Principal Identifying Features of the Syndrome of Nonverbal Learning Disabilities in Children

Michael C. S. Harnadek and Byron P. Rourke

The identifying features of the syndrome of nonverbal learning disabilities (NLD) were examined with a view to determining their relative discriminant validity. A stepwise linear discriminant function analysis of children with NLD (n=29), children with reading and spelling disabilities (Group R-S; n=27), and a group of nonclinical children (NC; n=27) on 15 neuropsychological variables yielded a subset of scores on four tests (Target Test; Trail Making Test, Part B; Tactual Performance Test; and Grooved Pegboard Test) that accurately (>95%) discriminated the NLD group from the R-S and NC subjects. Of the neuropsychological features of NLD described by Rourke (1987, 1988a, 1989), deficits in visual–perceptual–organizational, psychomotor coordination and complex tactile–perceptual skills appeared to be most representative (in the sense of most discriminative) of the NLD syndrome in the children examined. These are also the dimensions that are considered to be “primary” in the NLD model (Rourke, 1989). Replication of these results, employing children with other clinical disorders, is necessary.

Since 1971, we have intensively investigated two subtypes of children with learning disabilities (LD). Children in one group (referred to as Group R-S) are those who exhibit many relatively poor psycholinguistic skills in conjunction with very well-developed abilities in visual–spatial–organizational, tactile–perceptual, psychomotor, and nonverbal problem-solving areas. They exhibit very poor reading and spelling skills but significantly better, though still impaired, mechanical arithmetic competence. The other group—which we refer to as having the nonverbal learning disabilities (NLD) syndrome—exhibits outstanding problems in visual–spatial–organizational, tactile–perceptual, psychomotor, and nonverbal problem-solving skills within a context of clear strengths in psycholinguistic skills, such as rote verbal learning, regular phoneme–grapheme matching, amount of verbal output, and verbal classification. Children with NLD experience their major academic learning difficulties in mechanical arithmetic, while exhibiting advanced levels of word recognition and spelling (see Note). Both of these subtypes of children with LD have been the subject of much scrutiny in our laboratory (for reviews, see Rourke, 1975, 1978, 1982, 1987, 1988a, 1988b, 1989, 1993; Rourke & Finlayson, 1978; Rourke & Fisk, 1988, 1992; Rourke & Fuerst, 1992; Rourke & Strang, 1978, 1983; Strang & Rourke, 1983, 1985a, 1985b).

Nonverbal Learning Disabilities

The NLD syndrome has its research roots in studies that have been conducted in our laboratory since the late 1960s, some conclusions of which have been outlined above. The principal clinical manifestations of the NLD syndrome are as follows:

1. Bilateral tactile–perceptual deficits, usually more marked on the left side of the body;
2. Bilateral psychomotor coordination deficiencies, often more marked on the left side of the body;
3. Outstanding deficiencies in visual–spatial–organizational abilities;
4. Marked deficits in the areas of nonverbal problem solving, concept formation, hypothesis testing, and the capacity to benefit from positive and negative informational feedback in novel or otherwise complex situations. Included are significant difficulties in dealing with cause–effect relationships and marked deficiencies in the appreciation of incongruities (e.g., age-appropriate sensitivity to humor);
5. Very well-developed rote verbal capacities, including extremely well-developed rote verbal-memory skills;
6. Extreme difficulty in adapting to novel and otherwise complex situations. An overreliance on prosaic, rote (and, in consequence, inappropriate) behaviors in such situations;
7. Outstanding relative deficiencies in mechanical arithmetic as compared
to proficiencies in reading (word recognition) and spelling;
8. Much verbosity of a repetitive, straightforward rote nature. Content disorders of language, characterized by very poor psycholinguistic pragmatics (e.g., “cocktail party” speech). Misspellings almost exclusively of the phonetically accurate variety. Little or no speech prosody. Reliance on language as a principal means for social relating, information gathering, and relief from anxiety; and
9. Significant deficits in social perception, social judgment, and social interaction skills. A marked tendency toward social withdrawal and even social isolation as age increases. (Such children are very much at risk for the development of socioemotional disturbance, especially “internalized” forms of psychopathology.)

We have found that the NLD syndrome is manifested most clearly on a “developmental” basis. However, it is also seen in persons suffering from a wide variety of neurological diseases and disorders. These include significant tissue destruction within the right cerebral hemisphere, some types of hydrocephalus, many types of head injury, and other neuropsychological processes that have as one of their results significant destruction of neuronal white matter (long myelinated fibers). In addition to describing the clinical features of this syndrome, a model to explain the syndrome’s dynamics has been proposed (Rourke, 1987, 1988b, 1989). The model involves an extension of the theoretical tenets of Goldberg and Costa (1981), some integration with Piagetian developmental theory, and some relationships to known age-related developmental changes in neuropsychological test performance. For a full description of the syndrome and the “white matter” model designed to account for it, the interested reader is referred to Rourke (1989).

The principal dimensions of the NLD syndrome are thought to be deficits in visual–perceptual–organizational abilities, complex psychomotor skills, tactile perception, and nonverbal problem-solving skills, with age-appropriate development of rote verbal, simple motor, and psycholinguistic skills and abilities (Rourke, 1989). In the discussion that follows, it would be well to refer to Figure 1. For our present purposes, it should be emphasized that we see the patterns of academic and psychosocial deficits experienced by individuals who exhibit this subtype of learning disability as the direct result of the interaction of the primary, secondary, tertiary, and linguistic neuropsychological assets and deficits that are outlined in Figure 1.

For example, considering the hypothesized “deficit” stream, we would view the primary neuropsychological deficits experienced by the child with NLD as having to do with aspects of tactile and visual perception, complex psychomotor skills, and the capacity to deal adaptively with novel material. Such deficits would be expected to eventuate in disordered tactile and visual attention and stunted exploratory behavior; in turn, problems in memory for material delivered through the tactile and visual modalities, as well as deficits in concept formation and problem solving, would be expected to ensue. This set of deficits would be expected to result in the particular set of linguistic deficiencies outlined in Figure 1. The academic and psychosocial/adaptive deficiencies listed are the expected sequelae of these neuropsychological deficits. It is particularly important to note that we would expect this set of neuropsychological deficiencies to lead, in a necessary way, to a particular configuration of problems in psychosocial/adaptive behavior, both within and without the academic situation (Rourke, 1988a, 1989; Rourke & Fuerst, 1992). As suggested above, the reader may find that periodic reference to Figure 1 will be of some assistance in determining our rationale for the current study.

Some other researchers who have pursued research along lines similar to our own (e.g., Grace & Malloy, 1992; Tranel, Hall, Olson, & Tranel, 1987; Voeller, 1986; Weintraub & Mesulam, 1983) have arrived at conclusions regarding particular salient dimensions of LD that resemble the NLD syndrome. Some have accentuated the “right-hemisphere” nature of the deficits, others the psychosocial dimensions, and still others dimensions such as deficits in prosody. These formulations do not deal with issues regarding the relative importance of these dimensions. As noted above (and see Figure 1), the Rourke (1987, 1988b, 1989) formulation of the NLD syndrome and model is explicit with respect to the dimensions of NLD that are thought to be causative and sequential (i.e., primary → secondary → tertiary → linguistic) and dependent (i.e., academic and psychosocial).

At this juncture in our research program, we felt that it would be important to determine the relative discriminative validity of these various dimensions of the NLD syndrome. As a first step in this process, we thought it worthwhile to examine the relative discriminative validity of a wide range of neuropsychological assets and deficits, as measured by a comprehensive battery of neuropsychological tests. If a set of discriminators consistent with the Rourke (1989) model were to be found, it would then make sense to go on to investigate the other dimensions of the model in a similar manner.

Also, from a clinical point of view, although the neuropsychological, verbal, academic, and psychosocial/adaptive features of NLD have been identified, clearly defined clinical criteria for use in “diagnosing” this syndrome have not yet been established. The features that most readily identify the syndrome in children, and their specificity to NLD, are not known. We felt that this was, in and of itself, a sufficient reason to attempt to determine the most salient dimensions of NLD.
Hence, the purpose of the present study was to derive a constellation of the features that would be most useful for identifying children who exhibit NLD. This was accomplished by examining the relative discriminating power of the neuropsychological and academic characteristics of the syndrome. The accuracy with which this constellation of features differentiates children who display NLD from one other subtype of LD and from children who do not exhibit a clinical disorder provides a test of the discriminative validity of these selected dimensions of the syndrome.

The distinctive pattern of neuropsychological and academic assets and deficits exhibited by children of the R-S subtype described by Rourke and colleagues (Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983) renders them well suited for clinical comparison with individuals identified as having NLD. Group R-S children display deficiencies primarily on tests of a verbal and linguistic/psychoacoustic nature (primarily those that involve phonemic discrimination, blending, and segmentation), and on tests involving a large verbal or symbolic component (e.g., some aspects of mechanical arithmetic, finger graphesthesia). However, R-S children have been shown to exhibit age-appropriate development of visual-perceptual-organizational abilities, psychomotor coordination, complex tactile-perceptual abilities, and concept-formation and problem-solving abilities (Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983). The R-S subtype is most similar to the phonological-processing subtype of disabled readers, which has been investigated intensively by Shankweiler and Liberman (1989), Stanovich (1988), and Torgesen (Wagner & Torgesen, 1987). (The interested reader may wish to consult Torgesen, 1993, for a systematic comparison of this phonological subtype of disabled reader and the NLD subtype [syndrome].)

Incorporating these two clinical groups (NLD and R-S) and a third,
nondiagnostic (NC) group in this study allowed for the framing of some specific hypotheses with respect to the relative discriminative accuracy of various measures and dimensions vis-à-vis NLD, as follows:

1. The NLD group was expected to perform worse than—and, thus, be distinguishable from—the NC group on tests sensitive to those skills that have been found to be deficient in children with the NLD syndrome (e.g., visual-perceptual-organizational, psychomotor, tactile-perceptual, mechanical arithmetic, and conceptual and problem-solving).

2. Children within the R-S group were expected to exhibit age-appropriate development of these skills and abilities (with the exception of mechanical arithmetic); in addition, they were expected to be distinguishable from the NLD group by their relatively better performance on tests within the aforementioned realms.

3. The NLD group was expected to perform better than the R-S group on measures of some (primarily rote and straightforward) verbal and psycholinguistic abilities that are thought to develop in an age-appropriate manner in individuals who exhibit NLD, but not in children in the R-S group.

4. It was expected that the performances of the NLD and NC groups would not be distinguishable on the aforementioned verbal and psycholinguistic measures.

5. It was expected that those dimensions thought to be primary in the NLD syndrome (i.e., visual-spatial-organizational, tactile-perceptual, psychomotor) would be the principal variables that distinguished the NLD group from the R-S and NC groups.

Method

Subjects

The data used in the present study were drawn from two sources. A total of 29 children who exhibited the NLD syndrome and 29 children who matched the R-S academic achievement test profile were selected from a clinical data base of over 5,000 children who had received neuropsychological assessment because of suspected learning or perceptual difficulties. Data representing 25 of the 29 NLD subjects were collected as part of an earlier study (Casey, Rourke, & Picard, 1991). The data for 4 additional subjects were added to these 25 cases. Twenty-nine subjects free of learning or perceptual difficulties served as the nonclinical comparison group and were selected from data collected as part of a longitudinal study of children with reading disabilities (Rourke & Orr, 1977).

None of the 87 subjects used in the present study exhibited primary socio-emotional disturbance, sensory impairment, socioeconomic deprivation, or educational disadvantage. All spoke English as their native language. Subjects were matched for age; no significant differences between the three groups were evident, $F(2,80) = 1.66$, $p > .10$.

In accordance with the procedures used in Casey et al. (1991), a two-step process was employed to select the NLD subjects. First, a broad-based set of neuropsychological test criteria was employed to search the clinical data base for all children who exhibited the following constellation of characteristics: (a) good verbal capacity, (b) difficulty with mechanical arithmetic, (c) visual-perceptual-organizational deficits, (d) psychomotor deficits, and (e) tactile-perceptual deficits. The specific test criteria for these characteristics are provided in Table 1. Forty-two cases were identified in this manner.

At this point we would do well to emphasize that we are concerned in this study with the relative discriminative accuracy of various dimensions that are thought to be typical of children with NLD. That we chose children in terms of dimensions that are thought to be typical of such children (see above) is of no consequence. What is important to realize is that, having chosen children in terms of these criteria, we were then in a position to determine the relative discriminative (i.e., concurrent validity) power of these several and various dimensions.

The second step in the selection process involved a review of each case by two clinicians to determine if the child in question exhibited the behavioral consequences of the NLD syndrome. Twenty-nine cases were identified, and the reviewers were in 100% agreement that each case was consistent with the expected behavioral expression of NLD. Of the remaining cases,

| Characteristics                              | Criteria                                                                 |
|----------------------------------------------|                                                                         |
| Good verbal capacity                         | WISC VIQ > 79 and Speech-Sounds Perception Test or Auditory Closure Test ≤ 1 SD below mean. |
| Relative difficulty with mechanical arithmetic| WRAT Reading and Spelling > WRAT Arithmetic by 10 or more standard-score points. |
| Visual-perceptual-organizational deficits    | Target Test ≥ 1 SD below mean and VIQ > PIQ by 10 or more points.       |
| Psychomotor deficits                         | Performance (either hand) on Grooved Pegboard Test ≥ 1 SD below mean.    |
| Tactile-perceptual difficulties              | Performance (either hand) on dysgraphesthesia, finger agnosia, or astereognosis portion of Reitan-Klwe Sensory-Perceptual Exam ≥ 1 SD below mean. |

Note. NLD = nonverbal learning disabilities; WISC = Wechsler Intelligence Scale for Children; VIQ = Verbal Intelligence Quotient; PIQ = Performance Intelligence Quotient; WRAT = Wide Range Achievement Test.
eight were dropped because they (a) exhibited features not consistent with NLD or (b) demonstrated difficulties at the time of testing that rendered their results unreliable. Five additional subjects were excluded because they were too young and could not be matched for age with subjects in the other groups. Following the procedures employed in earlier studies of children with reading and spelling disabilities (e.g., Rourke & Finlayson, 1978), the R-S subjects were selected solely on the basis of their pattern of performance on the Wide Range Achievement Test (WRAT) (Jastak & Jastak, 1965). Children whose grade-equivalent scores on the Reading and Spelling subtests were at least 1.8 years below their grade-equivalent score on the Arithmetic subtest, and whose Reading and Spelling subtest centile scores did not exceed 14, were included in the R-S group. It is important to note that the R-S group was chosen solely on the basis of their pattern of performance on the WRAT, and not in terms of their neuropsychological assets and deficits (see Rourke, 1989, Chapter 8).

Testing and Measures

Subjects were individually administered a battery of neuropsychological tests (as outlined in Rourke, 1989) by extensively trained psychometric technicians in a standardized fashion. To guard against spurious classification results due to a small subject-to-variable ratio (Fletcher, Rice, & Ray, 1978), only 15 neuropsychological variables were used in the present study. Eight variables were chosen because they represented skills and abilities identified as deficient within the NLD syndrome (Rourke, 1989); these included (a) the Category Test (Reitan & Davison, 1974); (b) the Arithmetic subtest from the WRAT; (c) memory and (d) location scores from the Tactual Performance Test (TPT); (Reitan & Davison, 1974). Several composite scores were created to maximize the power of the analysis and to reduce alpha bias. Dominant- and nondominant-hand scores from the Grooved Pegboard Test (Klöve, 1963) and the TPT were averaged to yield composite (e) Grooved Pegboard and (f) TPT scores. Dominant- and nondominant-hand scores on the finger agnosia and finger dysgraphesthesia portions of the Reitan-Klöve Sensory-Perceptual Exam (Reitan, 1984) were averaged into a single (g) Tactile score. Finally, performances on the Target Test (Reitan, 1966) and the Trail Making Test, Part B (Reitan & Davison, 1974) were collapsed to form (h) a Visual-Perceptual-Organizational measure.

Seven tests on which children who exhibit the R-S academic achievement profile are expected to perform poorly (Rourke & Finlayson, 1978) were also included: (i) the Peabody Picture Vocabulary Test (PPVT) (Dunn, 1965); (j) the WRAT Reading subtest; (k) the WRAT Spelling subtest; (l) the Speech-Sounds Perception Test (SSPT) (Reitan & Davison, 1974); (m) the Auditory Closure Test (Kass, 1964); (n) the Sentence Memory Test (Benton, 1965); and (o) a phonemically cued test of verbal fluency (Rourke, Bakker, Fisk, & Strang, 1983). (Although the R-S subjects were selected on the basis of their pattern and levels of performance on the WRAT, it was necessary to include these academic achievement measures in the analysis so that comparisons could be effected with the NLD and NC groups on these important academic dimensions. In addition, we thought it was important to determine the relative discriminating power of these academic measures.) Scores on the selected neuropsychological and academic tests were converted to age-corrected T scores ($M=50$, $SD=10$) to allow for intergroup comparisons. Conversion of most of the neuropsychological test scores into T scores was based on the norms of Knights and Norwood (1980); scores for the WRAT subtests and the PPVT were converted based on their respective norms. T scores were calculated so that larger values represented better performance.

Results

Table 2 contains the descriptive characteristics for each of the three groups. Subjects in all groups were predominantly right-handed. All of the NC sample and the majority of the R-S sample consisted of males; the NLD cases were more equally divided into

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|     | Group Characteristics |
| --- | --- | --- |
|     | NLD | R-S | NC |
| N   | 29  | 29  | 29 |
| Sex |
| Males | 14  | 26  | 29 |
| Females | 15  | 3   | 0  |
| Handedness |
| Right | 25  | 27  | 27 |
| Left | 4   | 2   | 2  |
| Age (years) Mean | 11.48 | 11.39 | 10.76 |
| (SD) | (1.92) | (1.75) | (0.77) |
| WISC VIQ Mean | 101.03 | 99.53 | 109.72 |
| (SD) | (10.37) | (8.84) | (7.74) |

Note. NLD = nonverbal learning disabilities; R-S = reading-spelling learning disabilities; NC = nonclinical; WISC = Wechsler Intelligence Scale for Children; VIQ = Verbal Intelligence Quotient.
males and females—the proportion that is most often found (Rourke, 1989).

Of the original 87 cases, 4 subjects (2 from the R-S group and 2 from the NC group) were identified as outliers, due to extreme scores on several of the tests, and were dropped from further analyses. Assumptions of linearity, normality, homogeneity of the variance-covariance matrices, and multicollinearity or singularity were evaluated, based on the remaining 83 cases, and the results revealed no threat to multivariate analysis (Tabachnick & Fidell, 1983).

A one-way multivariate analysis of variance of the full 15-variable model was significant at the p < .001 level. Univariate tests of analysis of variance were, therefore, conducted across each variable. For all 15 variables, differences between groups were significant at least to the p < .05 level. Table 3 provides the means, standard deviations, and univariate F statistics for the 15 measures used in this study.

A series of planned comparisons was conducted to test the study hypotheses. The results of the group comparisons on all but the verbal-fluency variable were significant at the p < .01 level. The comparison of the three groups on the verbal-fluency variable was significant at the p < .05 level. As illustrated in Figure 2, the NLD group performed significantly more poorly than did the R-S and NC groups on the Visual-Perceptual-Organizational, Grooved Pegboard, Tactile, and TPT composite measures, and on the WRAT Arithmetic, TPT-Memory, TPT-Location, and Category Test variables. Furthermore, the performance of the NLD group on all variables except the TPT-Memory and Category Test variables fell within the impaired range (i.e., a T score < .40). In contrast, the performance of the NLD group on the verbal neuropsychological and academic tests was within the average range. The R-S group performed more poorly than did the NLD and NC groups on the PPVT, SSPT, Auditory Closure, Sentence Memory, verbal fluency, and WRAT Reading and Spelling variables.

To evaluate which of the neuropsychological and academic features of the NLD syndrome would be most useful in distinguishing the NLD cases from the remaining subjects, a stepwise linear discriminant function analysis was performed. In calculating the linear discriminant function analysis, test measures were employed as predictors and the analyses maximized Wilk's lambda. Approximately 75% of the cases were randomly selected to be used in the initial analysis. The remaining 25% of the cases were reserved for later cross-validation.

Two significant discriminant functions resulted, combined χ²(18, n = 63) = 210.61, p < .001. After removal of the first function, the second discriminant function retained a high degree of discriminating power, χ²(8, n = 63) = 85.97, p < .001. The two discriminant functions accounted for 69% and 31% of the total variance, respectively. The first function discriminated the NLD group from R-S and NC groups; the
FIGURE 2. Illustration of the level and pattern of performance for children in the three groups on a selection of neuropsychological measures.

(Abbreviations: WRAT, Wide Range Achievement Test; PPVT, Peabody Picture Vocabulary Test; SSPT, Speech-Sounds Perception Test; AC, Auditory Closure Test; SM, Sentence Memory Test; VF, phonemically cued test of verbal fluency; Read, WRAT Reading subtest; Spel, WRAT Spelling subtest; Art, WRAT Arithmetic subtest; VPO, visual-perceptual-organizational measure; combined Target Test and Trail Making Test, Part B, scores; GP, Grooved Pegboard Test, averaged dominant- and nondominant-hand performance; TPT, Tactual Performance Test, averaged dominant- and nondominant-hand performance; Loc, Tactual Performance Test, location score; Mem, Tactual Performance Test, memory score; TAC, tactual measure, averaged dominant- and nondominant-hand scores on the finger agnosia and finger dysgraphesthesia subtests of the Reitan-Klave Sensory-Perceptual Exam; Cat, Halstead Category Test.)

R-S group was separated from the NLD and NC subjects by the second discriminant function.

Eight of the 15 variables combined to account for the majority of the power in discriminating the NLD groups from the R-S and NC groups. The resultant predictor variables are provided in Table 4, as are their correlations with each of the two functions and their standardized canonical discriminant function coefficients. Increases in the number of predictors beyond the eight-variable model failed to increase the discriminating power of the functions significantly, \( F > 1.0 \).

As can be seen from Table 4, three measures (Visual-Perceptual-Organizational, Grooved Pegboard, and TPT) correlated substantially \( (r's = .45 \text{ to } .60) \) with the first function to discriminate the NLD group from the other two groups. Two measures (SSPT and WRAT Reading) loaded highly \( (r's = .44 \text{ and } .79, \text{ respectively}) \) on the second function to distinguish the R-S cases from the NLD and NC subjects.

Classification of the sample was performed using Lachenbruch's Leaving-One-Out Method (Fletcher et al., 1978; Lachenbruch, 1975) to reduce bias that would contribute to overfitting of the data. Using sample proportions as prior probabilities, all but one of the NLD cases (95%) and all of the R-S and NC cases were correctly classified, with an overall accuracy of 98%. A classification table is provided as Table 5.

Cross-validation with the hold-out sample resulted in all of the NLD and R-S subjects being correctly identified. The three misclassifications that did occur in the cross-validation came from the NC group.

Discussion

The principal finding of this study was that a subset of four neuropsychological tests (the Target Test; the Trail Making Test, Part B; the Tactual Performance Test; and the Grooved Pegboard Test) served to discriminate the NLD subjects from the R-S and NC subjects with a high degree of accuracy (> 95%). Two tests, the Reading subtest of the WRAT and the Speech-Sounds Perception Test, best discriminated the R-S children from the NLD and NC children. Several points should be mentioned regarding these findings: First, of the major (i.e., primary) neuropsychological features of NLD described by Rourke (1987), deficient age-related development in the realms of visual-perceptual-organizational ability, psychomotor coordination skill, and complex tactile-perception ability appear to be most characteristic of the syndrome in children. It would seem reasonable, therefore, to devote attention to children’s performance within these realms when the clinician is considering making a diagnosis of possible NLD, as well as when treatment programs are being considered.

Second, in interpreting the present results in terms of the NLD model described at the beginning of this article (see, also, Rourke, 1989), it becomes apparent that the neuropsychological deficits that distinguished the NLD group from the other two groups are those that are thought to be primary in the dynamics of this disorder (see Figure 1). A recent investigation by Casey et al. (1991) helps to explain why this might be expected. Casey et al. examined the manner in which the neuropsychological assets and deficits of children with NLD change over the course of development, by conducting a cross-sectional comparison study of the performance of NLD subjects in middle childhood to that of others in their early adolescence across a comprehensive array of neuropsychological tests. They found that the younger children were most deficient in visual-
spatial–organizational skills, complex motor skills, complex tactile skills, and problem-solving skills (e.g., see Figure 6 in Casey et al., 1991). Furthermore, an age-related decline in these same functions was more marked than for other skills and abilities. Thus, deficits that are thought to play a primary role in the manifestation of the NLD syndrome involve skills that not only are more poorly developed initially, but also fail to develop to the same extent or at the same rate as do most other neuropsychological skills and abilities.

Therefore, it is not surprising that the most salient identifying features of the NLD syndrome in children correspond to those skills and abilities that have been found to be among the least developed initially, and that continue to worsen (relative to age-peers) as children with NLD grow older.

Compared to the R-S and NC groups, the NLD group performed more poorly on tests of visual–perceptual–organizational skills, psychomotor coordination, complex tactile–perceptual skills, and conceptual and problem-solving skills. Furthermore, the NLD group's levels of performance were within the normal range and did not significantly differ from those of the NC group on tests of the more rote aspects of verbal and psycholinguistic skills. These findings correspond to the pattern of neuropsychological and academic assets and deficits that has been described for the NLD syndrome (Rourke, 1987, 1988b, 1989).

The R-S group performed more poorly than did the NLD and NC groups on the tests of rote verbal and psycholinguistic abilities, single-word reading, and spelling skills employed. Unlike the NLD group, however, the R-S children performed in an age-appropriate manner on tests of visual–perceptual–organizational skills, psychomotor coordination, tactile perception, memory for tactile information, and concept-formation and problem-solving abilities.

Although this study was not designed with this purpose in mind, it is interesting to note the close resemblance of the NLD and R-S groups' patterns of neuropsychological assets and deficits, as illustrated in Figure 2, to the findings of earlier research demonstrating differing patterns of neuropsychological assets and deficits between children of the R-S subtype and children who exhibited outstanding difficulties in mechanical arithmetic (Rourke, 1993; Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983, 1985b). The results of the present study are quite similar to

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<th>TABLE 4</th>
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<td><strong>Discriminant Function Analysis of Neuropsychological Variables: Results</strong></td>
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<tr>
<td><strong>Predictor variables</strong></td>
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<td></td>
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<tr>
<td>Visual–perceptual–organizational</td>
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<tr>
<td>Grooved Pegboard</td>
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<td>TPT</td>
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<td>TPT-Memory</td>
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<td>WRAT Reading</td>
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<td>SSPT</td>
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<td>Sentence Memory</td>
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<td><strong>Note.</strong> Boldface numbers = principal discriminating dimensions. F1 = first (NLD vs. NC and R-S) discriminant function; F2 = second (R-S vs. NC and NLD) discriminant function; NLD = nonverbal learning disabilities; R-S = reading-spelling learning disabilities; NC = nonclinical; Visual–perceptual–organizational = composite Trail Making Test, Part B, and Target Test score; Grooved Pegboard = composite Grooved Pegboard Test score; TPT = composite Tactual Perception Test score; TPT-Memory = memory score from Tactual Performance Test; Tactile = composite Reitan-Kline Sensory–Perceptual Exam finger agnosia and finger dysgraphesthesia score; WRAT = Wide Range Achievement Test; SSPT = Speech-Sounds Perception Test; Sentence Memory = Sentence Memory Test.</td>
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<th>TABLE 5</th>
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<td><strong>Discriminant Classification Results and Cross-Validation</strong></td>
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<tr>
<td><strong>Predicted group</strong></td>
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<tr>
<td><strong>Classification cases</strong></td>
</tr>
<tr>
<td>NLD</td>
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<tr>
<td>(95)</td>
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<td>R-S</td>
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<td>(0)</td>
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<td><strong>Validation cases</strong></td>
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<td>NLD</td>
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<td>R-S</td>
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<td>(0)</td>
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<td>NC</td>
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<td>(14)</td>
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<tr>
<td><strong>Note.</strong> NLD = nonverbal learning disability; R-S = reading-spelling learning disability; NC = nonclinical.</td>
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those illustrated in Figure 8-1 in Strang and Rourke (1985b); see also Rourke (1993, Figure 1). The NLD group's general level and pattern of performance on measures of visual-perceptual-organizational ability, psychomotor coordination, tactile-perceptual ability, and conceptual and problem-solving ability in the current study are comparable to those found for children who exhibit outstanding difficulties in mechanical arithmetic and average to above-average single-word reading and spelling skills. Similarities in patterns of performance on tests of verbal and psycholinguistic skills are also evident, although the children with NLD were less proficient on these tests.

Finally, the R-S group's performance fell below age expectations on two psycholinguistic tests (the SSPT and the Auditory Closure Test), and these children performed worse than the NLD group on all verbal and psycholinguistic tests, except for the phonemically cued test of verbal fluency. Thus, the present findings lend confirmatory support to the results of earlier subtyping studies (e.g., Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983) that formed the basis for our current understanding of the NLD syndrome.

**Limitations of the Study**

In interpreting the results of the current investigations, three caveats should be noted. First, caution is advised in interpreting the Target Test; the Trail Making Test, Part B; the Grooved Pegboard Test; and the Tactual Performance Test as being the best neuropsychological predictors of NLD in children. Although the present study yielded a subset of these four tests that best discriminated the children with NLD from those with R-S and NC children, other combinations of tests or other individual tests (e.g., the Category Test) may have enough predictive utility to warrant their consideration in any number of circumstances.

This situation arises due to the nature of the stepwise discriminant analysis. Predictor variables are selected for entry into the discriminant function equation on the basis of the size of their correlation with the function, and the amount of "independent" variance (i.e., variance not shared with other predictor variables) that they have to offer. Variance that is shared among intercorrelated predictor variables is assigned to the predictor that has the greater relationship with the discriminant function. Consequently, following the entry of one of a pair of intercorrelated predictor variables into the discriminant function equation and removal of the variance it shares with the other variable, the remaining predictor may lack sufficient independent variance to satisfy minimal entry requirements (Fletcher et al., 1978).

Second, the nature of the clinical group selected to serve as a contrast to the NLD sample probably contributed to the highly accurate rate of classification. High rates of correct identification are expected when groups exhibiting extreme differences on the predictor variables of interest are employed in a linear discriminant function analysis (Adams, 1979). Previous investigations employing samples of children of the R-S subtype who were selected according to criteria similar to those used in the present study (Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983) have demonstrated that these children exhibit neuropsychological test performances that are quite different and distinct from those that are expected for the NLD sample (e.g., Fletcher, 1985). Consequently, the rates at which membership for each group was correctly predicted were expected to be greater than would be the case if less-differentiated groups (e.g., the "Output Disorder" subtype: Rourke, 1989, Chapter 8) were included in the analysis.

Third, linear discriminant function analysis contributes to inflated accuracy of classification through the minimization of the amount of variance not attributable to between-group differences (Adams, 1979). The concern over possible overfitting of data is accentuated when stepwise procedures are employed (Tabachnick & Fidell, 1983). Although methods of classification were adopted that minimized spurious accuracy rates, inflated classification cannot be ruled out in the results of the present study.

Although the results of this investigation serve as an initial step in developing reliable criteria for identifying the NLD syndrome in children, several important aspects still need to be addressed. An insufficient amount of research has focused on deriving constellations of neuropsychological assets and deficits that would distinguish children who display the NLD syndrome from children displaying other clinical disorders. Replications of this study, employing clinical groups other than an R-S LD subtype, could address this issue and would contribute to the establishment of a critical set of clinical features for diagnostic purposes.

Finally, Rourke (1987, 1988b, 1989) suggested that children who have experienced clinical conditions in which substantial damage to cerebral white matter resulted (e.g., early-acquired moderate-to-severe closed-head injury) provide profiles of neuropsychological, academic, and socioemotional functioning that closely resemble those associated with the NLD syndrome. For example, based on the results of the research program conducted by Fletcher and associates (e.g., Fletcher & Levin, 1988), the NLD profile should be most evident in children with severe head injuries (who can be tested) and less evident in those with mild or moderate injuries.

The nature of the deficits in children with NLD is hypothesized to be radically dependent upon the severity of white-matter involvement and the age at which the damage was sustained. Thus, for example, severe or widespread white-matter disturbance occurring very early in life would be expected to eventuate in deficiencies in virtually all skills and abilities. However, milder degrees and extents
of dysfunction, such as may occur in later life, would be expected to eventuate in a milder impact on a child's neuropsychological abilities. In the case of linguistic skills, for example, once these functions have been reasonably well developed (e.g., by 5 years of age) they tend to be more impervious to white-matter disturbance. Another severity dimension of relevance in the psycholinguistic realm is the degree to which the verbal task is novel (Rourke, 1989).

Further comparisons of children with the NLD syndrome to those who exhibit other clinical and/or medical conditions will aid in the identification of childhood clinical disorders that have commonality with the NLD syndrome. This should help to further elucidate the mechanisms that underlie the NLD syndrome and provide opportunities to establish firmer diagnostic criteria for it. Recent attempts to do this have proven to be quite fruitful (e.g., Ewing-Cobbs, Fletcher, Levin, & Boudousque, 1993; Fletcher et al., 1992; Rovet, 1993; Sparrow, 1993; White, 1993).

NOTE

Children with "specific" arithmetic disabilities are referred to as "Group A" in Rourke and Finlayson (1978), Rourke and Strong (1978), and Strong and Rourke (1983), and as "Group A" in Strong and Rourke (1985a, 1985b).

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