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UNIQUENESS OF THE VISUAL PROCESSING DISABILITIES IN CHILDREN WITH NONVERBAL LEARNING DISABILITIES AND THEIR RELATIONSHIP TO PERFORMANCE IN ARITHMETIC

by

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A thesis submitted in conformity with the requirements for the degree of Master of Arts
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Visual processing difficulties have been described as a core problem of children with nonverbal learning disabilities (NLD; Rourke, 1989), but the specific nature of these difficulties has received little systematic investigation. The younger the age at which these kinds of difficulties are identified, the better the opportunity for successful intervention (Rourke, 1989). The present study systematically compared the simple and complex visuoperceptual and visual-spatial abilities of 6-year-old boys with NLD (n = 13) to a matched control group of boys with other learning disabilities (CLD) and to normative scores. A profile of strong average abilities on a simple discrimination task but relative visual-spatial weaknesses was unique to the NLD group, as was significantly poorer (p ≤ .01) performance on the more complex mental rotation task. The visual processing abilities of children with NLD were positively associated with their arithmetic scores, but no significant correlations were found for the CLD group.
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This thesis is dedicated to my brother Erick, who taught me about strength and courage.
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Chapter 1

Literature Review

Clinical Profile of Nonverbal Learning Disabilities

In describing their clinical experiences over 3 decades ago, Johnson and Myklebust, (1967) referred to a relatively uncommon type of learning disability (LD) which they named “nonverbal learning disabilities” (NLD; p. 273). Children with NLD were described as having at least average verbal intelligence but significant deficits in social perception and understanding the nonverbal aspects of communication and daily life (Johnson & Myklebust, 1967). They considered NLD to be a serious disability in which the interpretation of everyday experience itself was fundamentally distorted (Johnson & Myklebust, 1967). Since 1967, many other clinicians and researchers have attempted to delineate and refine the NLD phenotype (Casey, Rourke, & Picard, 1991; Casey & Strang, 1994; Del Dotto, Fisk, McFadden, & Rourke, 1991; Denckla, 1991; Gross-Tsur, Shalev, Manor, & Amir, 1995; Harnadek & Rourke, 1994; Humphries, Krekewich, & Snider, 1996; Johnson, 1987; Little, 1993; Myklebust, 1975; Ozols & Rourke, 1985; Ozols & Rourke, 1988; Palombo, 1995; Rourke, 1982; Rourke, 1987; Rourke, 1989; Rourke, 1993; Rourke & Tsatsanis, 1996; Rourke, Young, & Leenaars, 1989; Semrud-Clikeman & Hynd, 1990; Share, Moffitt, & Silva, 1988; Strang & Rourke, 1983; Strang & Rourke, 1985a; Strang & Rourke, 1985b; Worling, 1997).

Children with NLD have a characteristic pattern of neuropsychological assets and deficits in visual and auditory perception, motor and psychomotor functioning, language, academics,
social and adaptive skills, and socioemotional functioning (Rourke, 1989). They have impaired perceptual abilities in understanding visual details and visual relationships and exceptional difficulties with visual-spatial organization and synthesis (Johnson, 1987; Rourke, Del Dotto, Rourke, & Casey, 1990). Their auditory perceptual abilities, on the other hand are typically very well developed (Rourke, 1989; Rourke et al., 1990). They exhibit average simple motor skills, but have difficulties with bilateral complex psychomotor coordination and bilateral tactile-perceptual abilities, typically more marked on the left side of the body (Rourke, 1989; Rourke et al., 1990). These visual-spatial-motor deficits lead to the presentation of children with NLD as chronically clumsy (Johnson, 1987; Strang & Rourke, 1985a).

In terms of language skills, children with NLD develop an extensive vocabulary accompanied by a large amount of verbal associations (Rourke, 1989; Rourke et al., 1990; Rourke & Tsatsanis, 1996). They have excellent rote verbal abilities, especially for auditorily-presented material, and are extremely verbose (Casey & Strang, 1994; Rourke, 1989; Rourke & Tsatsanis, 1996; Strang & Rourke, 1985a). While their language form (phonology, morphology and syntax) is generally good, the quality of their communication (language content, organization, and pragmatics) tends to be especially deficient (Casey & Strang, 1994; Rourke & Tsatsanis, 1996) and is characteristic of "cocktail party" speech (Rourke & Tsatsanis, 1996, p. 32). They tend to interpret language concretely and fail to catch the implied meanings of more abstract language, such as sarcasm, humour, irony or metaphors (Denckla, 1991; Johnson, 1987; Palombo, 1995; Rourke & Tsatsanis, 1996). Additionally, they have great difficulty understanding and expressing affect, tone, and other aspects of nonverbal behaviour, such as body gestures (Casey & Strang, 1994; Johnson, 1987; Ozols & Rourke, 1985; Rourke, 1989;
Rourke & Tsatsanis, 1996; Strang & Rourke, 1985a). Overall, while children with NLD tend to talk a lot, they may not actually contribute much (verbally or nonverbally) which is meaningful and/or appropriate to the context of the conversation.

In terms of written language skills, they tend to develop good phoneme-grapheme matching skills (i.e., single word decoding and spelling, with most of their misspellings being phonetically accurate; Rourke, 1989; Rourke et al., 1990; Strang & Rourke, 1985a). However, higher-order academic skills, such as reading comprehension, concept-formation, problem-solving skills, and causative thinking are impaired (Rourke, 1989; Rourke et al., 1990). These problems impede performance in such academic subjects as science, mechanical arithmetic and higher level mathematics (Casey & Strang, 1994; Rourke, 1989; Rourke, 1993; Rourke et al., 1990; Strang & Rourke, 1985b). Performance in geography may also be affected by visual-spatial impairments (Casey & Strang, 1994). Graphomotor skills (i.e., handwriting) are typically hampered by poor visuomotor skills and poor spatial planning (Gross-Tsur et al., 1995; Johnson, 1987; Palombo, 1995; Rourke, 1989; Strang & Rourke, 1985a).

In terms of social skills, Johnson and Myklebust (1967) and Myklebust (1975) described children with NLD as having a marked deficit in social perception, or as being incapable of understanding their social environment and the consequences of behaviour. These children are unable to “pretend and anticipate” (Johnson & Myklebust, 1967, p. 272), and as such, cannot successfully play with other children. Dealing with novel situations is especially problematic for these children, and they tend to respond to new events with overlearned, stereotyped behaviours which may be inappropriate to the context (Rourke, 1989; Rourke et al., 1990). They tend to become socially isolated for various reasons including their inability to understand the nonverbal
aspects of play and communication, their rigid and typically inappropriate aspects of language and social behaviour, and their lack of a sense of humour (Casey & Strang, 1994; Del Dotto et al., 1991; Johnson, 1987; Palombo, 1995; Rourke & Tsatsanis, 1996; Strang & Rourke, 1985a).

In addition to their social alienation, children with NLD are typically unable to develop satisfactory levels of independence or adaptive functioning (Casey & Strang, 1994; Johnson, 1987; Rourke, 1989; Strang & Rourke, 1985a). For example, as young children, they have difficulties learning to dress and feed themselves and tie their shoelaces (Johnson, 1987; Strang & Rourke, 1985a). Throughout their life, their visual-spatial deficits continue to seriously impair their independence, such that they have problems orienting themselves in space and tend to get lost quite often, even in familiar places (Myklebust, 1975). They may also have a lot of difficulty crossing the street due to their inability to estimate the speed and direction of the traveling cars (Casey & Strang, 1994; Johnson, 1987).

In terms of their socioemotional functioning, Rourke and colleagues (Rourke, 1989; Rourke et al., 1990) suggest that young children with NLD have higher than expected rates of externalizing psychopathology (e.g. acting out), but tend to develop more internalizing forms of psychopathology (such as depression and anxiety) with age. This finding has been supported by other studies and case reports (Bigler, 1989; Cleaver & Whitman, 1998; Gross-Tsur et al., 1995). In carefully reviewing the literature of socioemotional functioning of NLD, however, Little (1993) concludes that while there is some evidence that children with NLD have higher than expected rates of psychopathology, the type of dysfunction (internalizing or externalizing) and its developmental pattern are not clear.
Estimates of the prevalence of NLD have ranged from about 10% (Rourke, 1989; Rourke, Fisk, & Strang, 1986) to 18% (Johnson, 1987) to even 29% (Van der Vlught, 1989) of the LD population, or about 10 - 29 in 1,000 live births. However, these estimates are based on clinical, and not epidemiological, studies suggesting that the true prevalence of NLD is unknown (Denckla, 1991). Only one epidemiological study to date has examined the NLD syndrome (Share et al., 1988). In a test of the construct validity of the NLD syndrome, this study of a large, representative sample of 11-year-old New Zealand children found that 30 / 925 children met the academic criteria of NLD, suggesting a prevalence rate of about 3% of the general population, consistent with clinical studies (Share et al., 1988). While clinical studies of NLD have reported an equal proportion of males to females (Rourke, 1989; Rourke et al., 1986), the validity of the NLD syndrome in girls has recently been questioned (Share et al., 1988).

Although estimated to be less prevalent, NLD is considered more debilitating (Johnson, 1987; Myklebust, 1975) and more resistant to remediation than are verbal learning disorders (Johnson, 1987). However, there have been, as of yet, no studies evaluating the effectiveness of intervention strategies for children with NLD. In fact, the need and call for controlled studies of the relative effectiveness of NLD interventions has been strongly voiced (Little, 1993; Semrud-Clikeman & Hynd, 1990). Currently, intervention strategies for children and adolescents with NLD have been recommended based solely on clinical experience (Foss, 1991; Ozols & Rourke, 1985; Palombo & Berenberg, 1995; Rourke, 1989; Strang & Rourke, 1985a; Strang & Rourke, 1985b).

Across clinicians, common intervention themes include the following. The intervention must be based on an assessment of the individual's strengths and weaknesses (Casey & Strang,
1994; Foss, 1991; Ozols & Rourke, 1985; Palombo & Berenberg, 1995; Rourke, 1989; Strang & Rourke, 1985a). It is important to offer psychoeducation about NLD to the individual child and to educate (and form alliances with) parents, teachers, and other relevant professionals. It is hoped that this will promote a better understanding of children with NLD and of their experience of the world (Foss, 1991; Palombo & Berenberg, 1995; Rourke, 1989). This is particularly important since these children tend to be consistently misunderstood (Johnson & Myklebust, 1967; Myklebust, 1975). Therapy should take place in a safe and positive environment which supports the child as an active participant in the therapeutic process and in problem solving with teachers, parents, and others (Foss, 1991; Palombo & Berenberg, 1995). It is important that parents, teachers, and therapists have realistic expectations of the capabilities of children with NLD and do not set unattainable goals; it is easy to hold unrealistic expectations of the capabilities of these children since their verbosity, advanced vocabulary, and good language form make them seem more knowledgeable or advanced than they actually are (Foss, 1991; Rourke, 1989; Rourke & Tsatsanis, 1996).

While the goals of therapy differ for each individual, therapy generally aims to improve functioning in (a) visual-spatial abilities, (b) arithmetic, (c) graphomotor skills, (d) social skills, (e) self esteem, (f) adaptive functioning, and / or (g) nonverbal reasoning (Casey & Strang, 1994; Foss, 1991; Myklebust, 1975; Ozols & Rourke, 1985; Palombo & Berenberg, 1995; Rourke, 1989; Strang & Rourke, 1985b). Treatment goals also include teaching generalization of learned skills to new situations and negotiating the use of compensatory strategies (such as the use of a computer for school assignments to compensate for poor graphomotor skills; Foss, 1991;
Palombo, 1995; Rourke, 1989). In some cases, medication for depression, anxiety, or attention deficit hyperactivity disorder may be indicated (Palombo & Berenberg, 1995).

Treatment goals are attained through a verbal parts-to-whole teaching strategy, which is systematic and involves prolonged repetitive practice, and feedback which is continuous and explicit (Foss, 1991; Rourke, 1989). Treatment strategies must target the deficits explicitly through direct instruction (Foss, 1991; Myklebust, 1975; Rourke, 1989; Strang & Rourke, 1985a; Strang & Rourke, 1985b). An example of a general treatment strategy includes (a) breaking down each task into its component parts (i.e., task analysis), (b) verbally labeling each step, (c) writing down each step and having the child memorize the sequence, then (d) encouraging the child to use verbal mediation (followed by verbal self-direction) to successfully perform the task independently (Foss, 1991; Palombo & Berenberg, 1995; Rourke, 1989; Strang & Rourke, 1985a). This strategy uses the strengths of the child with NLD (good rote auditory memory) to address his or her weaknesses. With some variations, this strategy could be used to improve arithmetic performance (Rourke, 1993; Strang & Rourke, 1985b), visual-spatial abilities (Foss, 1991), and graphomotor skills (Foss, 1991). Social skills may also be taught in this fashion (Foss, 1991). Direct instruction in social skills is often supplemented with role playing and with the labeling of the nonverbal and social behaviours displayed by others and by the child (Foss, 1991; Palombo & Berenberg, 1995; Rourke, 1989).

Generally, clinicians have reported a poor prognosis for individuals with NLD, since their serious deficits tend to continue into adulthood, affecting their job performance, insight, independence, and socioemotional functioning (Del Dotto et al., 1991; Johnson, 1987; Rourke et al., 1989). Generally, the prognosis of children with NLD tends to be poor if comprehensive
treatment is not begun early (Rourke, 1989). Even with treatment, though, Casey et al. (1991) found that the prognosis may still be poor in some areas (e.g. visual-perceptual-spatial and social skills). However, conclusions about prognosis with treatment must be tentative at this stage since this study was limited to following nine children over 2 years, and did not adequately describe the individual intervention programs the children underwent (Casey et al., 1991).

**Rourke's Developmental Model of NLD**

Rourke has been a prolific contributor to understanding the clinical picture of the NLD syndrome. In proposing a model of the NLD syndrome, Rourke has also contributed to the conceptualization of its neurological basis and developmental course (Rourke, 1989). His model is based on his series of subtyping studies dating back to the early 1970's (Ozols & Rourke, 1988; Rourke, Dietrich, & Young, 1973; Rourke & Finlayson, 1978; Rourke & Strang, 1978, cited from Rourke, 1989; Rourke & Telegdy, 1971; Rourke, Young, & Flewelling, 1971; Strang & Rourke, 1983) and on Goldberg and Costa's (1981) theory of differential hemispheric functioning.

In an attempt to identify specific LD subtypes, Rourke conducted his first two studies (Rourke & Telegdy, 1971; Rourke et al., 1971) examining the verbal, perceptual, motor and problem solving abilities of older children (aged 9 to 14 years) with LD and differing cognitive profiles: (a) high verbal intelligence quotient (VIQ) but low performance intelligence quotient (PIQ; HV-LP group), (b) low VIQ-high PIQ (LV-HP), and (c) equal VIQ and PIQ (VIQ = PIQ). The HV-LP group performed significantly better on the verbal and auditory perceptual dependent measures while the HP-LV were superior on the visual-perceptual tasks (Rourke et al., 1971).
On the majority of the complex motor and psychomotor tasks (including tests involving visual-motor coordination, spatial visualization and memory for spatial locations) the HP-LV group outperformed the HV-LP group (Rourke & Telegdy, 1971). In younger children (aged 5 to 8 years), Rourke et al. (1973) found very few significant differences among the groups, although the patterns of relative functioning were very similar to that of the older children.

Across these studies, Rourke (1989) noticed that the performance on the academic measures (Reading, Spelling and Arithmetic on the Wide Range Achievement Test; WRAT) also followed a specific pattern as a function of the cognitive profiles. Specifically, subjects in the HV-LP group tended to perform well on WRAT Reading and Spelling but poorly on Arithmetic, whereas a tendency for the opposite pattern (low Reading and Spelling but higher Arithmetic) was evident in the HP-LV group. In order to investigate the correlates of these academic patterns further, Rourke and his colleagues conducted a second set of studies (Rourke & Finlayson, 1978; Rourke & Strang, 1978, cited from Rourke, 1989; Strang & Rourke, 1983) of 9- to 14-year-old children with differing academic profiles on the WRAT: (a) equally impaired reading, spelling and arithmetic (group R-S-A); (b) arithmetic, although impaired, better than reading and spelling scores (group R-S); and (c) average reading and spelling but significantly deficient arithmetic scores (group A). On visual-perceptual and visual-spatial measures, groups R-S-A and R-S performed significantly better than group A, while group A was superior on verbal and auditory-perceptual measures (Rourke & Finlayson, 1978). Group A performed significantly worse, and in the impaired range, on some complex psychomotor and tactile-perceptual tests (Rourke & Strang, 1978, cited from Rourke, 1989), as well as on a measure of concept-formation and nonverbal problem solving abilities (Strang & Rourke, 1983).
In terms of socioemotional functioning, further studies revealed that as a whole, children with LD generally do not experience social-emotional problems at the clinical level (Rourke, 1988). However, when the socioemotional functioning was examined as a function of LD subtype, a different pattern emerged. The personality profiles of children in group A, as reported by parents, were suggestive of internalizing psychopathology (Strang & Rourke, 1985a), consistent with Fuerst, Fisk, and Rourke's (1990) cluster analysis that revealed the majority of subjects comprising the seriously emotionally disturbed clusters were children with HV-LP discrepancies.

Based on the above series of subtyping studies investigating the NLD phenotype (i.e. HV-LP / group A) and its distinctive neuropsychological pattern of assets and deficits, Rourke (1989) proposed a developmental and sequential model of the NLD syndrome. Rourke and his colleagues suggest that the underlying basis of NLD is sensorimotor dysfunction (Rourke, 1993; Rourke, 1995; Strang & Rourke, 1983). Specifically, they assume that children with NLD have experienced the same primary deficits (bilateral tactile-perception, bilateral psychomotor skills, and visual-perceptual-organization) since birth (Rourke, 1993; Rourke, 1995; Strang & Rourke, 1983). That is, children with NLD have difficulties integrating sensory information from an early age and consequently, tend to be very clumsy (Johnson, 1987). Their clumsiness is accompanied by reproachments from caregivers which act to discourage them from physically exploring their environment (Johnson, 1987; Rourke, 1995). Their deficits interact with their advanced oral language skills (verbosity, strong vocabulary, good language form) and lead them to explore their environment solely through verbal interactions with others (Rourke, 1989; Rourke, 1995). In fact, they are reinforced for doing so, since caregivers generally praise their loquaciousness.
The overall effect and interaction of these strengths and deficits impede the NLD child from developing *adequate sensorimotor experience*, which is believed (Piaget, 1954) to be critical for the development of higher-order cognitive functions (Denckla, 1991; Rourke, 1993; Strang & Rourke, 1985b). Rourke (1987) suggests that sensorimotor integration therapy may be very important in “attacking the [NLD] deficits” (p. 218), especially in younger children with NLD.

According to Rourke’s model of NLD, the neuropsychological assets and deficits are categorized in order of causation as primary, secondary, tertiary, verbal, academic and socioemotional functioning (Rourke, 1989; Rourke, 1993; Rourke et al., 1990). Primary neuropsychological assets include extremely well developed auditory-perceptual abilities, average simple motor skills and an appreciation for rote (especially auditory) material (Rourke, 1989; Rourke, 1993; Rourke et al., 1990). These lead to the secondary assets, which include well developed attention for simple repetitive auditory and verbal material (Rourke, 1989; Rourke, 1993; Rourke et al., 1990). These develop into the tertiary assets which include well developed memory skills for rote verbal material. These assets lead to excellent vocabulary, phonological skills and verbosity (mainly of a rote nature; Rourke, 1989; Rourke et al., 1990; Rourke & Tsatsanis, 1996).

Primary neuropsychological deficits include very poor bilateral tactile-perceptual skills and psychomotor coordination (both tending to be more marked on the left side of the body), impaired visual perception (particularly basic visual discrimination and recognition of visual relationships and details), impaired visual-spatial organization, and severe difficulties adapting to novel situations (Rourke, 1989; Rourke et al., 1990). These lead to the secondary deficits which
include poor attention to tactile and visual material and minimal physical exploration of the environment (Rourke, 1989; Rourke et al., 1990). These deficits lead to the tertiary deficits of poor memory for tactile and visual materials, and significant deficits in such higher-order cognitive skills as concept formation, problem solving (including strategy generation and hypothesis testing), and the appreciation of feedback, cause-and-effect relationships, and incongruities (Rourke, 1989; Rourke et al., 1990). These deficits are hypothesized to lead to verbosity which is characterized as rote, lacking in speech prosody, and displaying very poor pragmatics; children with NLD tend to rely on oral language to gather information and relate to others (Rourke, 1989; Rourke, 1993; Rourke et al., 1990).

All these assets and deficits interact to produce academic assets and deficits and socioemotional deficits. Academic assets include word decoding and spelling, while the deficits are in reading comprehension, mathematics, science and (early) graphomotor skills (Rourke, 1989; Rourke et al., 1990). The socioemotional or adaptive difficulties of individuals with NLD may include problems with independence, social judgment (including understanding nonverbal communication), interaction with others, and adaptation to novel situations (Rourke, 1989; Rourke et al., 1990). According to the model, these children may also be at a greater risk of developing internalized forms of psychopathology such as depression, anxiety, or suicidal behaviours as they grow older (Rourke, 1989; Rourke, 1993; Rourke et al., 1990). Overall, the gap between the assets and deficits tends to widen with age (Rourke & Tsatsanis, 1996).

The model of the NLD syndrome proposed by Rourke in 1982 (as cited in Rourke, 1989) synthesized the findings across this series of studies spanning almost two decades, and was partly based on Goldberg and Costa's (1981) theory of differential hemispheric functioning.
Specifically, Rourke (1982, as cited in Rourke, 1989) proposed that children with NLD (group A / HV-LP) performed similarly to those individuals with specific right hemisphere brain damage (RHBD). Namely, children with NLD performed well on tasks believed to be controlled mainly by the left hemisphere, but poorly on tasks believed to be controlled mainly by the right hemisphere. In refining this model, Rourke (1987; 1989) proposed that it is not the dysfunction of the right hemisphere per se that is the neurological basis of the NLD syndrome, but rather, significant problems in the development or functioning of white matter in the right hemisphere, which is responsible for intermodal integration. Specifically, Rourke (1993) proposed “disordered myelinization and/or myelin functioning [as] ‘the final common pathway’ that eventuates in the NLD syndrome” (p. 223). Since there is proportionately more white matter in the right hemisphere than in the left, children with white matter dysfunction or damage are clinically similar to children with NLD (see Rourke, 1987; Rourke, 1989; Rourke & Tsatsanis, 1996).

Clinical Picture of Individuals with Right-Hemisphere Brain Damage

Studies of children, adolescents and adults with RHBD, do in fact, support a clinical presentation similar to that of NLD (Gross-Tsur et al., 1995; Semrud-Clikeman & Hynd, 1990; Voeller, 1986; Weintraub & Mesulam, 1983). The terms NLD and developmental right-hemisphere syndrome (DRHS; Gross-Tsur et al., 1995), developmental learning disabilities of the right hemisphere (Denckla, 1991; Weintraub & Mesulam, 1983), or right hemisphere deficit syndrome (Voeller, 1986) have been used synonymously. The core problems of individuals with DRHS include left-sided neurological signs, poor visuospatial and interpersonal skills, poor
arithmetic achievement in the context of good reading skills, and socioemotional problems, such as introversion and depression (Voeller, 1986; Weintraub & Mesulam, 1983). Individuals with DRHS also have difficulty expressing and understanding nonverbal communication (Voeller, 1986). They generally have a significant discrepancy in their cognitive profiles (VIQ > PIQ) and in their academic profiles (Reading > Arithmetic; Voeller, 1986; Weintraub & Mesulam, 1983), as found in NLD. Children (mean age of 9 years) with DRHS have also been shown to have higher than expected rates of Attention Deficit Hyperactivity Disorder (Voeller, 1986). Some contention exists, however, over the claim that NLD and DRHS are manifestations of the same syndrome (Branch, Cohen, & Hynd, 1995).

Visual Processing: A Core Feature of NLD?

Recently, Harnadek and Rourke (1994) conducted a study which attempted to identify the most salient and specific characteristics of NLD, with a view to helping define clinical diagnostic criteria. They examined the relative discriminating power of the neuropsychological assets and deficits of children with NLD, compared to children with a verbal LD subtype (deficient reading and spelling but significantly higher, although still low, arithmetic) and to a nonclinical control group (Harnadek & Rourke, 1994). They found that visual-perceptual-organizational ability was one of three features most characteristic of and unique to NLD, supporting Rourke’s (1989) hypothesis that this is a primary deficit (Harnadek & Rourke, 1994).

In examining the developmental manifestations of NLD, Casey et al. (1991) found that features of the NLD syndrome begin to become manifest between the ages of 5 to 15 years. Visual-perceptual-organizational difficulties, as a whole, are apparent in young children, aged 5
to 8 years (Casey et al., 1991; Ozols & Rourke, 1988) and tend to worsen with age, relative to same aged-peers (Casey et al., 1991; Rourke et al., 1990). In fact, visual perception has been hypothesized to be a core feature of NLD as far back as 1967, when it was first described by Johnson and Myklebust (1967).

However, a few years later, Myklebust (1975) refined this theory of the core problems of NLD. In his revised theory, children with NLD do not have difficulties with visual perception per se, but with "gain[ing] significance beyond perception" (Myklebust, 1975, p. 117) or understanding what they are seeing. Based on his clinical experience, Myklebust (1975) believed that the core deficit in NLD was not visual perception, but higher-order cognitive processes such as imagery and memory (specifically storage, not recall). As an example, he reports that children with NLD can identify objects which form the components of a task, but yet cannot successfully perform tasks which require higher-order cognitive processing, such as synthesis and organization (e.g. Block Design, Object Assembly; Myklebust, 1975).

For the purposes of this thesis, basic visuoperceptual tasks of pattern analysis (e.g. visual discrimination) will be referred to as “simple tasks” while higher-order visual tasks (such as visual imagery) will be referred to as “complex tasks”. This is consistent with a levels-of-processing approach (Craik & Lockhart, 1972), in which tasks involving deeper processing, such as mental manipulation or elaboration of visual stimuli (e.g. imagery, semantic encoding) may be considered more complex than tasks which involve superficial processing (e.g. discrimination of objects based on physical attributes; Matlin, 1989).

Overall, then, Myklebust (1975) reports that children with NLD have problems in visual perception only as the task becomes more complex. Hence, their problems seem to lie not in
simple visual processing (e.g., visual recognition and discrimination), but in more complex levels of visual processing (e.g., visual imagery). Myklebust’s (1975) theory of the primary core deficits of NLD, therefore, contrasts directly with that of Rourke, who theorizes that impaired simple visual perception, particularly the “discrimination and recognition of visual detail and visual relationships” (Rourke et al., 1990, p. 366) is one part of the core of NLD. This theoretical contrast is particularly important since, according to Rourke’s (1989) model, visual perception is a primary deficit which, in conjunction with the other primary deficits, lead to the secondary, tertiary, verbal and socioemotional deficits of NLD. Rourke, therefore, claims that children with NLD have impaired visual processing at both the simple and complex levels.

Given the stark contrast of theories, it is important to understand upon what evidence these opposing theories are based. Myklebust’s (1975) theory is based solely on clinical experience. Rourke’s (1989) theory is based on empirical studies which examined the visual processing of children with NLD by using the following measures (a) WISC Picture Arrangement subtest (Wechsler, 1974), (b) WISC Object Assembly subtest (Wechsler, 1974), (c) WISC Block Design subtest (Wechsler, 1974), (d) WISC Picture Completion subtest (Wechsler, 1974), (e) the Target Test (Reitan & Davison, 1974), and (f) the Trail Making Test (Reitan & Davison, 1974). However, these measures clearly tap visuoperceptual and visual-spatial organization abilities at a very gross level, and involve variously complex cognitive abilities, such as visual perception of details, visual imagery, visual and visual-spatial memory, visual organization and planning, visual synthesis, conceptualization, nonverbal reasoning, etc. (Sattler, 1992).
The difficulties of children with NLD on complex tasks of visual-spatial processing have been replicated in an independent study by Humphries et al. (1996). This study found that children with NLD performed more poorly than a comparison group of children with LD who are not NLD on the Space Visualization Subtest of the Southern California Sensory Integration Test (Ayres, 1980), a complex task which involves mental rotation as the items progress in difficulty (Humphries et al., 1996). However, Humphries et al. (1996) did not compare simple to more complex visual processing tasks, and overall, Rourke did not assess simple visual abilities in developing his model of NLD.

Not only do the tasks on which Rourke based his model confound visual processing at the simple and complex levels, but they also confound visuoperceptual (i.e. “pattern-analysis”; Capruso, Hamsher, & Benton, 1995, p. 138) and visual-spatial abilities. Visuoperceptual judgments are based on the pattern, shape, or other physical attributes of a form or object, and include object discrimination and recognition (see Capruso et al., 1995). Visual-spatial judgments, on the other hand, are based on the relative relationships of configurational stimuli, and include transformations and rotations (Denckla, 1991). Research in the visual processing field consistently reports that visuoperceptual abilities are separate from and not necessarily related to visual-spatial abilities (Capruso et al., 1995; Denckla, 1991; Young, 1996). In fact, these two abilities are believed to be subserved by different parts of the brain (Capruso et al., 1995; Young, 1996). Hence, it also becomes important to study the contribution of each component separately instead of making generalizations about the visual processing abilities of children with NLD through gross measures.
While clinical descriptions and empirical studies all suggest that children with NLD have difficulties in visual processing at complex levels (Humphries et al., 1996; Rourke, 1989; Rourke et al., 1971; Strang & Rourke, 1983), there is a dearth of research or reported case studies which describe the performance of children with NLD on tasks of visual processing at simple levels (e.g., object recognition or visual discrimination). One exception is Myklebust's (1975) clinical observations that visual processing at the simple level is not impaired in children with NLD. A second exception refers to the only study, to the author's knowledge, which has assessed the performance of children with NLD on a simple visual-spatial task (Worling, 1997). Worling (1997) found that children with NLD were as capable as children with verbal LD and non-clinical (control) children in identifying objects in relation (i.e., above, below, etc.) to other objects in a simple picture. A third exception refers to a study by Strang and Rourke (1983) examining the concept formation abilities of these children as measured by the Halstead Category Test (Reitan & Davison, 1974). This test is comprised of six subtests and is considered “a relatively complex concept-formation test involving non-verbal abstract reasoning, hypothesis testing, and the ability to benefit from positive and negative informational feedback” (Strang & Rourke, 1983, p. 36). One subtest, however, (subtest 3) primarily involves visual discrimination. The underlying concept of this subtest is that the child must identify which figure is least like the other three figures displayed. This is the only subtest in which children with NLD performed at an average range, and did not differ from the comparison group of children with verbal LD (Strang & Rourke, 1983). Overall, then, in the NLD literature there is some minimal evidence which supports Myklebust’s (1975) contention that children with NLD have difficulties only in
more complex levels of visual processing, but no systematic comparison has been made between the performance of children with NLD on both more simple and complex visual processing tasks.

Similarly, the literature on hemispheric functioning has shown the importance of the right hemisphere in performing successfully on complex visual processing tasks. For example, in non-clinical subjects, the right hemisphere has been found to be important for processing complex visual-spatial tasks, such as spatial imagery and mental rotation (Deutsch, Bourbon, Papanicolaou & Eisenberg, 1988; Ditunno & Mann, 1990; Furst, 1976; Papanicolaou et al., 1987). Furthermore, some research involving the visual processing of adults with RHBD has found that these adults have significant difficulties with complex, but not necessarily simple, levels of visual processing (De Renzi & Spinnler, 1966; Humphreys & Riddoch, 1984; Koul & Lloyd, 1998; Warrington & James, 1967). For example, some research has shown that adults with RHBD generally have intact visual recognition or discrimination abilities (Humphreys & Riddoch, 1984; Layman & Greene, 1988; Myers & Brookshire, 1996; Taylor & Warrington, 1973), but great difficulty with more complex tasks such as associative learning (Koul & Lloyd, 1998), mental imaging (e.g., mental rotation, visual closure; Corballis, 1997; De Renzi & Spinnler, 1966; Ditunno & Mann, 1990; Newcombe & Russell, 1969; Ratcliff, 1979; Warrington & James, 1967; Warrington & Taylor, 1973), and visual memory (Brookshire & Lommel, 1974; King, 1981). In examining the cognitive functioning of children, adolescents, and adults with DRHS, Weintraub and Mesulam (1983) found that the vast majority of participants (8/10) performed in the average range on a simple task of visual recognition. Of the two participants who performed below average, they wrote, “Their errors were cases of true naming failure, rather than misperception of the stimulus items” (Weintraub & Mesulam, 1983, p. 466). This is
consistent with the scant evidence of intact simple, but impaired complex, visual processing in children with NLD. While one must be careful about generalizing the findings of adult studies to children (Semrud-Clikeman & Hynd, 1990), adult studies may still offer meaningful conceptualizations and comparisons (Denckla, 1973).

Overall, then, the research on the visual processing of children with NLD has not effectively made the distinction between simple (visual discrimination) and complex (visual imaging, memory, mental manipulation / rotation, etc.) levels of visual processing. Furthermore, the existing body of research has also not effectively made the distinction between the types of visual processing which may be difficult for children with NLD, such as visuoperceptual (or "pattern analysis") and visual-spatial processing. The research on RHBD, however, has more effectively made these distinctions and offers some support to Myklebust's (1975) theory that the core deficit of children with NLD is complex, and not simple, visual processing.

The Importance of Early Intervention Targeting Visual Processing Abilities

The importance of early intervention has been emphasized repeatedly (Rourke, 1987; Rourke et al., 1990). Even with intervention, though, the prognosis of individuals with NLD may remain fairly poor (Johnson, 1987; Rourke et al., 1990). In order to develop better interventions, researchers must further investigate the primary deficits of NLD in a systematic and detailed manner in young children who are just beginning to manifest this syndrome. In other words, since the primary deficits are hypothesized to lead to the series of other deficits, remediating the primary deficits early may prevent or mitigate the development of further problems (see Harnadek & Rourke, 1994; Rourke, 1987). Harnadek and Rourke (1994) found
that one of the primary neuropsychological deficits most characteristic of and unique to NLD was visual-perceptual-organization. In order to develop effective targeted interventions, therefore, it remains important to understand if children with NLD have differential difficulties across simple and complex visual tasks and across visual discrimination and visual-spatial relationships tasks. It is particularly important to intervene early (Rourke, 1989), since the visual processing deficits of children with NLD are believed to worsen as they grow older (Casey et al., 1991).

Although understanding the primary deficits of young children with NLD is believed to be very important, only three studies to date have examined the neuropsychological functioning of young children (aged 5 to 8) with NLD (Humphries et al., 1996; Ozols & Rourke, 1988; Rourke et al., 1973). Rourke’s studies found that, in terms of visual processing, young children with NLD were found to have minimal (Rourke et al., 1973) or some difficulties (Ozols & Rourke, 1988) with some complex visual tasks (such as the Object Assembly subtest of the WISC; Wechsler, 1974) relative to children with verbal LD. In comparing the visual processing abilities of young children with NLD to children with LD that was not NLD, Humphries et al. (1996) found that the two groups did not differ on a global measure of visual processing (Perceptual Quotient of the Test of Visual Perceptual Skills; Gardner, 1982), but did significantly differ in a visual-motor integration task and in a complex task of visual-spatial perception (Space Visualization subtest of the Southern California Sensory Integration Test; Ayres, 1980). The scant literature on young children with NLD suggests that they may have subtle difficulties with visual processing at complex levels. Their visual processing at simple levels, however, has not been investigated.
NLD and Arithmetic Abilities: The Importance of Visual Processing

A reliable association between visual problems and arithmetic difficulties has been reported for over 20 years (see Denckla, 1991). Visual-spatial abilities, in particular, have been found to be important for overall mathematical calculation in younger children (Kindergarten-Grade 1; Jordan, Levine, & Huttenlocher, 1995), older children (mean ages 9 - 14; Badian, 1983; McLeod & Crump, 1978; Rourke & Finlayson, 1978), and young adults (Badian, 1983). In young children, however, the specific contributions of visual-spatial abilities to arithmetic performance (e.g. counting, single digit operations, etc.) is unclear; some researchers argue their contribution is minimal (Denckla, 1991) while others argue their contribution may be quite significant (see Geary, 1993; Jordan et al., 1995).

Simple or elementary arithmetic performance involves two separate types of processing which work in conjunction with each other: declarative knowledge and procedural knowledge (Ashcraft, Yamashita, & Aram, 1992; Pellegrino & Goldman, 1987). Declarative knowledge is considered to be an organized and interconnected network which holds the basic facts of addition, subtraction, multiplication, etc. (Ashcraft et al., 1992; Pellegrino & Goldman, 1987). Procedural knowledge refers to knowledge about how to solve mathematical calculations in the form of rules, strategies, algorithms, and heuristics (Ashcraft et al., 1992; Pellegrino & Goldman, 1987). Children with a mathematical disabilities (MD) may show difficulties with one or both of these componential processes and/or with visual-spatial skills (reviewed in Geary, 1993).

The poor functioning of children with NLD in mechanical arithmetic is a reflection of the interaction between their neuropsychological assets (good to excellent rote verbal memory) and deficits (visuospatial, visuomotor, and problem solving skills, such as concept-formation,
hypothesis testing, ability to benefit from experience; Rourke, 1993; Strang & Rourke, 1985b).

Specifically, the good rote auditory memory of children with NLD enables them to recall number facts and theorems verbatim (Rourke, 1989). Their deficits, on the other hand, contribute to errors in (written) arithmetic calculations. An error analysis of the written calculation of children with NLD (aged 9 to 14 years) revealed that older children made the same types of errors as did the younger children (Rourke, 1993; Strang & Rourke, 1985b). The most prevalent types of errors were categorized into the following seven non-mutually exclusive categories (Rourke, 1993; Strang & Rourke, 1985b). Problems with spatial organization led to errors such as the misalignment of numbers in columns and problems with directionality, such as subtracting the minuend from the subtrahead. Problems with visual detail led to errors such as the misreading of mathematical signs and the omission of necessary visual detail in the answer (such as a dollar sign or decimal). Some procedural errors were also committed, with children either adding or missing a necessary step in the arithmetic calculation; at times children applied the wrong procedure (e.g. addition instead of multiplication). Children with NLD also tended to "[fail] to shift psychological set" (Strang & Rourke, 1985, p. 176), such that, when several problems of one type (e.g. addition) were then followed by a different type of arithmetic problem (e.g. subtraction), children with NLD tended to apply the former (incorrect) mathematical operation.

A further mathematical error was attributed to children’s poor graphomotor skills, which led to an inability to read some of the numbers they had written, and also to errors resulting from the overcrowding of large, poorly fashioned numbers into the limited space available on the WRAT protocol (Rourke, 1993; Strang & Rourke, 1985b). Some errors were due to memory problems (i.e. fact retrieval), although these types of errors were not the most common. The
most frequent type of error committed by children with NLD were errors in judgment and reasoning. Children attempted problems which were out of their realm of experience (i.e. too difficult), produced answers that were unreasonable (e.g. the answer to a subtraction question was larger than the minuend), and were unable to generalize their mathematical skills to new problems which differed only slightly from those to which they were accustomed.

**Methodological Considerations for LD Research**

Research in the field of LD has shown that children with LD, as a whole, do not form a homogeneous group (Fletcher, 1985; Lyon, 1985). Subtypes of LD (such as NLD) have been shown to be reliably replicated and to have construct validity (Casey & Rourke, 1991; Cleaver & Whitman, 1998; Fletcher & Satz, 1985; Loveland, Fletcher & Bailey, 1990; Share et al., 1988; Van der Vlugt, 1989; 1991). However, simply reducing the heterogeneity within the LD group as a means of reducing the error variance is not sufficient (Fletcher & Satz, 1985). The heterogeneity between groups must also be considered (Fletcher & Satz, 1985). For example, comparing the performance of children with LD to typical (control) children in a contrasting-groups paradigm is not advisable, since the large variability between the groups (both within and across tasks) may be a confounding factor (Fletcher & Satz, 1985). Differences between these groups may be found very easily simply because the groups naturally differ on a large number of factors, including neuropsychological, cognitive and social factors (Fletcher & Satz, 1985).

Another common source of error variability in LD studies refers to the dependent measures. The construct validity of the dependent measures may not be strong, resulting in measures that tap into several factors, and not only into the factors of interest (Fletcher & Satz, 1985).
In other words, it is clear that real differences between the LD and comparison/control groups may be falsely minimized or exaggerated simply due to the composition of the groups and the purity of the dependent measures. Therefore, in order to find meaningful differences, the measures should be as pure as possible, and the groups being compared should be as homogenous as possible, both within and between groups. The present study attempts to address both methodological concerns. First, unlike previous studies which used measures of visual processing which confounded visuoperceptual and visual-spatial processing at both simple and complex levels, this study attempts to separate out the levels of processing and the types of visual ability assessed. Second, in order to minimize misleading differences between LD and comparison children, this study will compare children with NLD to a very similar group of matched children with LD but who are not NLD. Among other variables, a key factor on which the groups will be matched is the presence of sensorimotor dysfunction which has been reported to be a core feature of NLD (Rourke, 1987). There are children with LD who have sensorimotor dysfunction but who do not fit the NLD profile (Fisher & Murray, 1991; Humphries et al., 1996). Comparing children with NLD and sensorimotor dysfunction to children with LD who also have sensorimotor dysfunction but who are not NLD, will permit a determination of the uniqueness of visual processing deficits associated with NLD. Any differences between the two groups can be attributed to the uniqueness of the NLD syndrome and not to sensorimotor dysfunction in general.
Purposes of the Present Study

The purposes of the present study are trifold. First, this study aims to determine the visual processing profile of a group of young children (mean age of 6 years) with NLD. Their relative performance is examined on four visual tasks which vary in type and complexity of processing (simple visuoperceptual, simple visual-spatial, complex visuoperceptual, and complex visual-spatial abilities). To determine if the profile of children with NLD on these four tasks is unique, the relative performance of a group of children who are LD but not NLD (control LD group; CLD) is also examined.

Second, the present study aims to determine if performance on each of the four visual tasks, as well as the relative difficulty across tasks, of young children with NLD differs from that of the CLD group. This study will systematically compare the two groups of children with LD to each other and to test norms.

Third, this study aims to determine if there is an association between the visual processing and arithmetic performance of young children with NLD. This study will examine correlations between visual processing and math ability in the NLD and CLD groups.

Research Questions, Hypotheses and Justifications

NLD Visual Processing Disability Profile

1. Do children with NLD do more poorly on a complex than simple visual-spatial task, or are their problems in the visual-spatial domain more pervasive, also occurring at the simple level?
Children with NLD will perform significantly weaker on a complex visual-spatial task than on a simple visual-spatial task.

This hypothesis is supported by the empirical studies of the impaired complex visual-spatial processing conducted by Rourke (summarized in Rourke, 1989) and by Humphries et al. (1996), and by the simple visual-spatial processing conducted by Worling (1997). This hypothesis is further supported by clinical experience of children with NLD (Myklebust, 1975). Furthermore, the literature on adults with RHBD found that they performed poorly in areas of complex visual-spatial tasks, such as those involving visual-spatial memory (e.g., King, 1981) and mental rotation (Corballis, 1997).

2. Do children with NLD do more poorly on a complex than simple visuoperceptual task (i.e. pattern analysis), or do they have difficulties in visuoperception even at the simple level?

Children with NLD will perform significantly weaker on a complex visuoperceptual task than on a simple visuoperceptual task.

This is supported both by clinical and empirical evidence that children with NLD have no difficulty on simple visuoperceptual tasks, such as object recognition and visual discrimination (Myklebust, 1975; Strang & Rourke, 1983). This is also supported by the intact visual recognition skills of adults with RHBD (Layman & Greene, 1988) and individuals with DRHS (Weintraub & Mesulam, 1983). Furthermore, children with NLD (Myklebust, 1975; Rourke, 1989) and adults with RHBD (De Renzi & Spinnler, 1966)
have been found to do poorly on complex tasks of visuoperceptual abilities (such as tasks involving visual closure or visual imagery).

3. Is there a difference in the performance of children with NLD between visuoperceptual versus visual-spatial tasks?

   Based on the current NLD literature, it is difficult to make a prediction because when performance of children with NLD on visuoperceptual and visual-spatial tasks is discussed, the distinctions between whether tasks are more simple or complex as described in this thesis are not clear. This study will provide clarification of this point by permitting a comparison of both simple and complex visuoperceptual and visual-spatial tasks.

Comparison of NLD and CLD Groups in Visual Processing

4. Do children with NLD differ from a CLD group only in complex visual-spatial abilities, or do they also differ in simple visual-spatial abilities?

   Children with NLD will perform significantly weaker than the CLD group and normative data on a complex visual-spatial task (involving mental rotation), but not on a simple visual-spatial task (involving visual discrimination).

   This hypothesis is supported by Humphries et al. (1996), who found that children with NLD in this sample performed significantly weaker than a CLD group on a complex visual-spatial task. Children with NLD have also been found to consistently perform significantly poorer than other children with LD on complex visual-spatial tasks, such as
visual-spatial memory (summarized in Rourke, 1989). On a simple visual-spatial task, children with NLD are not expected to differ from other children with LD. This hypothesis is supported by Worling (1997) who found that children with NLD were as capable as verbally-impaired children and non-clinical (control) children in identifying objects in relation to other objects in a simple picture.

5. Are the visual processing problems of children with NLD only visual-spatial in nature, or do they also have problems in other visuoperceptual abilities (pattern analysis), either at a simple and / or complex level when compared to the CLD group?

Children with NLD will perform significantly weaker than CLD children on a complex (e.g. visual closure), but not simple (e.g. visual discrimination), visuoperceptual task.

Studies by Rourke and his colleagues have strongly suggested that children with NLD have severe difficulties with complex visuoperceptual tasks, or tasks which involve visual recognition or discrimination plus some form of higher-order mental operation (imagery, memory, problem solving, etc.; Rourke, 1989). In terms of simple visuoperceptual tasks, children with NLD have performed in the average range on tests of visual discrimination and visual recognition (Myklebust, 1975; Strang & Rourke, 1983). Some research on individuals with RHBD or DRHS has been consistent with these findings (e.g., De Renzi & Spinnler, 1966; Weintraub & Mesulam, 1983).
Overall, this study predicts that the groups will differ on the complex, but not simple, tasks of visuoperceptual and visual-spatial abilities. This is consistent with Myklebust’s (1975) conception of NLD as a disorder which impairs visual functioning only at a complex level of processing. The predictions of this study are based on the available relevant research. However, since the vast majority of the literature in the area of visual perceptual processing of children with NLD has not directly addressed some of the questions of interest in this study (i.e. since empirical support is necessarily limited), the hypotheses of this study regarding performance on simple tasks may be viewed as somewhat tentative.

6. Do children with NLD differ from a CLD group on the relative difficulty of visual-spatial versus visuoperceptual tasks?

   Based on the current literature, no specific directional predictions can be made. Since the difference between these types of processing is unclear for the NLD group (as previously described in Research Question #3), this study, with its inclusion of simple and complex visual processing tasks, will permit a comparison of the relative differences between these aspects of visual processing between the two groups of children with LD.

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Relationship of Visual Processing Abilities of Children with NLD to their Performance in Arithmetic

7. Is there a relationship between the visual processing disabilities of children with NLD and their problems in arithmetic?

   *It is predicted that the areas of most difficulty within the NLD group will*
correlate most strongly with their math difficulties. Therefore, within the NLD group, there will be a stronger positive relationship between the complex tasks (across both visuoperceptual and visual-spatial abilities) and math performance than between the simple visual tasks and math performance.

This hypothesis is supported by the finding that the neuropsychological assets and deficits are related to the mathematical functioning of children with NLD (Rourke, 1993; Strang & Rourke, 1985b). However, this hypothesis must also be viewed as somewhat tentative, since the relationship between visual processing and arithmetic has not yet been investigated in very young children with NLD.
Chapter 2

Method

Participants

The two samples were selected from a database of 103 children collected for a previous treatment study examining the effectiveness of sensorimotor integration therapy in children with sensorimotor problems and LD (ethics approval 84/202; Humphries, Wright, McDougall, & Vertes, 1990; Humphries, Wright, Snider, & McDougall, 1992; Humphries, Snider, & McDougall, 1993). Only pretest scores were used for the purposes of the present study. Subjects were referred to the Child Development Clinic of the Hospital for Sick Children by their family physicians or school boards due to problems with motor coordination and/or any related problems with school or social skills. Participants, the majority of whom were boys, were Caucasian and came from a middle class background. The sample ranged in age from 58-107 months (M=78.54 months; SD=11.48) and the majority of participants were in Kindergarten or Grade 1. Written consent for participation in the study was obtained from the parents of all participants. For the purposes of the original treatment study, participants were identified as having both sensorimotor dysfunction and LD (Humphries et al., 1992).

Grouping Criteria

A child with sensorimotor dysfunction has difficulty interpreting and integrating information received through the different sensory systems (e.g., tactile, visual, proprioceptive)
and consequently has difficulty responding functionally and adaptively to his/her environment (Humphries et al., 1992). Sensorimotor dysfunction was identified according to the following criteria:

I. No primary sensory impairment or physical handicap (such as cerebral palsy, neuromuscular disorder), emotional disturbance, English as a second language, bilingualism, or cultural difference.

II. Evidence of sensorimotor dysfunction according to the following criteria:

   A. any score significantly below the mean (by at least 1 SD) on the Southern California Sensory Integration Test (SCSIT; Ayres, 1980) was considered a "deviant" score;

   B. deviant scores must fall into groupings or clusters, such that two or more deviant scores were required to identify dysfunction in a particular area. For example, for a somatosensory dysfunction to be identified, at least three deviant subtest scores must be present;

   C. clinical observations consistent with clustering results (indicating a particular dysfunction) from the SCSIT;

   D. "positive" clusters were judged to be reliable, as evaluated by therapists who took into account the standard error of measurement for relevant subtests (Clark & Pierce, 1988). For example, the larger the standard error of measurement of a subtest score, the less weight given to that score in identifying a sensorimotor dysfunction cluster, due to the reduced confidence in validly interpreting that score.
III. Children with LD were identified according to the following criteria:

A. A score of at least 85 on VIQ, PIQ or FSIQ of the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974) or the Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Wechsler, 1967). The WISC-R or WPPSI was administered depending on the age of the child.

B. A significant discrepancy (more than one SD) between their highest IQ standard score and their achievement standard score (Reading, Spelling, or Arithmetic) on the Wide Range Achievement Test -Revised (WRAT-R; Jastak & Wilkinson, 1984). Although controversy has developed about this discrepancy approach to identifying LD in recent years (e.g., Siegel, 1989), at the time the original treatment study was conducted, this was the commonly accepted method of diagnosis. The following rule was used to determine which IQ estimate (VIQ, PIQ, or FSIQ) should be compared to academic performance. The FSIQ was used if there was no significant difference between VIQ and PIQ. For the WISC-R, a significant difference refers to at least 12 standard points (Sattler, 1992); for the WPPSI, a significant difference refers to between 9.5-11.2 standard points, depending on the age of the child (Sattler, 1992). When a significant difference emerged between VIQ and PIQ, the highest of these two IQ scores was used (Kaufman, 1979).

IV. For the purposes of the present study, participants were divided into two groups based on their cognitive (IQ) and academic profiles. Inclusionary criteria for the NLD group was comprised of:
A. a significant discrepancy between VIQ and PIQ such that VIQ was higher than PIQ; for the WISC-R, a significant discrepancy at the .05 level refers to a difference of at least 12 standard points (Sattler, 1992) and for the WPPSI, a significant discrepancy at the .05 level refers to a difference of at least 9.5-11.2 standard points, depending on the child’s age (Sattler, 1992);

B. VIQ≥85; and

C. a significant discrepancy between Arithmetic and Reading (a difference of at least 8 standard points is significant at the .05 level) on the WRAT-R (Sattler, 1992).

In conjunction with a diagnosis of sensorimotor dysfunction, these IQ and academic criteria for identifying LD are consistent with how the disorder has been described in the literature (Harnadek & Rourke, 1994).

V. Inclusionary criteria for the CLD Group were comprised of:

A. no significant discrepancy between VIQ and PIQ;

B. FSIQ≥85; and

C. no significant discrepancy between Reading and Arithmetic on the WRAT-R.

Thirteen boys met the criteria for the NLD group. Twenty children (19 boys and 1 girl) met the criteria for the CLD Group. Two children of the CLD group were missing data for one of the dependent measures (Space Visualization subtest of the SCSIT); for these participants, the mean score of the CLD group on this subtest was entered. The participants were then matched (i.e., paired) as closely as possible on the following variables: VIQ, gender, age, father’s education, and type (vestibular dysfunction, tactile and vestibular dysfunction, tactile-based
dyspraxia, vestibular dyspraxia, generalized, tactile dysfunction or tactile and vestibular
dyspraxia) and degree (mild, moderate or severe) of sensorimotor dysfunction. Overall, then, the
two samples were comprised of 26 boys. Of the 13 matched CLD participants, 11 scored below
the 25th percentile (standard score of 90) on one or more of the achievement measures. The most
frequent area of difficulty for the CLD group was Spelling. Of the 13 NLD participants, all
scored below the 25th percentile on one or more of the achievement measures. Their most
frequent areas of difficulty were Arithmetic and Spelling. It is important to note that Spelling
scores in this study are viewed as more reflective of the visual motor integration problems (i.e.
forming letters and copying designs) of both groups of children with sensorimotor problems.

**Instruments**

**Descriptive Measures**

*Southern California Sensory Integration Test (SCSIT)* (Ayres, 1980). The results of
participants on the standardized subtest of the SCSIT, as well as clinical observations by
occupational therapists, were used to identify sensorimotor dysfunction. The SCSIT was
designed to assess the sensorimotor functioning of children aged 4 to 8 with learning,
behavioural, or developmental problems. The subtests were designed to evaluate praxis, tactile,
and vestibular processing, form and spatial perception, and visual-motor coordination. All
subtests require performance-based, not verbal, responses (Ayres, 1980).

The mean test-retest reliability of the subtests of the SCSIT for children aged 4 to 8 is
0.51 (Ayres, 1980). Although this reliability is not high, therapists took the subtest reliabilities
into account when identifying sensorimotor dysfunction; furthermore, SCSIT results had to be
confirmed by clinical observation in order for a child to be identified as having a sensorimotor dysfunction. Factor analytic studies using the SCSIT revealed that this test consistently identified several different patterns of dysfunction (Fisher & Murray, 1991). The 6 most common patterns of sensorimotor dysfunction include: 1. Dyspraxia, or problems in motor planning (also referred to as somatosensory-based dyspraxia); 2. Poor Bilateral Integration, also referred to as vestibular bilateral integration disorder; 3. Tactile Defensiveness, or an aversiveness to being touched; 4. Poor Form and Space Perception, both in the tactile and visual sensory systems; 5. Auditory-Language Dysfunction; and 6. Poor Eye-Hand Coordination (Fisher & Murray, 1991). Ayres stressed that the typologies were not discrete, but could overlap (Ayres, 1972 as cited in Fisher & Murray, 1991). Indeed, a child with several types of sensorimotor dysfunction could be more accurately identified as having Generalized Sensory Integrative Dysfunction (Fisher & Murray, 1991).

Wide Range Achievement Test-Revised (WRAT-R; Jastak & Wilkinson, 1984). Results of participants on the WRAT-R, as well as their IQ estimates, were used to identify LD. The WRAT-R is a standardized, timed, and individually administered brief achievement test which assesses performance on Reading, Spelling and Arithmetic. For the Reading subtest, the child is asked to recognize and name letters and read single words aloud. For the Spelling subtest, the child is asked to copy marks, and write his or her name as well as single words read aloud by the tester. For the Arithmetic subtest, the child is asked to count, read numbers, and solve oral and written math problems or computations. Within each subtest, the items are arranged in increasing order of difficulty. Performance on the WRAT-R is indicative of the level of mastery
of the mechanics of these academic subjects (Sattler, 1992).

The WRAT-R has shown to have excellent test-retest reliability (ranging from $r = 0.94$ to $r = 0.96$) on a sample of young children aged 7 to 10. Strong test-retest reliability (ranging from $r = 0.79$ to $r = 0.90$) was also found on a sample of older children, aged 13-16. Construct validity has also been shown by the increase in raw scores with increasing age. The WRAT-R has also been shown to correlate moderately to high ($r = 0.60$'s to $r = 0.80$'s) with other achievement and ability tests. While the WRAT-R has been revised to the WRAT-III, the WRAT-R was the most updated version available at the time of the original treatment study (Humphries et al., 1992).

**Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974).** The WISC-R is a standardized individually administered intelligence test for children aged 6 years 0 months, to 16 years 11 months. It is comprised of 12 subtests (6 of which contribute to the Verbal Scale or Verbal IQ and the other 6 of which contribute to the Performance Scale or Performance IQ). Altogether, when the results of all the subtests are taken into account, a Full Scale IQ is calculated. Mean reliability coefficients (split-half or test-retest) range from 0.77-0.86 for the Verbal subtests and from 0.70-0.85 for the Performance subtests. The mean reliability of the Full Scale IQ is 0.96; while that of the Verbal IQ is 0.94 and that of the Performance IQ is 0.90. Criterion validity studies have found that the FSIQ correlates highly with other intelligence tests (e.g., $r = 0.78$ with the Standard-Binet: Fourth Edition; $r = 0.72$ with the McCarthy Scales of Children’s Abilities) and more modestly with achievement tests (e.g., $r = 0.56$, $r = 0.59$, $r = 0.52$ with Reading, Spelling and Arithmetic subtests of the WRAT, respectively; $r = 0.71$ with Peabody Individual Achievement Test; see Sattler, 1992).
The **Wechsler Preschool and Primary Scale of Intelligence** (WPPSI; Wechsler, 1967). The WPPSI is a standardized individually administered intelligence test for children aged 3 years 10 months, to 6 years 7 months. It is similar to the WISC-R, but contains subtests which are more suitable for younger children. It is comprised of 11 subtests (6 of which contribute to the Verbal Scale or Verbal IQ and the other 5 of which contribute to the Performance Scale or Performance IQ). As with the WISC-R, a Full Scale IQ may be calculated which takes account of performance on all the subtests. Mean reliability coefficients (split-half or test-retest) range from 0.81-0.85 for the Verbal subtests and from 0.77-0.87 for the Performance subtests. Mean reliabilities are 0.96, 0.94 and 0.93 for the FSIQ, VIQ, and PIQ, respectively. Criterion validity studies have found that the FSIQ correlates highly with the FSIQ of the WISC-R ($r = 0.86$); the VIQ correlates highly with the VIQ of the WISC-R ($r = 0.82$) and the PIQ also correlates well with the PIQ of the WISC-R ($r = 0.73$; Yule, Gold, & Busch, 1982 as cited in Sattler, 1992). The FSIQ of the WPPSI also correlates more modestly with achievement tests (e.g., $r = 0.61$ with the Sentence Reading Test NS6, $r = 0.53$ with Vernon’s Graded Spelling, and $r = 0.72$ with Vernon’s Graded Arithmetic-Mathematics Test (Yule, Gold, & Busch, as cited from Sattler, 1992).

**Dependent Measures**

**Test of Visual-Perceptual Skills (non-motor)** (TVPS; Gardner, 1982). The TVPS is a standardized, individually administered motor-free test which assesses the child’s visual-perceptual abilities across the following areas: visual discrimination, visual memory, visual-
spatial relationships, visual form constancy, visual sequential memory, visual figure-ground and visual closure. It provides a profile of performance across these seven subtests which may help identify the child's relative strengths and weaknesses in visual perceptual processing.

Three subtests from the TVPS were used to examine the questions of interest in the present study. The fourth dependent measure is a subtest from the SCSIT. The four dependent measures are listed according to type and complexity of visual processing skill:

I. Visuoperceptual Ability – Simple

Visual Discrimination Subtest (TVPS). This is a motor-free task in which the child is shown a target form and asked to “Find it among the five forms below” (Gardner, 1982). Hence, the child must match the target form from among a series of forms of various shapes. This task clearly involves a simple visuoperceptual judgment (i.e. making a simple visual discrimination) and does not directly involve discriminating among spatial relationships. The reliability coefficient reported for this subtest ranges from $r = 0.66$ to $r = 0.77$ in young children aged 4- to 8- years-old, with a mean reliability coefficient of $r = 0.72$ (Gardner, 1982).

II. Visuoperceptual Ability – Complex

Visual Closure (TVPS). This is a motor free task in which the child is shown a form and asked to “Look at the figures below which are incomplete (pointing to these forms). [The child is then asked to ] point to the one form that would be like the form above, if completed” (Gardner, 1982). The forms are “incomplete” such that parts of the lines comprising the forms are dashed-not solid. The child, therefore, must discriminate the features of the forms, but in
addition “close” the incomplete form mentally (through imaging) before responding. This task is clearly visuoperceptual, in that it involves pattern analysis (i.e. discrimination and recognition), and also involves complex visual processing (i.e. mental imagery or “closing” the form) but without explicit mental manipulation of visual-spatial relationships. This type of task, which involves mental imagery, is consistent with that which Myklebust believed to be problematic for children with NLD. The reliability coefficient reported for this subtest ranges from $r = 0.72$ to $r = 0.84$ in young children aged four to eight years old, with a mean reliability coefficient of $r = 0.76$ (Gardner, 1982).

III. Visual-Spatial Ability--Simple

Visual-Spatial Relationships (TVPS). This is a motor free task in which the child is presented with five forms (four of which are identical in visual-spatial configuration, and 1 of which is either entirely or only partly presented in a different direction). The child is asked to point to the form which is “going a different way” or which has a part which is “going a different way”. This can be considered as a simple task (i.e. visual discrimination) which explicitly involves a visual-spatial processing component. The reliability coefficient reported for this subtest ranges from $r = 0.70$ to $r = 0.83$ in young children aged four to eight years old, with a mean reliability coefficient of $r = 0.76$ (Gardner, 1982).

IV. Visual-Spatial Ability--Complex

Space Visualization Subtest (SCSIT). This is a motor-free task in which the child is presented with two blocks and must indicate which one fits into the hole in a form board. The
child is prevented from picking up the blocks and practicing which one fits in the hole. As the test progresses in difficulty, the forms are not presented in the same orientation as the hole in the form board, which means the child must mentally rotate the blocks in order to pick the correct block. This subtest assesses spatial perception and, as the items become more difficult, mental manipulation of spatial features (e.g., mental rotation). Clearly, then, this task can be considered as a complex visual-spatial task, since it involves complex mental manipulation (i.e. imagery and rotation) of spatial configurations. This type of task, which involves mental imagery, is consistent with that which Myklebust believed to be problematic for children with NLD. The average test-retest reliability coefficient reported for this subtest in young children aged 4- to 8-years-old is 0.72 (as cited in Humphries et al., 1996).

**Arithmetic Standard Score, Readiness and Calculation Scores, WRAT-R** (Jastak & Wilkinson, 1984). One of the purposes of the present study was to correlate the visual processing abilities of the two groups with arithmetic performance. However, because the children in this sample were so young and those from the NLD group had serious difficulties with arithmetic (and indeed were selected as such), their arithmetic performance was examined at a finer grained level (Franchi, 1998). Specifically, the math performance was recorded as three scores: WRAT-R standard score, WRAT-R Arithmetic Readiness raw score and WRAT-R Written Calculation raw score. Arithmetic Readiness refers to the raw score at the beginning of the WRAT-R Arithmetic subtest in which performance on readiness items for written arithmetic calculation is assessed. Children are asked to count objects, identify numbers and solve simple oral calculation problems.
The Arithmetic Readiness raw score can range from 0 - 15. Arithmetic Calculation refers to the actual written arithmetic calculation (addition, subtraction, etc.) questions on the Arithmetic subtest of the WRAT-R. The Arithmetic Calculation raw score can range from 0 - 40. To calculate the Arithmetic Standard Score, the Arithmetic Readiness raw score is added to the Arithmetic Calculation raw score to get a Total raw score, which may then be converted into a standard score via the standardization tables in the manual (Jastak & Wilkinson, 1984).

**Control for Verbal Mediation.** When administered the TVPS and SCSIT subtests, the children in this study could have used verbal mediation as an aid to successfully complete the tasks. Although the actual usage of verbal mediation was not controlled for during the task administration, whether both groups in this study had equal specific verbal abilities to use the strategy of verbal mediation was evaluated beyond knowing their overall verbal IQ. This is an attempt to control for a possible confounding factor. Specifically, if one group is better able to verbally mediate, then children in that group may have performed better on the dependent measures simply because of this ability, and not due to their visual perceptual abilities per se.

Since the components of verbal mediation are essentially vocabulary and memory for language, the following measures were used as an attempt to control for verbal mediation. The goal was to equate the two groups in their abilities in these two verbal tasks:

I. **Vocabulary Subtest (WISC-R; Wechsler, 1974/WPPSI; Wechsler, 1967).** In this subtest of word knowledge, the child is presented with a series of words which increase in difficulty as the test progresses. The child is asked to explain the meaning of each word aloud.
II. **Producing Model Sentences subtest of the Clinical Evaluation of Language Functions** (CELF; Semel-Mintz & Wiig, 1968). This subtest was administered as a dependent measure in the initial treatment study (Humphries et al., 1992). This is a standardized, individually administered subtest in which the child is read a sentence aloud and asked to repeat the sentence aloud as accurately as possible. The sentences increase in length and complexity as the test progresses.

**Procedure**

*Testing*

All the psychological tests, WISC-R (Wechsler, 1974), WPPSI (Wechsler, 1967), WRAT-R, Jastak & Wilkinson, 1984, CELF (Semel-Mintz & Wiig, 1968), and TVPS (Gardner, 1982) were administered at the Child Development Clinic by psychometrists with Masters degrees in clinical psychology who were supervised by a registered psychologist. The sensorimotor test (SCSIT; Ayres, 1980) was administered by occupational therapists certified in SCSIT administration. Each child was assessed individually in a small assessment room with only the child and tester present. An individual testing session lasted for about 2.5 to 3 hours. All children were administered the four visual processing tests in the same order: SCSIT-Space Visualization followed by TVPS-Visual Discrimination, TVPS-Visual-Spatial Relationships and TVPS-Visual Closure.
Data Analyses

The children in the NLD and CLD Groups were matched (i.e. paired) as closely as possible on age, gender, VIQ, father's education, and type and severity of sensorimotor dysfunction. In order to maximize the effects of the matching procedure (and minimize error variance), paired t-tests were carried out comparing the pairs of children on the background variables and verbal mediation measures.

In order to understand the relative profiles of each of the two groups across the four visual processing tasks (i.e. within group differences), paired t-tests (i.e. repeated measures) were conducted within each group comparing the relative performances on simple, complex, visuoperceptual, and visual-spatial tasks. In order to compare the performance across the four visual processing tasks between the two groups, paired t-tests were conducted across groups on all four tasks, as well as on relative performance across tasks. To gain a more comprehensive understanding of the two profiles of visual perceptual processing, each group’s performance on each visual processing task was also compared to that of the tests’ norms, using one-sample t-tests.

In order to understand the association between the four visual processing tasks and math ability (WRAT-R Arithmetic standard scores, WRAT-R Arithmetic Readiness raw scores and WRAT-R Arithmetic Written Calculation raw scores) scatter plots were graphed for each group; arithmetic performance was graphed as a function of visual processing ability. Since none of the associations seemed curvilinear, Pearson correlation coefficients were conducted between all the visual processing and arithmetic measures. In order to gain a better understanding of the math performance of the two groups, paired samples t-tests (between the groups) were conducted
comparing the WRAT-R Arithmetic Readiness and WRAT-R Written Calculation raw scores. The Total WRAT Arithmetic score had already been compared in identifying the two groups.
Chapter 3

Results

Demographic, Background and Descriptive Variables

Children’s age ranged from 61 - 105 months for the NLD Group and from 58 - 98 months for the CLD Group. Between-group comparisons of the demographic variables (age and SES), group identification test measures (WISC-R/WPPSI VIQ and PIQ, and WRAT-R Reading and Arithmetic Scores), and other important background variables (degree of sensorimotor dysfunction, WRAT-R Spelling score, CELF Producing Model Sentences score and WISC-R/WPPSI Vocabulary score) are summarized in Table 1. Mean FSIQ for the CLD Group is also reported in Table 1; mean FSIQ is not reported for the NLD Group because the significant discrepancy between their VIQ and PIQ scores renders interpretation of their FSIQ invalid (Myklebust, 1975; Sattler, 1992).

There were no significant differences between the groups on age, Verbal IQ, or degree of sensorimotor dysfunction. SES was computed 3 ways, each of which did not differ significantly between groups: fathers’ education, mothers’ education, and highest occupation in the family as rated by Blishen’s Canadian SES index (Blishen, Carroll, & Moore, 1987). Parents’ education was coded according to the following ordinal scale: 1 = less than high school; 2 = some high school; 3 = high school diploma; 4 = some college / university; 5 = college / university graduate; and 6 = post-graduate / professional degree. For the SES index of highest occupation in the family, each parent’s occupation was assigned an SES index, as per Blishen et al. (1987). The
higher index of the two was then selected for comparative analyses. In cases where only one
parent was working the SES index of that parent was included in the analyses. The three SES
indices (mothers' education, fathers' education and highest occupation in the family) were
missing for two pairs of participants.

On the measures of academic performance, the two groups did not significantly differ, as
expected, on WRAT-R Reading standard scores. However, as expected, the NLD group scored
significantly lower than the CLD group on WRAT-R Arithmetic Standard Scores ($p \leq .0001$).
The NLD group also scored significantly lower than the CLD group on WRAT-R Spelling
Standard Scores ($p \leq .001$). On PIQ, the NLD group performed significantly lower than the CLD
group, as expected ($p \leq .0001$). (See Table 1.)

To evaluate whether the two groups had equal ability to use verbal mediation as a strategy
to complete the visual processing tasks successfully, the groups were compared on sentence
memory (CELF-Producing Model Sentences) and word knowledge (WISC-R / WPPSI
Vocabulary). There were no significant differences between the groups on these subtests (see
Table 1). One pair of participants had missing data for the CELF-Producing Model Sentences
subtest, and was therefore not included in that analysis. While the extent to which the two
groups actually used the strategy of verbal mediation to help complete the visual processing tasks
cannot be determined by these results, it can be concluded that both groups had equal ability to
use this strategy, thereby minimizing its potential confounding effects.
Table 1

Paired-Samples t-tests Comparing Demographic Variables, Background Variables, and Descriptive Measures

<table>
<thead>
<tr>
<th>Demographic Variable / Independent Measure</th>
<th>NLD$^a$</th>
<th>CLD$^b$</th>
<th>df</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mo.)</td>
<td>M 76.54, SD 13.28</td>
<td>M 78.69, SD 11.43</td>
<td>12</td>
<td>-1.04</td>
</tr>
<tr>
<td>Mother's Highest Level of Education$^c$</td>
<td>M 4.36, SD 1.43</td>
<td>M 3.64, SD 1.21</td>
<td>10$^d$</td>
<td>1.31</td>
</tr>
<tr>
<td>Father's Highest Level of Education$^c$</td>
<td>M 4.45, SD 1.51</td>
<td>M 4.09, SD 1.14</td>
<td>10$^d$</td>
<td>0.80</td>
</tr>
<tr>
<td>Highest Occupation in the Family$^e$</td>
<td>M 55.84, SD 19.32</td>
<td>M 52.63, SD 8.64</td>
<td>10$^d$</td>
<td>0.48</td>
</tr>
<tr>
<td>Degree of Sensorimotor Dysfunction$^f$</td>
<td>M 2.00, SD 0.91</td>
<td>M 1.77, SD 0.73</td>
<td>12</td>
<td>0.82</td>
</tr>
<tr>
<td>VIQ (WISC-R/WPPSI)$^g$</td>
<td>M 104.46, SD 11.44</td>
<td>M 101.69, SD 6.70</td>
<td>12</td>
<td>1.36</td>
</tr>
<tr>
<td>PIQ (WISC-R/WPPSI)$^g$</td>
<td>M 87.08, SD 8.47</td>
<td>M 100.00, SD 7.34</td>
<td>12</td>
<td>-6.47***</td>
</tr>
<tr>
<td>FSIQ$^h$ (WISC-R/WPPSI)$^g$</td>
<td>M --, SD 7.22</td>
<td>M 100.62, SD--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Reading (WRAT-R)$^g$</td>
<td>M 93.46, SD 10.41</td>
<td>M 92.31, SD 5.53</td>
<td>12</td>
<td>0.43</td>
</tr>
<tr>
<td>Spelling (WRAT-R)$^g$</td>
<td>M 68.85, SD 14.88</td>
<td>M 87.69, SD 12.16</td>
<td>12</td>
<td>4.18**</td>
</tr>
<tr>
<td>Arithmetic (WRAT-R)$^g$</td>
<td>M 77.54, SD 11.30</td>
<td>M 91.85, SD 5.40</td>
<td>12</td>
<td>-4.96***</td>
</tr>
</tbody>
</table>

Table 1 continued on next page...
Table 1 (continued)

Demographic Variables, Background Variables, and Descriptive Measures

<table>
<thead>
<tr>
<th>Demographic Variable / Independent Measure</th>
<th>NLD(^a)</th>
<th>CLD(^b)</th>
<th>df</th>
<th>(t) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producing Model Sentences (CELF)(^c)</td>
<td>M</td>
<td>32.50</td>
<td>29.50</td>
<td>11(^d)</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>11.63</td>
<td>10.83</td>
<td></td>
</tr>
<tr>
<td>Vocabulary (WISC-R/ WPPSI)(^f)</td>
<td>M</td>
<td>11.46</td>
<td>10.38</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.90</td>
<td>2.10</td>
<td></td>
</tr>
</tbody>
</table>

Note. NLD Group = Children with Nonverbal Learning Disability; CLD = Control children with learning disabilities that are not NLD.

\(^a\)\(n = 13\). \(^b\)\(n = 13\). \(^c\)Parent education was coded as: 1 = less than high school; 2 = some high school; 3 = high school diploma; 4 = some college / university; 5 = college / university graduate; and 6 = post-graduate / professional degree. \(^d\)There are fewer degrees of freedom in these analyses due to missing data. Two pairs of participants had missing data for parents' highest level of education and occupations. One pair of participants had missing data for the Producing Model Sentences subtest. \(^e\)Parents' occupations were coded according to Blishen et al.'s (1987) SES index. The highest SES index between parents is reported. \(^f\)Degree of sensorimotor dysfunction was coded as: 1 = mild; 2 = moderate, and 3 = severe. \(^g\)Standard scores. \(^h\)FSIQ for the NLD Group is not reported, since the significant discrepancy between the VIQ and PIQ renders interpretation of the FSIQ inappropriate (Sattler, 1992). \(^i\)Raw scores are reported, because the only standardized scores available were grade equivalents and percentile scores.

**\(p \leq .001\). ****\(p \leq .0001\).
Frequency distributions of background variables which are quantitative in nature are reported in Table 2. Both groups were composed of 13 boys, which is not surprising given the large percentage of boys (87%) in the original referred sample (Humphries et al., 1992; Humphries et al., 1996). The sample in this study was distributed across seven types of sensorimotor dysfunction (vestibular dysfunction, tactile and vestibular dysfunction, tactile-based dyspraxia, vestibular dyspraxia, generalized dysfunction, tactile dysfunction, and tactile and vestibular dyspraxia) and across three levels of severity (mild, moderate, and severe). The frequency distributions of background variables reported in Table 2 include: type and degree of sensorimotor dysfunction, school placement and interventions outside of school which the participants have undergone. The reporting of these background variables is meant to be descriptive in nature only.

Level of Significance

Because of the multiple comparisons in this study and the possibility of increasing the occurrence of Type I error, the level of significance was set at the more conservative level of .01 rather than the traditional level of .05. This more conservative alpha level was expected to control for any significant results which are spurious in nature (Howell, 1982).
### Table 2

**Frequency Distributions of Demographic and Background Variables**

<table>
<thead>
<tr>
<th>Demographic or Background Variable</th>
<th>NLD&lt;sup&gt;a&lt;/sup&gt;</th>
<th>CLD&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Sensorimotor Dysfunction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vestibular Dysfunction</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Tactile and Vestibular Dysfunction</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Tactile-based Dyspraxia</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Vestibular Dyspraxia</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Generalized</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Tactile Dysfunction</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tactile and Vestibular Dyspraxia</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>Degree of Sensorimotor Dysfunction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Moderate</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Severe</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>School Placement&lt;sup&gt;c&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular Class (without supports)</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Withdrawal/Teacher Assistant</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Special Education (Part-time)</td>
<td>0</td>
<td>1</td>
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<td>Special Education (Full-time)</td>
<td>0</td>
<td>1</td>
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<tr>
<td><strong>Interventions Outside of School&lt;sup&gt;c&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
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<tr>
<td>Tutoring</td>
<td>0</td>
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<tr>
<td>Speech/Language Therapy</td>
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<td>1</td>
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<tr>
<td>Behaviour Therapy</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ritalin-Previous or Current Use</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

**Note.** NLD Group = Children with Nonverbal Learning Disability; CLD = Control children with learning disabilities that are not NLD.

<sup>a</sup>n = 13. <sup>b</sup>n = 13. <sup>c</sup>Two participants from the CLD group and 1 participant from the NLD group
had missing data.

**Visual Processing Disability Profiles (Comparisons Within Each Group)**

Means, standard deviations and repeated measures t-tests comparing performance on the four visual processing tasks within each group are reported in Tables 3 and 4. For the NLD Group, there was no significant difference when comparing the group’s performance on visuoperceptual abilities (simple versus complex tasks), or on visual-spatial abilities (simple versus complex tasks). On simple tasks (visuoperceptual versus visual-spatial tasks), the NLD group performed significantly lower on the visual-spatial task than on the visuoperceptual task, \( p \leq .001 \). On the complex tasks (visuoperceptual versus visual-spatial tasks), the NLD group showed no significant difference. On comparisons cutting across both the type and complexity of the visual processing tasks, the NLD group performed significantly lower on the complex visual-spatial task than on the simple visuoperceptual task, \( (p \leq .001) \), but did not differ on the simple visual-spatial versus complex visuoperceptual tasks. (See Table 3.)

For the CLD Group, there was a significant difference when comparing the group’s performance on visuoperceptual ability (simple versus complex) tasks \( (p \leq .006) \), with the group scoring lower on the complex task. There was no significant difference when comparing the CLD group’s performance on visual-spatial ability (simple to complex) tasks. Across simple tasks and across complex tasks (i.e., visuoperceptual vs. visual-spatial abilities), there were no significant differences within the CLD group. On comparisons cutting across both the type and complexity of the visual processing tasks, the CLD group did not differ in performance. (See Table 4.)
Table 3

Profile of Visual Processing Measures Within the NLD\textsuperscript{a} Group

<table>
<thead>
<tr>
<th>Visual Processing Measures</th>
<th>M</th>
<th>SD</th>
<th>df</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visuoperceptual (Simple versus Complex)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Discrimination</td>
<td>11.15</td>
<td>3.76</td>
<td>12</td>
<td>2.59</td>
</tr>
<tr>
<td>TVPS Visual Closure</td>
<td>9.00</td>
<td>3.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual-Spatial (Simple versus Complex)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual-Spatial Relationships</td>
<td>7.69</td>
<td>3.28</td>
<td>12</td>
<td>1.04</td>
</tr>
<tr>
<td>SCSIT Space Visualization\textsuperscript{b}</td>
<td>6.72</td>
<td>2.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple (Visuoperceptual vs. Visual-Spatial)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Discrimination</td>
<td>11.15</td>
<td>3.76</td>
<td>12</td>
<td>4.43**</td>
</tr>
<tr>
<td>TVPS Visual-Spatial Relationships</td>
<td>7.69</td>
<td>3.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex (Visuoperceptual vs. Visual-Spatial)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Closure</td>
<td>9.00</td>
<td>3.67</td>
<td>12</td>
<td>2.02</td>
</tr>
<tr>
<td>SCSIT Space Visualization\textsuperscript{b}</td>
<td>6.72</td>
<td>2.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Visuoperceptual vs. Complex Visual-Spatial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Discrimination</td>
<td>11.15</td>
<td>3.76</td>
<td>12</td>
<td>4.71**</td>
</tr>
<tr>
<td>SCSIT Space Visualization\textsuperscript{b}</td>
<td>6.72</td>
<td>2.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Visual-Spatial vs. Complex Visuoperceptual</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Spatial Relationships</td>
<td>7.69</td>
<td>3.28</td>
<td>12</td>
<td>1.84</td>
</tr>
<tr>
<td>TVPS Visual Closure</td>
<td>9.00</td>
<td>3.67</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. NLD Group = Children with Nonverbal Learning Disability

\textsuperscript{a}n=13. \textsuperscript{b}The scores of the SCSIT Space Visualization subtest were converted to a scale commensurable to that of the TVPS subtests, in which the $M=10$ and $SD=3$ in the normal
population. Since the SCSIT Space Visualization scores are \( z \) scores (with a \( M \) of 0 and \( SD \) of 1 in the normal population), they were converted into a commensurable scale by the following formula: \( x = 3z + 10 \), where \( x \) is the unknown (converted) score, 3 is the standard deviation in the normal population, \( z \) is the SCSIT score, and 10 is the mean in the normal population (Gravetter & Wallnau. 1988).

\(* * p \leq .001\)
Table 4

Profile of Visual Processing Measures Within the CLD* Group

<table>
<thead>
<tr>
<th>Visual Processing Measures</th>
<th>M</th>
<th>SD</th>
<th>df</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visuoperceptual (Simple to Complex)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Discrimination</td>
<td>11.77</td>
<td>3.59</td>
<td>12</td>
<td>3.29*</td>
</tr>
<tr>
<td>TVPS Visual Closure</td>
<td>8.54</td>
<td>1.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual-Spatial (Simple to Complex)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual-Spatial Relationships</td>
<td>9.38</td>
<td>3.31</td>
<td>12</td>
<td>0.52</td>
</tr>
<tr>
<td>SCSIT Space Visualization</td>
<td>8.90</td>
<td>1.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple (Visuoperceptual vs. Visual-Spatial)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Discrimination</td>
<td>11.77</td>
<td>3.59</td>
<td>12</td>
<td>2.10</td>
</tr>
<tr>
<td>TVPS Visual-Spatial Relationships</td>
<td>9.38</td>
<td>3.31</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Complex (Visuoperceptual vs. Visual-Spatial)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Closure</td>
<td>8.54</td>
<td>1.85</td>
<td>12</td>
<td>-0.47</td>
</tr>
<tr>
<td>SCSIT Space Visualization</td>
<td>8.90</td>
<td>1.75</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Simple Visuoperceptual vs. Complex Visual-Spatial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Discrimination</td>
<td>11.77</td>
<td>3.59</td>
<td>12</td>
<td>2.27</td>
</tr>
<tr>
<td>SCSIT Space Visualization</td>
<td>8.90</td>
<td>1.75</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Simple Visual-Spatial vs. Complex Visuoperceptual</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Spatial Relationships</td>
<td>9.38</td>
<td>3.31</td>
<td>12</td>
<td>-0.92</td>
</tr>
<tr>
<td>TVPS Visual Closure</td>
<td>8.54</td>
<td>1.85</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

Note. CLD Group = Control children with learning disabilities that are not NLD.

*a_n = 13. b_The scores of the SCSIT Space Visualization subtest were converted to a scale commensurable to that of the TVPS subtests, as explained in Table 3.

*p ≤ .01
Comparisons of Visual Processing Abilities Between the NLD and CLD Groups

Means, standard deviations and paired samples t-tests comparing the performance on each of the 4 visual processing tasks between the two groups are reported in Table 5. In terms of the Visuoperceptual measures, the two groups did not differ on the Simple level or the Complex level. In terms of the Visual-Spatial measures, the two groups did not differ on the Simple level task, but did significantly differ on the Complex level ($p \leq .009$), as was previously reported by Humphries et al. (1996). The NLD Group scored lower than the CLD Group. (See Table 5.)

Comparisons of the relative difficulty of the visuoperceptual versus visual-spatial tasks between the NLD and CLD groups is reported in Table 6. The two groups did not significantly differ on any comparisons. (See Table 6.)

Comparison of the NLD and CLD Groups' Visual Processing Scores to Test Norms

Means, standard deviations, and one-sample t-tests comparing the performance of each group on each visual processing task with that of the normative group are reported in Table 7. No significant differences were found between the NLD Group and the normative group on three visual processing tasks: TVPS Visual Discrimination, TVPS Visual Closure, and TVPS-Visual-spatial Relationships. On SCSIT Space Visualization, however, the NLD Group scored significantly lower than the normative group ($p \leq .0001$). No significant differences were found between the CLD Group and the normative group on all four visual processing tasks. (See Table 7.)
### Table 5
Comparison of Visual Processing Measures Between Groups

<table>
<thead>
<tr>
<th>Visual Processing Measure</th>
<th>NLD&lt;sup&gt;a&lt;/sup&gt;</th>
<th>CLD&lt;sup&gt;b&lt;/sup&gt;</th>
<th>df</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visuoperceptual –Simple</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS-Visual Discrimination</td>
<td>M    11.15</td>
<td>11.77</td>
<td>12</td>
<td>-0.376</td>
</tr>
<tr>
<td></td>
<td>SD    3.76</td>
<td>3.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Visuoperceptual-Complex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS-Visual Closure</td>
<td>M    9.00</td>
<td>8.54</td>
<td>12</td>
<td>0.448</td>
</tr>
<tr>
<td></td>
<td>SD    3.67</td>
<td>1.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Visual-Spatial –Simple</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS-Visual-Spatial Relationships</td>
<td>M    7.69</td>
<td>9.38</td>
<td>12</td>
<td>-1.22</td>
</tr>
<tr>
<td></td>
<td>SD    3.28</td>
<td>3.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Visual-Spatial -Complex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCSIT-Space Visualization</td>
<td>M    6.72</td>
<td>8.90</td>
<td>12</td>
<td>-3.13*</td>
</tr>
<tr>
<td></td>
<td>SD    2.40</td>
<td>1.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>Note.</sup> NLD Group = Children with Nonverbal Learning Disability; CLD = Control children with learning disabilities that are not NLD.

<sup>a</sup>n = 13.  <sup>b</sup>n = 13.  <sup>c</sup>The scores of this subtest were converted to a scale commensurable with that of the TVPS subtests, in which the M = 10 and SD = 3 in the normal population, as explained in Table 3. The converted scores, as presented in the table, allow comparison with the TVPS scores. The original SCSIT mean and standard deviation for the NLD group was -1.09 and 0.80, respectively and -0.37 and 0.58 for the CLD group, respectively. A paired samples t-test using test using the original SCSIT scores rendered the same results (p ≤ .01).

<sup>*p ≤ .01.</sup>
Table 6

Relative Performances Across Visual Processing Tasks for the NLD and CLD Groups

<table>
<thead>
<tr>
<th>Group and Processing Measure</th>
<th>NLD(^a)</th>
<th>CLD(^b)</th>
<th>df</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Visuoperceptual minus Simple</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Spatial Abilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>3.46</td>
<td>2.38</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.82</td>
<td>4.09</td>
<td></td>
</tr>
<tr>
<td>Complex Visuoperceptual minus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Visual Spatial Abilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>2.28</td>
<td>-0.36</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>4.07</td>
<td>2.82</td>
<td></td>
</tr>
<tr>
<td>Simple Visuoperceptual minus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Visual Spatial Abilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>4.43</td>
<td>2.87</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>3.39</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>Complex Visuoperceptual minus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple Visual Spatial Abilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1.31</td>
<td>-0.85</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.56</td>
<td>3.31</td>
<td></td>
</tr>
</tbody>
</table>

Note. NLD Group = Children with Nonverbal Learning Disability; CLD = Control children with learning disabilities that are not NLD; there were no significant differences across all comparisons.

\(^a\)\(n = 13\). \(^b\)\(n = 13\).
Table 7

Comparison of NLD and CLD Performance to Normative Performance$^a$

<table>
<thead>
<tr>
<th>Group &amp; Visual Processing Measures</th>
<th>NLD Group$^b$</th>
<th>CLD Group$^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Visuoperceptual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple--TVPS Visual Discrimination</td>
<td>11.15</td>
<td>3.76</td>
</tr>
<tr>
<td>Complex--TVPS Visual Closure</td>
<td>9.00</td>
<td>3.67</td>
</tr>
<tr>
<td>Visual-Spatial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple--TVPS Visual-Spatial Relations</td>
<td>7.69</td>
<td>3.28</td>
</tr>
<tr>
<td>Complex--SCSIT Space Visualization</td>
<td>6.72</td>
<td>2.40</td>
</tr>
</tbody>
</table>

Note. NLD Group = Children with Nonverbal Learning Disability; CLD = Control children with learning disabilities that are not NLD.

$^a$The $M$ and $SD$ of normative samples are 10 and 3, respectively, for each TVPS subtest and for the (converted) SCSIT Space Visualization Subtest. $^b_n = 13$. $^c_n = 13$.

$***p \leq .0001.$
Relationship of Visual Processing Abilities to Performance in Arithmetic

Pearson correlations between the Arithmetic measures (WRAT-R Arithmetic Standard Score, WRAT-R Arithmetic Readiness Raw Score, and WRAT-R Arithmetic Written Calculation Raw Score) and the visual processing measures (TVPS-Visual Discrimination, TVPS-Visual Closure, TVPS-Visual-Spatial Relationships, and SCSIT Space Visualization) for both groups are reported in Table 8. For the NLD Group, significant correlations were found between TVPS Visual Discrimination and Arithmetic Written Calculation \( (r = 0.69, p = .009) \); TVPS Visual Closure and Arithmetic Readiness \( (r = 0.72, p = .006) \); TVPS Visual-Spatial Relationships and Arithmetic Readiness \( (r = 0.76, p = .003) \); TVPS Visual-Spatial Relationships and Arithmetic Written Calculation \( (r = 0.69, p = .009) \); and SCSIT Space Visualization and Arithmetic Standard Score \( (r = 0.72, p = .005) \). For the CLD Group, there were no significant correlations among any of the visual processing and arithmetic performance variables. Means, standard deviations and paired samples t-tests comparing the WRAT-R Arithmetic Readiness Raw Score and the WRAT-R Arithmetic Written Calculation Raw Score between the two groups are reported in Table 9. The two groups differed significantly on Arithmetic Readiness \( (p \leq .002) \) but did not on Arithmetic Written Calculation. (See Table 9.)
Table 8

Pearson Correlations Among Visual Processing Measures and Arithmetic Performance for the NLD and CLD Groups

<table>
<thead>
<tr>
<th>Visual Processing Measure</th>
<th>Arithmetic Standard Score&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Arithmetic Readiness&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Arithmetic Written Calculation&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NLD Group&lt;sup&gt;c&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Discrimination</td>
<td>0.41</td>
<td>0.53</td>
<td>0.69*</td>
</tr>
<tr>
<td>TVPS Visual Closure</td>
<td>0.36</td>
<td>0.72*</td>
<td>0.62</td>
</tr>
<tr>
<td>TVPS Visual-Spatial Relationships</td>
<td>0.24</td>
<td>0.76*</td>
<td>0.69*</td>
</tr>
<tr>
<td>SCSIT Space Visualization</td>
<td>0.72*</td>
<td>0.12</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>CLD Group&lt;sup&gt;d&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVPS Visual Discrimination</td>
<td>-0.33</td>
<td>0.33</td>
<td>0.03</td>
</tr>
<tr>
<td>TVPS Visual Closure</td>
<td>-0.24</td>
<td>-0.12</td>
<td>-0.11</td>
</tr>
<tr>
<td>TVPS Visual-Spatial Relationships</td>
<td>-0.03</td>
<td>0.34</td>
<td>0.41</td>
</tr>
<tr>
<td>SCSIT Space Visualization</td>
<td>0.20</td>
<td>-0.03</td>
<td>0.29</td>
</tr>
</tbody>
</table>

*Note.* NLD Group = Children with Nonverbal Learning Disability; CLD = Control children with learning disabilities that are not NLD.

<sup>a</sup>WRAT-R Arithmetic subtest.  <sup>b</sup>WRAT-R Arithmetic subtest raw test scores.  <sup>c</sup>n = 13.  <sup>d</sup>n = 13.

*<sup>p</sup> ≤ .01
Table 9

Comparison of Arithmetic Readiness and Written Calculation Measures Between the NLD and CLD Groups

<table>
<thead>
<tr>
<th>Arithmetic Measure</th>
<th>NLD(^a)</th>
<th>CLD(^b)</th>
<th>df</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arithmetic Readiness Raw Score(^cd)</td>
<td>9.69</td>
<td>12.38</td>
<td>12</td>
<td>-3.84*</td>
</tr>
<tr>
<td>M</td>
<td>2.78</td>
<td>2.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Arithmetic Written Calculation\(^c\)

| M | 1.15 | 2.08 |
| SD | 2.08 | 2.22 |

Note. NLD Group = Children with Nonverbal Learning Disability; CLD = Control children with learning disabilities that are not NLD.

\(^a_n = 13. \quad ^b_n = 13. \quad ^cWRAT-R Arithmetic Subtest raw test scores. \quad ^dMaximum value possible is 15.\)

\(^*p \leq .01\)
Chapter 4

Discussion

The present results indicate that the visual processing abilities of children with NLD are characterized by greater difficulty on visual-spatial tasks than in making basic visuoperceptual discriminations. Their TVPS Visual Discrimination score was well within the average range, while their TVPS Visual Spatial Relationships score fell just within the lower end of the average range and their SCSIT Space Visualization score was below the average range at a level of clinical significance. Their relative greater difficulty in making visual-spatial interpretations occurs regardless of whether they do or do not have to engage in the mental manipulation of spatial content, as evidenced by their lower scores on the both the SCSIT Space Visualization and TVPS Visual Spatial Relationships subtests. The greater difficulty experienced by children with NLD on visual-spatial tasks is unique to them. It is not found in the profile of children in the CLD group, who have other types of LD and who also have sensorimotor dysfunction. The profile of the children in the CLD group only shows a difference between the TVPS Visual Closure and Visual Discrimination abilities with scores on both subtests falling within the average range. Children with NLD are also distinguished from both the CLD group, as well as in a comparison with test norms, by their lower scores specifically on the SCSIT Space Visualization subtest, or in their ability to mentally manipulate spatial relationships. The functional relevance of these findings is demonstrated by the fact that various aspects of the visual processing abilities of children with NLD are strongly associated with both their
calculation and weaker readiness abilities in arithmetic on the WRAT-R. Their space visualization difficulties, in particular, are strongly related to their overall poorer arithmetic abilities compared to children their own age. Among the CLD children who, as a group, perform better in arithmetic, no such associations with visual processing are found.

Distinguishing between performance on visual-spatial tasks and those that do not involve a visual-spatial component seems to be a key factor in understanding the profile of young children with NLD. Despite the absence of differences for these children between their performance on simple versus complex tasks within each of the visuoperceptual and visual-spatial areas, they do show a performance difference across these two areas. Their poorer scores on both spatial tasks, in comparison to their strong average visual discrimination skills, testifies to their spatial difficulties. The finding that this profile was unique to them compared to the control group of children with LD, and that the mental manipulation of spatial content distinguished their performance from that of both the clinical control group and normative test performance, further confirms the need to assess the extent of spatial difficulties among young children with NLD. Although much of the literature on the visual processing abilities of children with NLD was focused either directly or indirectly on whether their performance is better on what have been referred to as “simple” versus “complex” tasks, the present results suggest that this distinction can be made more meaningful by also giving greater consideration to the types of processing involved (e.g. visual discrimination versus visual-spatial/space visualization abilities).

Despite the fact that Rourke (1989) does not distinguish between the performance of children with NLD on more simple discrimination versus higher-order visual processing tasks, apparently suggesting that both levels of processing can be a problem, the present results suggest
that discrimination is not a difficulty. It is the higher level mental manipulation of spatial content that presents a problem. These results are more in keeping with Myklebust’s (1975) clinically-based contention that children with NLD have more difficulty with more complex higher order cognitive abilities (e.g. mental imagery) than with basic visual processing abilities.

The findings of the current study have important implications for the identification and treatment of very young children with NLD. This study suggests that their visual discrimination abilities are intact and not a primary deficit of NLD. Identification and intervention with children with NLD targeted at impaired basic visual processing abilities such as discrimination, therefore, may not be necessary. Mental imaging of visual-spatial relationships, on the other hand, seems to be a significant and unique problem for young children with NLD. Therefore, impaired performance on a standardized mental rotation task (Space Visualization) may be an important part of the specific diagnostic criteria of NLD in young children, although this finding needs to be replicated and further investigated before any firm conclusions may be drawn.

Currently, most children with NLD are identified late in childhood, when the opportunity to remediate the primary deficits early has passed (Rourke, 1987; 1989). Identifying children with NLD at a young age, when they are just beginning to manifest the syndrome and before the deficits have an opportunity to worsen, is believed to be very important for a better prognosis (Rourke, 1989). Also, the addition of a specific intervention component, aimed at improving this type of mental imagery, to a comprehensive treatment approach (Rourke, 1989; Strang & Rourke, 1985) may improve the prognosis of children with NLD.

Consistent with Strang and Rourke’s (1985) findings that the arithmetic errors of NLD children are related to their specific neuropsychological deficits, the current study found that the
overall math ability of young children with NLD was strongly related to their performance on the visual-spatial task involving mental rotation (Space Visualization); no significant relationships were found between visual processing and arithmetic performance for the CLD group. One explanation for this difference between groups is the possibility that the aspects of visual processing assessed in this study are more important for the beginning stages of arithmetic acquisition. Because the CLD group is more advanced in their math abilities (they were selected as such), the visual processes assessed may not be as important for success in arithmetic in this more advanced group. Other factors that were not assessed in this study (e.g. language) may correlate more strongly with performance in the more advanced arithmetic tasks for the CLD group. The fact that visual-spatial abilities correlated with math skills in the young children with NLD is consistent with past studies (Geary, 1993; Jordan et al., 1995) and contradicts the argument that visual-spatial abilities are not important for children just beginning to learn math (Denckla, 1991), at least for boys with NLD.

The majority of the difference between the two LD groups on arithmetic performance can clearly be attributed to their performance on the readiness section, in which the NLD group was found to have many more difficulties than the CLD group. (The two groups did not differ in the Written Calculations section of the WRAT-R seemingly due to a floor effect.) This finding has important implications for academic intervention for young children with NLD. It suggests that children with NLD, if they can be identified very young, should be given intensive direct instruction in developing the precursor skills necessary for learning the mechanics of arithmetic. Without receiving more intensive training in visual processing skills associated with arithmetic than is usually the case, young children with NLD may begin instruction in mechanical
arithmetic before they are ready, further compounding their delay, confusion, and frustration with math. A caveat here is that one must be careful in interpreting correlations, since a significant correlation does not necessarily equal causation (Gravetter, 1988). This is especially important in the area of learning disabilities, in which previous interventions based on a causative interpretation of correlational evidence have been unsuccessful (Willows, 1991). Nevertheless, it is hoped that this study will serve as a catalyst for future studies to examine more closely the causative role of visual processing in NLD, especially as it relates to arithmetic performance.

Limitations

Limitations of the current study include the fact that inclusion into the NLD group did not include a spelling-arithmetic discrepancy, as has been suggested by Rourke (1989). However, careful consideration of the sample (including their young age) justified not including spelling as an inclusionary NLD criterion. First, Humphries et al. (1996) found that children with NLD differed significantly from an LD group without NLD on visual-motor integration. Hence their ability to form letters which would be legible, both in terms of proper letter formation and in terms of proper spacing, would most likely be impaired. Indeed, Rourke's theory of NLD describes the graphomotor problems of young children with NLD as very poor. Only with repetitive practice do their graphomotor abilities improve to average levels (Rourke, 1989). Second, some studies examining the NLD/DRHS syndrome have not included spelling in the NLD inclusionary criteria (e.g., Weintraub & Mesulam, 1983). Third, in a study examining the relative discriminant power of NLD characteristics, spelling ability did not appear to be a particularly important in discriminating the NLD group from the other LD group (Harnadek &
Rourke, 1994). For all these reasons, but particularly the young age of the children in this sample, it was decided not to include average written spelling ability as part of the NLD inclusionary criteria.

Another limitation of the current study is the size and composition of the samples. With more participants, perhaps some of the findings which only approached significance would have actually reached significance at the $p \leq .01$ level. Future studies with larger samples can assess the reliability of the current findings in young children with NLD. Also, it is not possible to generalize these findings to young girls with NLD, since both LD samples were comprised only of boys. This may reflect a referral bias, such that more boys than girls are referred to a developmental clinic due to motor coordination problems, academic problems and/or social difficulties. Alternatively, the lack of young girls with NLD may reflect the "true state of affairs"; it is possible that the onset of NLD in girls occurs later in childhood. This supposition is consistent with exploratory research that has found that the right hemisphere may develop more slowly in girls than in boys (see Semrud-Clikeman & Hynd, 1990) and with research that has questioned the validity of NLD in girls (Share et al., 1988). Furthermore, it may be harder to identify this syndrome in young girls due to a combination of both reasons (referral bias and neurodevelopmental pattern in girls).

Furthermore, the inclusionary criteria of LD in the CLD sample was based on the IQ-achievement discrepancy definition of LD, which was the commonly accepted practice at the time of the original treatment study (Humphries et al., 1992). However, there has since been much criticism of this discrepancy-based approach in the literature (see Fletcher et al., 1998; Humphries & Bone, 1990; Siegel, 1989). The use of the discrepancy-based definition of the LD
group in the current study poses a limitation on the interpretation and generalizability of the present results. As a group, the comparison children were bordering the clinical range on the three achievement measures, with their lowest performance in Spelling, consistent with their problems in sensorimotor functioning. However, on an individual basis, the majority of the children in the comparison group (about 85%) scored in the clinical range (below the 25th percentile, or standard score of 90) on at least one achievement measure, which is consistent with more recent achievement-based definitions of LD (e.g., Siegel, 1989). Future research comparing the NLD syndrome to other learning disabilities should use the more recent achievement-based definitions of LD. Replication of the present results using a more contemporary definition of LD for the comparison group is needed.

A final limitation of the current study is concerned with the attempt that was made to fit standardized tasks into the simple/complex and visuoperceptual/visual-spatial categorizations. Without replication and validation studies, the validity of these distinctions remains unknown.

**Conclusions and Implications**

This study contributes to the current NLD literature in several ways. First, it helps to clarify the nature of visual processing difficulties in young children with NLD. They seem capable of making basic visual discriminations but have most difficulty with the spatial aspects of interpreting visual information. Their impaired performance in spatial processing that requires mental imagery and mental rotation is a unique feature of NLD and may be important in helping to identify very young children with NLD. This is an important finding in light of the reported difficulty of identifying NLD at a young age (Rourke, 1989). This finding suggests that
Future research investigating the clinical picture of NLD should attempt to further refine the operational definitions used herein of simple and complex visual processing across visuoperceptual and visual-spatial tasks and identify more tasks that meet these criteria. This would help further elucidate the nature of the processing difficulties of children with NLD across different types of tasks and varying levels of complexity, as well as provide estimates of convergent validity. Replication of the current findings (especially with young girls) may lead to better methods than are currently available to identify and treat young children with NLD. Future research should also examine the relative contributions of visual processing to mathematical ability in young children with NLD. A mathematical error analysis, such as that done by Strang and Rourke (1985) with young children with NLD would help to better identify their particular areas of weaknesses in the beginning stages of mathematical acquisition.
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