with children who have nonverbal learning disabilities in the absence of other evidence of brain dysfunction. In studies of attention deficits, right hemisphere dysfunction has not been limited only to the children with attention deficits disorders. Thus, current data are not sufficient to fully support a right hemisphere substrate for either disorder.

For example, when 15 children having documented damage or dysfunction in the right hemisphere were examined, 14 of the group met the criteria for DSM-III classification of attention deficit disorder, and the group as a whole showed weaker arithmetic than reading and spelling achievement, and better verbal than visuospatial abilities (Voeller, 1986). However, no control subjects who did not have right-hemisphere disorders were included in the study, so the specificity of attentional and nonverbal learning disorders to right hemisphere dysfunction was not established in this study.

Regional cerebral blood flow distributions were determined in six children with ADHD, 13 with ADHD in combination with other neurological disorders, and nine normal controls (Lou, Henriksen, Bruhn, Borner, & Nielsen, 1989). Both groups with ADHD showed hypoperfusion and, by inference, hypofunction in the right striatal region. It is not clear from these data, however, whether right striatal hypofunction is limited to subjects with ADHD, or whether it may occur in other neurological disorders, since the finding was not specific to the six children who had only ADHD.

Departures from the usual brain morphology have also been seen in ADHD children. A magnetic resonance imaging (MRI) study revealed that, compared with normal controls, ADHD children and dyslexic children did not show the usual pattern of right larger than left frontal regions, but rather had symmetrical frontal lobes (Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990). Again, this finding was not exclusive to children with ADHD, and the possibility remains that similar deviations from normal morphology may be found in other disorders.

In another MRI study, the corpus callosum was examined in 7 ADHD children and 10 normal controls (Hynd, Semrud-Clikeman, Lorys, Novey, Eliopulos, & Lyytinen, 1991), and the ADHD children were found to have a smaller corpus callosum than nondisabled controls. Because of the wide-ranging and pervasive involvement of the corpus callosum in integrated brain functioning, it is difficult to specify a local site of dysfunction which may be indicated by these findings.

Some authors have noted similarities between the characteristics of children with attentional disorders - defective attention and response inhibition, restlessness, a neglect of the left side on letter cancellation tasks, motor impersistence, and decreased activation of the right striatum - and those seen in adults with right hemisphere dysfunction (Heilman, Voeller, & Nadeau, 1991; Voeller & Heilman, 1988a, 1988b). These observations have been cited to support the speculation of a right hemisphere dysfunction in ADHD. Syndromes seen in adults with neurological disorders may not be directly relevant to children whose brain development is not yet fully mature, however, and it is difficult to know to what extent these characteristics, when seen in children, may simply reflect variations in normal course of development (Reschly & Gresham, 1989).

Thus, the neurological data are not definitive in demonstrating a link between attentional difficulties, nonverbal learning disorders, and right hemisphere dysfunction. Nevertheless, the present findings of an association among weak math scores, weak configural approach to drawing, and weak attentional performance, is consistent with these models, and thus supports the conjecture of a right-hemisphere substrate for nonverbal learning disorders.

Do Nonverbal Learning Disabilities Exist?

The present study varied somewhat from traditional approached to evaluating NLD, in that visuoconstructional performance was not looked on as a single entity, but rather was broken into two components which were assessed separately. The subjects in this study who would be considered to show the NLD-type deficit in visuoconstructional performance, are those subjects who had very low configural scores on the California Global Local Learning Test, since that measure was identified as the best discriminator among the drawing measures. Using this criterion, the NLD triad of weaknesses in social competence, math performance, and configural organization occurred together in only three of 120 subjects, who were included in the Low Configural sub-group. Five other subjects included in the Low Configural sub-group showed the deficits in social competence and configural organization, but had academic profiles other than a specific math impairment. It was equally likely that a subject showing weak social competence and weak configural ability, would have a specific reading disorder or a specific math disorder. Thus, these data do not support the usefulness of the NLD model for describing a significant subset of the learning-disabled population.

It may be argued that subjects who have deficits in visuoperceptual functions which are sufficiently serious to qualify for the label of NLD, would be significantly impaired in both components of visuoconstructional performance, and would have been excluded from the present study because they were unable to reach the cut-off score on the WISC-R Block Design screening measure. Of the 107 subjects who, for one reason or another, did not meet the screening criteria for inclusion in the study groups, eighteen had scaled scores of less than seven on the Block Design test. Of these eighteen, four had specific disorders in arithmetic (of the other fourteen, one had a specific reading disorder; six had disorders in both reading and math; and seven were normal achievers). Because social performance data were not collected on these subjects, it cannot be determined how many showed social deficits. However, it is apparent that even if all four subjects who had a combination of weak visuospatial performance and impaired arithmetic, also showed social performance deficits, this group constitutes a small proportion of the total group studied. This combination of deficits may be explained as easily by normal variation in test results, as by invoking a "syndrome" to account for a very small proportion of subjects. Thus, the present data do not support the existence of a nonverbal learning disability characterized by deficits in visuospatial, math, and social performance.

The Best Discriminators

Which variables, then, discriminated most successfully among the groups of subjects? Using the data from the copy trial of the Rey-Osterrieth Complex Figure Test, the best discriminator was Taylor's accuracy score. The drawings of the Average Achievers were significantly more accurate than those of the learning disabled groups (which were not discriminable from one another). The Hyperactivity Index and the Social Skills Rating System were also useful discriminators used singly, but their discriminating power overlapped to a large extent with that of the Taylor accuracy score, so that they add little information when the Taylor scoring is also used. It is possible that the Taylor Accuracy score and Hyperactivity Index are not independent. It may be the case that attentional difficulties are reflected in lower scores on both measures, as well as on the Social Skills Rating System. This possibility could be clarified by performing a factor analysis on these data.

Using data from the recall trial, the Hyperactivity Index best discriminated the Average Achievers from the learning disabled groups. The SSRS Teacher ratings were also good individually, but were redundant in combination with the Hyperactivity Index.

The best discrimination among all four groups was obtained using a combination of scores measuring drawing style and social competence: Binder's Configural score from the recall trial of the Rey-Osterrieth Complex Figure, the Hyperactivity Index, the GL Normalized score from the California Global Local Learning Test, and the SSRS Student self-rating. Even though this combination was the most effective in the study, the Low Math and Low Reading groups were still not discriminable, nor were the Average Achievers and the Low Overall groups.

It is notable that drawing style contributed significantly only in the recall trial, not in the copy trial. This suggests that while individuals may perceive both details and configurations equally efficiently, at some point during the process of storing, consolidating, or retrieving information in memory, the components of a visuospatial display are processed differently.

Several scores from the Social Skills Rating System were found to be significant discriminators, despite the fact that this measure was developed and normed using an American subject sample. This discrimination may possibly have been more well-defined if, in the current study, the scores were normed on the present sample, using z-scores based on the Average Achievers group, as was done with the drawing style variables. This procedure may have resulted in less reliable scores, however, since the sample size used to calculate the z-scores would be much smaller than that used for the original norming.

Group Profiles

The Average Achievers and the Low Overall groups were not discriminable from each other on the basis of social competence or drawing performance. It would appear that these variables are primarily useful in discriminating those having a specific learning disorder (either in reading or in math) from those who do not (i.e. those who are either average achievers or who are generally low academically).

An interesting finding in this study is the lack of statistical discrimination between the Low Math and the Low Reading groups. Although their academic profiles are very different, their scores on measures of social performance and drawing style did not discriminate them statistically. This may be partially due to greater heterogeneity within the Low Math group. This group consistently received the lowest classification rates in the discriminant analyses. Inspection of the means and standard deviations given in Table 7 shows that the Low Math group had greater variability in the Hyperactivity Index. Other authors have noted that there are a number of cognitive abilities involved in math performance, and that math disorders therefore can arise from a number of factors (Badian, 1983; Gordon, 1992; Rourke, 1993; Semrud-Clikeman & Hynd, 1990; Strang & Rourke, 1985; Tuokko, 1986). Perhaps only a subgroup of math-disabled students experiences difficulties with configural processing and social performance. More precise delineation of the mathematical and cognitive abilities of math-disabled subjects would be required to answer this question.

Another reason for the difficulty discriminating the Low Math and Low Reading group may lie in their opposite results on drawing the figures from the two drawing tests used. The Low Math group had the least configural approach of any group on the California Global Local Learning Test, but had a fairly strong rating on Binder's Configural score for the Rey-Osterrieth Complex Figure (recall trial). The Low Reading group had the opposite results. These diametrically-opposed findings may have cancelled each other out and diluted the discrimination between the two groups. However, this finding also raises questions about how the two drawing tasks differ in their cognitive demands, and therefore how the two learning-disabled groups may differ in their cognitive processing abilities.

Comparison of Measures of Drawing Style

The hypothesis which received the strongest support was Hypothesis 1, which postulated a connection between specific arithmetic disorder and weak configural scores on drawing tasks. This finding was validated using only the California Global Local Learning Test results, however, and not any of the various scoring systems which have been devised to capture drawing style on the Rey-Osterrieth Complex Figure Test. In fact, correlations between these two sets of scores were very low from the sample as a whole, suggesting that they are not in fact equivalent measures. Only in those children who scored the lowest on the California Global Local Learning Test were the measures correlated. It has already been noted that the California Global Local Learning Test was designed specifically to measure configural versus detail processing, while the Rey-Osterrieth Complex Figure Test was not. What might the important differences be between the two?

First, the method of administration of the two measures is quite different. In the case of the Rey-Osterrieth Complex Figure, the child is allowed to copy the design while it is displayed continuously for at least three and up to five minutes. Later, without prior warning, the child is asked to draw it from memory, without seeing it again. Thus, only the recall trial has a memory component, and it is a measure of incidental learning. In contrast, on the California Global Local Learning Test, each pair of designs is shown to the child for only ten seconds, immediately following which the child reproduces the designs from memory. There are three trials, so that each pair of three designs is shown to the child three times, thus allowing for intentional learning to take place. The designs themselves are simpler than the Rey-Osterrieth Complex Figure.

These differences in administration and figure complexity raise the following issues.

1. Complexity level of the designs. The designs of the California Global Local Learning Test are much simpler than the Rey-Osterrieth Complex Figure. Therefore, less perceptual analysis and re-synthesis is required

to reproduce the configuration of the designs. These designs may have presented difficulties only to those who were less adept at processing of configurations (i.e. the Low Math group), and may thus have been a better discriminator in this age group. The Rey-Osterrieth Complex Figure Test, on the other hand, may have been difficult perceptually for all the children in the age group used in this study, and therefore not a good discriminator among them.

2. Exposure time. The shorter exposure time of the California Global Local Learning Test would be a disadvantage to those whose rate of mental processing is slower. For those who tend to process details before configurations, there may not be enough time to proceed from the details to the configurations during the short exposure time. Perhaps the weaker configural performance of the Low Math group on this measure reflects a slower rate of mental processing in that group, as well as a tendency to process details before configurations.

The shorter exposure time may represent a benefit to those who are more distractible and inattentive, as the test proceeds more quickly, helping the child to focus attention, and allowing less time during which attention may wander.

3. Immediate versus delayed recall. The immediate recall required with the California Global Local Learning Test may allow for better performance by those who are distractible, or who have difficulty storing information in long-term memory.
4. Intentional recall with the California Global Local Learning Test versus incidental recall with the Rey-Osterrieth Complex Figure Test. Those who have more difficulty with recall of the latter figure may be less automatic in their transfer of information to long-term memory.
5. A single exposure of the Rey-Osterrieth Complex Figure versus repeated exposures over three trials of the designs of the California Global Local Learning Test. Repeated exposures are beneficial also to those who have difficulty with distractibility or long-term memory storage.

When comparing the performance of the Low Math group and the Low Reading group on these drawing tasks, one wonders whether the Low Math group shows the following cognitive characteristics.

1) Slower information processing than the Low Readers, thereby benefitting from the longer exposure time given on the Rey-Osterrieth Complex Figure. The shorter exposure time on the California Global Local Learning

Test may not be sufficient for them to finish processing the details of the figures and move on to the configurations.

2) Weak ability to process configurations. The Low Math and the Low Reading group received similar scores on most measures of their copy of the Rey-Osterrieth Complex Figure (Table 8), thus showing a similar level of difficulty in copying a complex configuration. It would appear that the simpler configurations of the California Global Local Learning Test are better able to discriminate the groups, in that the Low Math group had difficulty even with these simple figures.

3) Better incidental learning than the Low Readers, shown by better retention of the configuration of the Rey-Osterrieth Complex Figure. The Low Readers, in turn, may be better intentional learners, and better able to benefit from repetition.

There have been quite a number of scoring systems devised for evaluating approach to drawing the Rey-Osterrieth Complex Figure. In this study, only four variables from two scoring systems were found to be significant discriminators: Binder's Configural and Missing scores; and Bennett-Levy's Good Continuation and Symmetry scores. These are among the most simple and straightforward of the various systems, and this study would suggest that they are also the most useful.

Practical Applications

The primary aim of this study was to determine whether drawing style might provide a simple indicator of susceptibility to the basic subtypes of learning disorder, as well as provide insight into aspects of the cognitive underpinnings of those learning disorders. The results indicate that drawing style is not a particularly reliable indicator, at least for detecting the basic subtypes examined in this study. The most important indicator of learning disorder in this study was the Hyperactivity Index. The present results confirm previous findings that children with attentional problems are at high risk of developing learning problems as well as social difficulties, and underline the importance of identifying these children early in their school career, closely monitoring their academic and social progress, and providing appropriate interventions as necessary.

In the area of psychometrics, the present study compared a number of methods of evaluating configural and detail-oriented drawing performance. The results provide some guidance in choosing among the various methods, in that the simplest methods were the most effective in separating groups, at least in the learning disabled population.

Future Directions

A number of issues have been raised by this study which deserve further investigation. It would be worthwhile to look at subtypes of reading- and mathematically-disabled children to determine in more detail their cognitive processing and social competence characteristics. For example, it would be interesting to compare groups such as L- and P-type dyslexics, those showing different subtypes of math disabilities, or attention deficit disordered children with and without hyperactivity, on these drawing tasks, to see whether they perform as would be expected for those with dysfunctions in the left or right cerebral hemispheres. It would also be interesting to include measures of social competence and attentional performance to determine how social competence relates to academic profile, visuospatial processing, and attentional performance in these subtypes.

In view of the differing results obtained with the two drawing measures in this study, further work using both tests in a variety of clinical groups would be of interest, to gather more data on the comparability of the two measures, and how each relates to other measures of cognitive processes. Subject samples might include groups having specific brain lesions or impairments, as well as specific disabilities such as learning disorders or subtypes of dementia.

In conclusion, the results of this study support the association of deficits in social competence with deficits in attentional performance, moreso than with visuospatial processing deficits. Relevance to learning and memory processes of the delineation of components of visuospatial processing (configuration and detail-oriented) was supported. Finally, the results suggest that the Rey-Osterrieth Complex Figure Test and the California Global Local Learning Test measure different aspects of visuoconstructional performance.

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Appendix A

List of Participating Schools

School	Number of Students Participating: Initial n=227	Final n=86
School District #61		
Blanshard Elementary School	8	2
Cloverdale Elementary School	10	3
Glanford Elementary School	2	2
Gordon Head Elementary School	6	3
Lakehill Elementary School	1	1
Margaret Jenkins Elementary School	4	3
Rockheights Elementary School	17	9
Torquay Elementary School	4	2
Victoria West Elementary School	3	3
School District #62		
David Cameron Elementary School	6	4
Glenlake Elementary School	8	4
John Stubbs Elementary School	18	6
Millstream Elementary School	3	2
Savory Elementary School	6	3
Willway Elementary School	3	1
School District #63		
Beaver Lake Elementary School	5	3
Brentwood Elementary School	2	1
Keating Elementary School	1	1
North Saanich Middle School	29	0
Saanichton Elementary School	4	2
Sansbury/McTavish Elementary School	1	0
Sidney Elementary School	4	2
Independent Schools		
Discovery School	12	4
Pacific Christian School	11	3
St. Andrew's Elementary School	25	8
St. Joseph's Elementary School	27	13
St. Patrick's Elementary School	7	1

Appendix B

Letter to Teachers

Mary Anne Leason
Home Phone: 477-5304

Teachers: Would you like to participate in a research project on learning styles?

PURPOSE: To investigate how different patterns of academic achievement and social skills are related to visual learning style. This project could lead to easier identification of children at risk for academic and social difficulties, and more effective teaching strategies.

SUBJECTS: Children aged 9 to 14 who meet the following criteria:

1. average intelligence
2. right-handed
3. average achievement in reading and arithmetic

   OR

   achievement at least one year below age level in reading OR arithmetic OR both (not due to medical or environmental reasons).

METHOD: Children will be seen individually for one or two testing sessions of approximately 45 minutes each.

Session 1: Academic screening with standardized tests of reading and arithmetic achievement and general mental ability.

Only those children who meet the criteria will return for the second testing session.

Session 2: Two drawing tasks to measure visual learning style. Also, the child will rate his/her own social skills using a standardized questionnaire.

The child's teacher will also complete two rating scales of the child's social skills and behaviour. Total time to complete both would be about 15 minutes per child. Only a few students per classroom would take part in this study, so the time commitment required of the teacher would be minimal.

INVOLVEMENT OF TEACHERS:

- to select appropriate students to receive the letters explaining the project.
- to send home the letters (which will be provided) and to collect those which are returned.
- to release students from class for one or two 45-minute individual testing sessions.
- to complete rating scales on the students

All results will be shared with school personnel, provided the parents give permission.

Appendix C

Letter to Parents and Consent Form

Mary Anne Leason, M.A.

Dear Parent or Guardian:

I am a doctoral student in psychology at the University of Victoria. Having had five years' experience in assessment of children while employed at the Arbutus Society for Children, School District #63 (Saanich), and the University, I am now undertaking a research project on how learning style is related to school achievement and social skills. This project, approved by the University and the School Board, could lead to easier identification of children at risk for academic and social difficulties, and improved ways to help those children.

For this study, I will be testing children of varying levels of achievement in reading and arithmetic. Your child's teacher has identified him/her as someone who may be interested in volunteering for this project. This letter is to ask your permission for your child to participate.

The students taking part in the study will be seen by me for one or two testing sessions of approximately 45 minutes each. Testing will take place at school, during the school day. Children will be tested individually or in small groups. In the first session, the child will be given standard tests of general mental ability, as well as reading and arithmetic, so that I will know the level at which the child is working in those subjects. Some children will return for a second testing session. In the second session, the child will be shown geometric forms and asked to draw them. Most children enjoy these tasks. In addition, the child will rate his/her own social skills using a short, standardized questionnaire (Sample question: "I make friends easily": never/sometimes/always). The child's teacher will also be asked to complete two rating scales of the child's social skills and behaviour.

I will be happy to discuss with you, your child's results in all the tests given. If you wish, these results can also be shared with school district personnel. Otherwise, all results will remain confidential, and will be used anonymously for research purposes only. You will receive an outline of the research findings when the study is completed.

If you would like your child to participate, or would like more information about this project, please fill out the attached form and return it to your child's teacher as soon as possible.

Thank you.

- -

Mary Anne Leason, M.A.

Research Project on Learning

PLEASE COMPLETE THIS FORM AND RETURN IT TO THE SCHOOL AS SOON AS POSSIBLE. THANK YOU.

I give permission for my child to participate in this project.	____ YES	____ NO
I give permission for the school to release my child's achievement test scores to the experimenter.	____ YES	____ NO
I would like to be informed about my child's results after testing.	____ YES	____ NO
I give permission to release my child's test results to the school.	____ YES	____ NO
I would like more information about this project.	____ YES	____ NO

____________________ Child's name

__________ Birthdate

____________________ School/Grade

______________________________ Parent or Guardian name (please print)

______________ Date

______________________________ Parent or Guardian signature

______________ Phone number

Appendix D

Correlation Matrix for all Variables

in the Two-Group Analyses

POOLED WITHIN-GROUPS CORRELATION MATRIX

	ZGLNORM	SSKTEACH	H_INDEX	SSKSTUD	SSKPROB	ZSOLID	ZTAYLOR	ZGOODCON	ZSYMMET	ZCONFIG	ZFRAG
ZGLNORM	1.00000										
SSKTEACH	0.10991	1.00000									
H_INDEX	0.05792	-0.49383	1.00000								
SSKSTUD	-0.00386	0.29270	-0.15195	1.00000							
SSKPROB	0.13277	-0.62709	0.57332	-0.25010	1.00000						
ZSOLID	0.16983	0.14206	-0.00004	0.07772	-0.07799	1.00000					
ZTAYLOR	0.17764	0.15556	-0.14568	0.07001	-0.01962	-0.14054	1.00000				
ZGOODCON	-0.11059	-0.13616	0.07242	-0.13963	-0.08404	0.04328	0.05375	1.00000			
ZSYMMET	0.03499	-0.01594	0.30524	0.01509	0.00811	0.13250	0.22067	0.25572	1.00000		
ZCONFIG	-0.14551	-0.08613	0.13538	-0.00505	-0.06612	0.09284	-0.00933	0.63797	0.38432	1.00000	
ZFRAG	0.12904	0.08577	-0.13490	0.01202	0.06331	-0.08757	0.06629	-0.62075	-0.36579	-0.99286	1.00000
ZMISSING	0.13547	0.00150	-0.00168	-0.05841	0.02241	-0.04255	-0.47714	-0.13341	-0.14871	-0.04296	-0.07655
ZLEVEL	0.02028	0.03228	-0.10764	0.04644	-0.08729	-0.00499	0.54093	0.25516	0.16392	0.22861	-0.18751
ZSTYLE	-0.06880	-0.01581	0.06666	-0.02074	-0.11733	0.13038	0.03371	0.67619	0.24578	0.86165	-0.84683
ZSTART	-0.13526	-0.16159	0.26918	-0.13015	0.09593	-0.00393	-0.04086	0.35959	0.12315	0.46519	-0.46047
ZPROGRSS	0.19320	0.16542	-0.15647	0.10399	0.04421	-0.07562	-0.08343	-0.77158	-0.31599	-0.76656	0.74868
ZLORING	-0.15391	-0.16364	0.14884	-0.15789	0.16320	0.06686	-0.65344	0.04370	-0.18417	-0.03235	-0.00154
ZCLUSTER	-0.17181	-0.14522	0.22951	-0.14038	-0.06813	0.00755	0.10456	0.74031	0.39085	0.80913	-0.78484
ZRTAYLOR	0.20196	-0.04568	0.09353	0.21344	0.03944	0.01981	0.47366	0.22421	0.34842	0.25707	-0.22339
ZRGOODCO	0.14385	-0.01794	0.11507	0.05757	0.00347	0.09837	0.16144	0.55367	0.29849	0.55483	-0.54179
ZRSYMM	0.10875	0.02441	0.19815	0.10232	-0.02325	0.03235	0.34023	0.34527	0.54745	0.41582	-0.40428
ZRCONFIG	0.05622	0.00461	0.18363	0.05097	-0.00259	0.08504	0.07823	0.52735	0.35194	0.67841	-0.68068
ZRFRAG	0.03494	-0.06075	-0.13016	-0.06097	0.05466	-0.11029	0.04401	-0.44568	-0.22323	-0.61691	0.62310
ZRMISSG	-0.11465	0.06267	-0.09772	0.00102	-0.05846	0.01142	-0.15433	-0.19920	-0.21701	-0.20690	0.20291
ZRLEVEL	0.03094	-0.08673	-0.01619	-0.06978	0.06052	0.09127	0.29433	0.19412	0.07486	0.08311	-0.05699
ZRSTYLE	0.00790	0.05765	0.04759	0.14938	-0.09856	0.13966	-0.15683	0.45488	0.17395	0.50013	-0.51024
ZRSTART	-0.07153	-0.14683	0.20158	-0.07278	0.05017	0.04509	-0.08905	0.47403	0.13754	0.38063	-0.39475
ZRPROGR	-0.05715	0.10871	-0.15872	-0.06559	-0.00065	-0.07547	-0.18014	-0.60085	-0.26062	-0.57354	0.56765
ZRLORING	-0.15391	-0.16364	0.14884	-0.15789	0.16320	0.06686	-0.65344	0.04370	-0.18417	-0.03235	-0.00154

GROUP1	ZRLEVEL	ZRSTYLE	ZRSTART	ZRPROGR	ZRLORING
1	1.01116	1.01440	1.03099	1.03155	0.86824
2	0.77633	1.09221	0.86766	1.16079	0.76123
TOTAL	0.87280	1.05775	0.92758	1.11378	0.81261

POOLED WITHIN-GROUPS CORRELATION MATRIX

	ZGLNORM	SSKTEACH	H_INDEX	SSKSTUD	SSKPROB	ZSOLID	ZTAYLOR	ZGOODCON	ZSYMMET	ZCONFIG	ZFRAG
ZGLNORM	1.00000										
SSKTEACH	0.10991	1.00000									
H_INDEX	0.05792	-0.49393	1.00000								
SSKSTUD	-0.00386	0.29270	-0.15195	1.00000							
SSKPROB	0.13277	-0.62709	0.57332	-0.25010	1.00000						
ZSOLID	0.16983	0.14206	-0.00004	0.07772	-0.07799	1.00000					
ZTAYLOR	0.17764	0.15556	-0.14568	0.07001	-0.01962	-0.14054	1.00000				
ZGOODCON	-0.11059	-0.13616	0.07242	-0.13963	-0.08404	0.04328	0.05375	1.00000			
ZSYMMET	0.03499	-0.01594	0.30524	0.01509	0.00811	0.13250	0.22067	0.25572	1.00000		
ZCONFIG	-0.14551	-0.08613	0.13538	-0.00505	-0.06612	0.09284	-0.00933	0.63797	0.38432	1.00000	
ZFRAG	0.12904	0.08577	-0.13490	0.01202	0.06331	-0.08757	0.06629	-0.62075	-0.36579	-0.99286	1.00000
ZMISSING	0.13547	0.00150	-0.00168	-0.05841	0.02241	-0.04255	-0.47714	-0.13341	-0.14871	-0.04296	-0.07655
ZLEVEL	0.02028	0.03228	-0.10764	0.04644	-0.08729	-0.00499	0.54093	0.25516	0.16392	0.22861	-0.18751
ZSTYLE	-0.06880	-0.01581	0.06666	-0.02074	-0.11733	0.13038	0.03371	0.67619	0.24578	0.86165	-0.84683
ZSTART	-0.13526	-0.16159	0.26918	-0.13015	0.09593	-0.00393	-0.04086	0.35959	0.12315	0.46519	-0.46047
ZPROGRSS	0.19320	0.16542	-0.15647	0.10399	0.04421	-0.07962	-0.08343	-0.77158	-0.31599	-0.76656	0.74868
ZLORING	-0.15391	-0.16364	0.14884	-0.15789	0.16320	0.06686	-0.65344	0.04370	-0.18417	-0.03235	-0.00154
ZCLUSTER	-0.17181	-0.14522	0.22951	-0.14038	-0.06813	0.00755	0.10456	0.74031	0.39085	0.80913	-0.78484
ZRTAYLOR	0.20196	-0.04568	0.09353	0.21344	0.03944	0.01981	0.47366	0.22421	0.34842	0.25702	-0.22339
ZRGOODCO	0.14385	-0.01794	0.11507	0.05757	0.00347	0.09837	0.16144	0.55367	0.29849	0.55483	-0.54179
ZRSYMM	0.10875	0.02441	0.19815	0.10232	-0.02325	0.03236	0.34023	0.34527	0.54745	0.41582	-0.40428
ZRCONFIG	0.05622	0.00461	0.18363	0.05097	-0.00259	0.08504	0.07823	0.52735	0.35194	0.67841	-0.68068
ZRFRAG	0.03494	-0.06075	-0.13016	-0.06097	0.05466	-0.11029	0.04401	-0.44568	-0.22323	-0.61691	0.62310
ZRMISSG	-0.11465	0.06267	-0.09772	0.00102	-0.05846	0.01142	-0.15433	-0.19920	-0.21701	-0.20690	0.20291
ZRLEVEL	0.03094	-0.08673	-0.01619	-0.06978	0.06052	0.09127	0.29433	0.19412	0.07486	0.08311	-0.05699
ZRSTYLE	0.00790	0.05765	0.04759	0.14938	-0.09856	0.13966	-0.15683	0.45488	0.17395	0.50013	-0.51024
ZRSTART	-0.07153	-0.14683	0.20158	-0.07278	0.05017	0.04509	-0.08905	0.42403	0.13754	0.38063	-0.39475
ZRPROGR	-0.05715	0.10871	-0.15872	-0.06559	-0.00065	-0.07547	-0.18014	-0.60085	-0.26062	-0.57354	0.56765
ZRLORING	-0.15391	-0.16364	0.14884	-0.15789	0.16320	0.06686	-0.65344	0.04370	-0.18417	-0.03235	-0.00154

	ZMISSING	ZLEVEL	ZSTYLE	ZSTART	ZPROGRSS	ZLORING	ZCLUSTER	ZRTAYLOR	ZRGOODCD	ZHSYMM	ZRCONFIG
ZMISSING	1.00000										
ZLEVEL	-0.34036	1.00000									
ZSTYLE	-0.10952	0.16991	1.00000								
ZSTART	-0.03170	-0.04347	0.58109	1.00000							
ZPROGRSS	0.13674	-0.24120	-0.67608	-0.48906	1.00000						
ZLORING	0.28330	-0.53324	0.00330	0.23538	0.01635	1.00000					
ZCLUSTER	-0.18976	0.22889	0.74385	0.52572	-0.81325	0.00422	1.00000				
ZRTAYLOR	-0.27730	0.35761	0.26268	0.11666	-0.25772	-0.38336	0.28335	1.00000			
ZRGOODCD	-0.09981	0.31833	0.58005	0.26363	-0.51993	-0.16224	0.53732	0.67692	1.00000		
ZRSYMM	-0.08956	0.34249	0.35435	0.16557	-0.43361	-0.38315	0.47415	0.63795	0.62907	1.00000	
ZRCONFIG	0.03044	0.20659	0.65713	0.39495	-0.59545	-0.09756	0.59155	0.56830	0.75885	0.64964	1.00000
ZRFRAG	-0.06230	-0.22152	-0.54815	-0.36799	0.50604	-0.00938	-0.47952	-0.11545	-0.44074	-0.29834	-0.68301
ZRMISSG	0.02994	-0.02488	-0.25639	-0.11044	0.22175	0.14089	-0.24658	-0.62802	-0.51390	-0.52842	-0.56141
ZRLEVEL	-0.21728	0.35389	0.17497	0.15947	-0.20283	-0.09729	0.16504	0.31859	0.30226	0.26255	0.25587
ZRSTYLE	0.09303	-0.00663	0.52474	0.29860	-0.40410	0.06620	0.46445	0.19053	0.46364	0.27003	0.59595
ZRSTART	0.12462	-0.05334	0.53745	0.62013	-0.45864	0.20661	0.42868	0.19076	0.39100	0.31966	0.49954
ZRPROGR	0.03963	-0.23917	-0.59220	-0.34472	0.61625	0.14576	-0.54349	-0.61919	-0.78307	-0.73254	-0.77906
ZRLORING	0.28330	-0.53324	0.00330	0.23538	0.01635	1.00000	0.00422	-0.38336	-0.16224	-0.38315	-0.09756

	ZRFRAG	ZRMISSG	ZRLEVEL	ZRSTYLE	ZRSTART	ZRPROGR	ZRLORING
ZRFRAG	1.00000						
ZRMISSG	-0.22100	1.00000					
ZRLEVEL	-0.17638	-0.14181	1.00000				
ZRSTYLE	-0.53636	-0.18805	-0.05996	1.00000			
ZRSTART	-0.33135	-0.29159	0.34533	0.44319	1.00000		
ZRPROGR	0.44784	0.53284	-0.22490	-0.51705	-0.51351	1.00000	
ZRLORING	-0.00938	0.14089	-0.09729	0.06620	0.20661	0.14576	1.00000

CORRELATIONS WHICH CANNOT BE COMPUTED ARE PRINTED AS 99.0.

	ZMISSING	ZLEVEL	ZSTYLE	ZSTART	ZPROGRSS	ZLORING	ZCLUSTER	ZRTAYLOR	ZRGOODCO	ZRSYMM	ZRCONFIG
ZMISSING	1.00000										
ZLEVEL	-0.34036	1.00000									
ZSTYLE	-0.10952	0.16991	1.00000								
ZSTART	-0.03170	-0.04347	0.58109	1.00000							
ZPROGRSS	0.13674	-0.24120	-0.67608	-0.48906	1.00000						
ZLORING	0.28330	-0.53324	0.00330	0.23538	0.01635	1.00000					
ZCLUSTER	-0.18976	0.22889	0.74385	0.52572	-0.81325	0.00422	1.00000				
ZRTAYLOR	-0.27730	0.35761	0.26268	0.11666	-0.25772	-0.38336	0.28335	1.00000			
ZRGOODCO	-0.09981	0.31833	0.58005	0.26363	-0.51993	-0.16224	0.53732	0.67692	1.00000		
ZRSYMM	-0.08956	0.34249	0.35435	0.16557	-0.43361	-0.38315	0.47415	0.63795	0.62907	1.00000	
ZRCONFIG	0.03044	0.20659	0.65713	0.39495	-0.59545	-0.09756	0.59155	0.56830	0.75885	0.64964	1.00000
ZRFRAG	-0.06230	-0.22152	-0.54815	-0.36799	0.50604	-0.00938	-0.47952	-0.11545	-0.44074	-0.29834	-0.68301
ZRMISSG	0.02994	-0.02488	-0.25639	-0.11044	0.22175	0.14089	-0.24658	-0.62802	-0.51390	-0.52942	-0.56141
ZRLEVEL	-0.21729	0.35389	0.17497	0.15947	-0.20283	-0.09729	0.16504	0.31859	0.30226	0.26255	0.25587
ZRSTYLE	0.09303	-0.00668	0.52474	0.29860	-0.40410	0.06620	0.46445	0.19053	0.46364	0.27003	0.59595
ZRSTART	0.12462	-0.05334	0.53745	0.62013	-0.45864	0.20661	0.42868	0.19076	0.39100	0.31966	0.49954
ZRPROGR	0.03963	-0.23917	-0.59220	-0.34472	0.61625	0.14576	-0.64349	-0.61919	-0.78307	-0.73254	-0.77906
ZRLORING	0.28330	-0.53324	0.00330	0.23538	0.01635	1.00000	0.00422	-0.38336	-0.16224	-0.38315	-0.09756

	ZRFRAG	ZRMISSG	ZRLEVEL	ZRSTYLE	ZRSTART	ZRPROGR	ZRLORING
ZRFRAG	1.00000						
ZRMISSG	-0.22100	1.00000					
ZRLEVEL	-0.17638	-0.14181	1.00000				
ZRSTYLE	-0.53636	-0.18805	-0.05996	1.00000			
ZRSTART	-0.33135	-0.29159	0.34533	0.44319	1.00000		
ZRPROGR	0.44784	0.53284	-0.22490	-0.51705	-0.51351	1.00000	
ZRLORING	-0.00938	0.14089	-0.09729	0.06620	0.20661	0.14576	1.00000

CORRELATIONS WHICH CANNOT BE COMPUTED ARE PRINTED AS 99.0.

WILKS LAMBDA (U-STATISTIC) AND UNIVARIATE F-RATIO
WITH 1 AND 77 DEGREES OF FREEDOM

VARIABLE	WILKS LAMBDA	F	SIGNIFICANCE
ZGLNORM	0.96525	2.772	0.1000
SSKTEACH	0.92108	6.597	0.0121
H_INDEX	0.91125	7.500	0.0077
SSKSTUD	0.95482	3.643	0.0600
SSKPROB	0.91762	6.913	0.0103
ZSOLID	0.99794	0.1587	0.6915
ZTAYLOR	0.89881	8.669	0.0043
ZGOODCON	0.99804	0.1516	0.6981
ZSYMMET	0.99952	0.3682E-01	0.8483

Appendix E

Correlation Matrix for all Variables in the Four-Group Analyses

POOLED WITHIN-GROUPS CORRELATION MATRIX

	ZGLNORM	SSKTEACH	H_INDEX	SSKSTUD	SSKPROB	ZSOLID	ZTAYLOR	ZGOODCON	ZSYMMET	ZCONFIG	ZFRAG
ZGLNORM	1.00000										
SSKTEACH	0.08556	1.00000									
H_INDEX	0.08619	-0.48533	1.00000								
SSKSTUD	-0.03804	0.27780	-0.13837	1.00000							
SSKPROB	0.15212	-0.62396	0.57104	-0.23674	1.00000						
ZSOLID	0.16442	0.13714	0.00558	0.06963	-0.07407	1.00000					
ZTAYLOR	0.18160	0.16203	-0.15530	0.06072	-0.01822	-0.14145	1.00000				
ZGOODCON	-0.10280	-0.13517	0.06421	-0.16709	-0.08219	0.04379	0.03397	1.00000			
ZSYMMET	0.04813	-0.01018	0.30082	0.00670	0.00853	0.13453	0.20976	0.24024	1.00000		
ZCONFIG	-0.17879	-0.11029	0.15478	-0.05676	-0.04952	0.08630	-0.02099	0.64258	0.38652	1.00000	
ZFRAG	0.16155	0.10987	-0.15424	0.06398	0.04667	-0.08092	0.07856	-0.62468	-0.36743	-0.99254	1.00000
ZMISSING	0.13823	0.00151	-0.00169	-0.06015	0.02251	-0.04260	-0.48037	-0.13557	-0.14980	-0.04389	-0.07821
ZLEVEL	0.01286	0.07324	-0.10911	0.00153	-0.07583	-0.01074	0.53630	0.22987	0.14808	0.19769	-0.15467
ZSTYLE	-0.08332	-0.02727	0.07402	-0.05723	-0.10763	0.12699	0.02183	0.67459	0.23821	0.85979	-0.84446
ZSTART	-0.13516	-0.16240	0.26920	-0.14135	0.09786	-0.00416	-0.04765	0.35593	0.11768	0.46939	-0.46453
ZPROGRSS	0.19902	0.17019	-0.15793	0.12448	0.03986	-0.07829	-0.07497	-0.77226	-0.31049	-0.77120	0.75283
ZLDRING	-0.16522	-0.16636	0.15789	-0.14318	0.16117	0.06875	-0.64801	0.07184	-0.17018	-0.01384	-0.02115

- D I S C R I M I N A N T   A N A L Y S I S -

ON GROUPS DEFINED BY GROUP1

```
        120 (UNWEIGHTED) CASES WERE PROCESSED.
         41 OF THESE WERE EXCLUDED FROM THE ANALYSIS.
             0 HAD MISSING OR OUT-OF-RANGE GROUP CODES.
             7 HAD AT LEAST ONE MISSING DISCRIMINATING VARIABLE.
            34 HAD BOTH.
         79 (UNWEIGHTED) CASES WILL BE USED IN THE ANALYSIS.
```

NUMBER OF CASES BY GROUP

GROUP1	NUMBER OF CASES UNWEIGHTED	WEIGHTED	LABEL
1	29	29.0	average
2	14	14.0	low reading
3	17	17.0	low math
4	19	19.0	low read and math
TOTAL	79	79.0	

POOLED WITHIN-GROUPS CORRELATION MATRIX

	ZGLNORM	SSKTEACH	H_INDEX	SSKSTUD	SSKPROB	ZSOLID	ZTAYLOR	ZGOODCON	ZSYMMET	ZCONFIG	ZFRAG
ZGLNORM	1.00000										
SSKTEACH	0.08556	1.00000									
H_INDEX	0.08619	-0.48533	1.00000								
SSKSTUD	-0.03804	0.27780	-0.13837	1.00000							
SSKPROB	0.15212	-0.62396	0.57104	-0.23674	1.00000						
ZSOLID	0.16442	0.13714	0.00558	0.06963	-0.07407	1.00000					
ZTAYLOR	0.19160	0.16203	-0.15530	0.06072	-0.01822	-0.14145	1.00000				
ZGOODCON	-0.10280	-0.13517	0.06421	-0.16709	-0.08219	0.04379	0.03397	1.00000			
ZSYMMET	0.04813	-0.01018	0.30082	0.00670	0.00853	0.13453	0.20976	0.24024	1.00000		
ZCONFIG	-0.17879	-0.11029	0.15478	-0.05676	-0.04952	0.08630	-0.02099	0.64258	0.38652	1.00000	
ZFRAG	0.16155	0.10987	-0.15424	0.06398	0.04667	-0.08092	0.07956	-0.62468	-0.36743	-0.99254	1.00000
ZMISSING	0.13823	0.00151	-0.00169	-0.06015	0.02251	-0.04260	-0.48037	-0.13557	-0.14980	-0.04383	-0.07821
ZLEVEL	0.01286	0.02324	-0.10911	0.00153	-0.07583	-0.01074	0.53630	0.22987	0.14808	0.19769	-0.15467
ZSTYLE	-0.08332	-0.0272[illegible]	0.07402	-0.05723	-0.10763	0.12699	0.02183	0.67459	0.23921	0.85979	-0.84446
ZSTART	-0.13516	-0.162[illegible]0	0.26920	-0.14135	0.09786	-0.00416	-0.04765	0.35593	0.11768	0.46939	-0.46453
ZPROGRSS	0.19902	0.17019	-0.15793	0.12448	0.03986	-0.07829	-0.07497	-0.77226	-0.31049	-0.77120	0.75283
ZLORING	-0.16522	-0.16836	0.15799	-0.14318	0.16117	0.06875	-0.64801	0.07194	-0.17018	-0.01384	-0.021[illegible]5

	ZGLNORM	SSKTEACH	H_INDEX	SSKSTUD	SSKPROB	ZSOLID	ZTAYLOR	ZGOODCON	ZSYMMET	ZCONFIG	ZFRAG
ZCLUSTER	-0.17803	-0.15066	0.23125	-0.17372	-0.06223	0.00533	0.08918	0.73418	0.38148	0.81241	-0.78726
ZRTAYLOR	0.18688	-0.06809	0.11016	0.16917	0.06001	0.01156	0.47374	0.20690	0.34670	0.22102	-0.18560
ZRGOODCO	0.11380	-0.04600	0.14083	0.00579	0.02450	0.09061	0.16001	0.56407	0.30470	0.53498	-0.52137
ZRSYMM	0.08846	0.00268	0.22130	0.04325	-0.00206	0.02365	0.33508	0.33003	0.55445	0.38384	-0.37170
ZRCONFIG	0.01188	-0.03434	0.22639	-0.03828	0.03086	0.07534	0.06333	0.53768	0.36317	0.66207	-0.66466
ZRFRAG	0.07009	-0.03765	-0.15414	-0.01647	0.03755	-0.10333	0.04949	-0.45281	-0.22771	-0.60280	0.60929
ZRMISSG	-0.09644	0.08807	-0.11531	0.06869	-0.08343	0.02180	-0.13935	-0.17359	-0.20759	-0.16144	0.15730
ZRLEVEL	0.00907	-0.10215	-0.00075	-0.07813	0.06670	0.08840	0.31190	0.21811	0.09054	0.08250	-0.05558
ZRSTYLE	-0.01311	0.04109	0.06020	0.10136	-0.06302	0.13550	-0.18119	0.44452	0.16363	0.47648	-0.48715
ZRSTART	-0.07424	-0.14693	0.20424	-0.07474	0.05054	0.04498	-0.08863	0.43245	0.13966	0.38921	-0.40360
ZRPROGR	-0.03276	0.13879	-0.18160	0.00045	-0.02438	-0.06825	-0.16698	-0.60010	-0.25437	-0.55034	0.54413
ZRLORING	-0.16522	-0.16838	0.15799	-0.14318	0.16117	0.06875	-0.64801	0.07194	-0.17018	-0.01384	-0.02115

	ZMISSING	ZLEVEL	ZSTYLE	ZSTART	ZPROGRSS	ZLORING	ZCLUSTER	ZRTAYLOR	ZRGOODCO	ZRSYMM	ZRCONFIG
ZMISSING	1.00000										
ZLEVEL	-0.34920	1.00000									
ZSTYLE	-0.11081	0.14196	1.00000								
ZSTART	-0.03175	-0.05615	0.58217	1.00000							
ZPROGRSS	0.13728	-0.22810	-0.67382	-0.48707	1.00000						
ZLORING	0.28650	-0.52132	0.02231	0.24679	0.00362	1.00000					
ZCLUSTER	-0.19214	0.20228	0.74004	0.52451	-0.81261	0.02793	1.00000				
ZRTAYLOR	-0.28486	0.32656	0.23722	0.11112	-0.24723	-0.37253	0.26376	1.00000			
ZRGOODCO	-0.10235	0.29647	0.57144	0.26614	-0.52207	-0.15372	0.53744	0.66339	1.00000		
ZRSYMM	-0.09296	0.30405	0.32951	0.16098	-0.42929	-0.37024	0.46042	0.61495	0.61211	1.00000	
ZRCONFIG	0.03261	0.14989	0.65557	0.41163	-0.61276	-0.06958	0.59641	0.53597	0.74880	0.61752	1.00000
ZRFRAG	-0.06352	-0.20019	-0.53994	-0.37244	0.50736	-0.02054	-0.47831	-0.07865	-0.41573	-0.26707	-0.67307
ZRMISSG	0.03116	0.03712	-0.22569	-0.10307	0.20785	0.11397	-0.21955	-0.60401	-0.49021	-0.49188	-0.51835
ZRLEVEL	-0.21924	0.37823	0.18216	0.16677	-0.21138	-0.11361	0.18104	0.33117	0.30247	0.27808	0.27098
ZRSTYLE	0.09572	-0.06060	0.50904	0.29762	-0.39742	0.09768	0.45004	0.14473	0.44017	0.22113	0.56642
ZRSTART	0.12462	-0.05342	0.54440	0.62198	-0.46107	0.20774	0.43521	0.19660	0.40082	0.33267	0.53588
ZRPROGR	0.04136	-0.19059	-0.57951	-0.34825	0.62139	0.11915	-0.63903	-0.59376	-0.77670	-0.71046	-0.75862
ZRLORING	0.28650	-0.52132	0.02231	0.24679	0.00362	1.00000	0.02793	-0.37253	-0.15372	-0.37024	-0.06958

	ZRFRAG	ZRMISSG	ZRLEVEL	ZRSTYLE	ZRSTART	ZRPROGR	ZRLORING
ZRFRAG	1.00000						
ZRMISSG	-0.28358	1.00000					
ZRLEVEL	-0.17078	-0.15388	1.00000				
ZRSTYLE	-0.52131	-0.13164	-0.05814	1.00000			
ZRSTART	-0.33760	-0.30447	0.34723	0.45687	1.00000		
ZRPROGR	0.42458	0.49270	-0.24570	-0.46289	-0.53700	1.00000	
ZRLORING	-0.02054	0.11397	-0.11361	0.08768	0.20774	0.11915	1.00000

CORRELATIONS WHICH CANNOT BE COMPUTED ARE PRINTED AS 99.0.

	ZGLNORM	SSKTEACH	H_INDEX	SSKSTUD	SSKPROB	ZSOLID	ZTAYLOR	ZGOODCON	ZSYMMET	ZCONFIG	ZFRAG
ZCLUSTER	-0.17603	-0.15066	0.23125	-0.17372	-0.06223	0.00533	0.08918	0.73418	0.38148	0.81241	-0.78726
ZRTAYLOR	0.18688	-0.06809	0.11016	0.16917	0.06001	0.01156	0.47374	0.20690	0.34670	0.22102	-0.18580
ZRGOODCO	0.11380	-0.04600	0.14083	0.00575	0.02450	0.09061	0.16001	0.56407	0.30470	0.53498	-0.52137
ZRSYMM	0.08846	0.00268	0.22130	0.04325	-0.00206	0.02365	0.33508	0.33003	0.55445	0.38384	-0.37170
ZRCONFIG	0.01188	-0.03434	0.22639	-0.03828	0.03086	0.07534	0.06333	0.53768	0.36317	0.66207	-0.66466
ZRFRAG	0.07009	-0.03765	-0.15414	-0.01647	0.03755	-0.10333	0.04949	-0.45281	-0.22771	-0.60280	0.60929
ZRMISSG	-0.09644	0.08807	-0.11531	0.06869	-0.08343	0.02180	-0.13935	-0.17359	-0.20759	-0.16144	0.15730
ZRLEVEL	0.00907	-0.10215	-0.00075	-0.07813	0.06670	0.08840	0.31190	0.21811	0.09054	0.08250	-0.05558
ZRSTYLE	-0.01311	0.04109	0.06020	0.10136	-0.08302	0.13550	-0.18119	0.44452	0.16363	0.47648	-0.48715
ZRSTART	-0.07424	-0.14893	0.20424	-0.07474	0.05054	0.04498	-0.08863	0.43245	0.13966	0.38921	-0.40360
ZRPROGR	-0.03276	0.13879	-0.18160	0.00045	-0.02438	-0.06825	-0.16698	-0.60010	-0.25437	-0.55034	0.54413
ZRLORING	-0.16522	-0.16836	0.15799	-0.14318	0.16117	0.06875	-0.64801	0.07194	-0.17018	-0.01384	-0.02115

	ZMISSING	ZLEVEL	ZSTYLE	ZSTART	ZPROGRSS	ZLORING	ZCLUSTER	ZRTAYLOR	ZRGOODCO	ZRSYMM	ZRCONFIG
ZMISSING	1.00000										
ZLEVEL	-0.34920	1.00000									
ZSTYLE	-0.11081	0.14196	1.00000								
ZSTART	-0.03175	-0.05615	0.58217	1.00000							
ZPROGRSS	0.13728	-0.22810	-0.67382	-0.48707	1.00000						
ZLORING	0.28650	-0.52132	0.02231	0.24679	0.00362	1.00000					
ZCLUSTER	-0.19214	0.20228	0.74004	0.52451	-0.81261	0.02793	1.00000				
ZRTAYLOR	-0.28486	0.32656	0.23722	0.11112	-0.24723	-0.37253	0.26376	1.00000			
ZRGOODCO	-0.10235	0.29647	0.57144	0.26614	-0.52207	-0.15372	0.53744	0.66339	1.00000		
ZRSYMM	-0.09296	0.30405	0.32951	0.16098	-0.42929	-0.37024	0.46042	0.61495	0.61211	1.00000	
ZRCONFIG	0.03261	0.14989	0.65557	0.41163	-0.61276	-0.06958	0.59641	0.53597	0.74880	0.61752	1.00000
ZRFRAG	-0.06352	-0.20019	-0.53994	-0.37244	0.50736	-0.02054	-0.47891	-0.07865	-0.41573	-0.26707	-0.67307
ZRMISSG	0.03116	0.03712	-0.22569	-0.10307	0.20785	0.11397	-0.21955	-0.60401	-0.49021	-0.49188	-0.51835
ZRLEVEL	-0.21924	0.37823	0.18216	0.16677	-0.21138	-0.11361	0.18104	0.33117	0.30247	0.27808	0.27098
ZRSTYLE	0.09572	-0.06060	0.50904	0.29762	-0.39742	0.09768	0.45004	0.14473	0.44017	0.22113	0.56642
ZRSTART	0.12462	-0.05342	0.54440	0.62158	-0.46107	0.20774	0.43521	0.19660	0.40082	0.33267	0.53588
ZRPROGR	0.04136	-0.19059	-0.57951	-0.34825	0.62139	0.11915	-0.63903	-0.59376	-0.77670	-0.71046	-0.75862
ZRLORING	0.28650	-0.52132	0.02231	0.24679	0.00362	1.00000	0.02733	-0.37253	-0.15372	-0.37024	-0.06958

	ZRFRAG	ZRMISSG	ZRLEVEL	ZRSTYLE	ZRSTART	ZRPROGR	ZRLORING
ZRFRAG	1.00000						
ZRMISSG	-0.28358	1.00000					
ZRLEVEL	-0.17078	-0.15388	1.00000				
ZRSTYLE	-0.52131	-0.13164	-0.05814	1.00000			
ZRSTART	-0.33760	-0.30447	0.34723	0.45687	1.00000		
ZRPROGR	0.12458	0.49270	-0.24070	-0.48289	-0.53700	1.00000	
ZRLORING	-0.02054	0.11397	-0.11361	0.09768	0.20774	0.11915	1.00000

CORRELATIONS WHICH CANNOT BE COMPUTED ARE PRINTED AS 99.0