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ABSTRACT

The study reports a cluster analysis of Luria-Nebraska Neuropsychological Battery sources of 25 learning disabled adults. The cluster analysis suggested the presence of three subgroups within this sample, one having high elevations on the Rhythm, Writing, Reading, and Arithmetic Rhythm scales, the second having an extremely high evelation on the Rhythm scale with lesser elevations on the Motor, Tactile, Vision and academically related scales, and the third subgroup having a normal profile, only remarkable for slight elevations on the Writing and Arithmetic scales. Analyses of variance were performed with cluster membership as the independent variable and various measures from Wechsler Adult Intelligence Scale-Revised and Wide Range Achievement Test as the dependent measures. Essentially all findings were statistically significant, thereby supporting the external validity of the cluster solution. It was suggested that the first subgroup had its difficulties primarily in the language development area, while the second subgroup had its major difficulties in perceptual, attentional and motor skills that support language development. The third subgroup did not appear to have a clearly identifiable neuropsychological basis for its relatively mildly deficient academic performance levels. In general, the study provided preliminary evidence of the capabilities of the Luria-Nebraska Neuropsychological Battery to identify neuropsychological differences among different types of learning disabled adults. (CL)

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CLUSTER ANALYSIS OF THE LURIA-NEBRASKA NEUROPSYCHOLOGICAL BATTERY WITH LEARNING DISABLED ADULTS

In a previous study, we reported that a group of 25 young adults with learning disability demonstrated a pattern of neuropsychological characteristics that was quite similar to what has been reported for learning disabled children (McCue, Shelly, Goldstein & Katz-Garris, 1984). That study focused on the sample as a whole and provided descriptive group statistical data. However, further inspection of individual cases included in that study indicated that there appeared to be a substantial amount of diversity in test performance among the subjects. That diversity, along with recent emphasis in the field of learning disability on subtypal analysis (Doehring, Hoshko, & Bryans, 1979; Fletcher & Satz, 1985; Rourke, 1985; Satz, Taylor, Friel & Fletcher, 1978), stimulated the present study, which represents an attempt to determine whether the variability noted among our subjects is random, or amenable to organization within meaningful subtypes of learning disability. Subtypal analysis is of some significance in the learning disability area, since there have been some demonstrations that the heterogeneity of the condition may have important implications for development of educational strategies used in its remediation (Bakker, 1984).

Morris, Blashfield, & Satz, (1981) have provided methodological guidelines for the application of cluster analysis as a procedure for developing neuropsychologically based typologies, although the work of their and other groups has not employed the Luria-Nebraska Neuropsychological Battery (LNNB) (Golden, Hammeke & Purisch, 1980) in cluster analytic studies with learning disabled individuals. While the construct validity of the LNNB has been questioned, (Snow & Hynd, 1984) with the assertion made by some that it is only sensitive to the presence or absence of brain damage, it nevertheless seems that the diversity of items contained in the LNNB, as well as several full scales that have strong potential for measuring academic skills (Shelly & Goldstein, 1982), might suggest that the LNNB could shed substantial light on neuropsychological aspects of learning disability. Our previous study also indicated that the LNNB factor scales profile provided some interesting findings regarding language abilities in learning disabled individuals.

The establishment of a viable typology by means of cluster analysis requires several methodological steps since different algorithms may yield different solutions, and random data can be organized into what may appear to be meaningful clusters. It is therefore necessary to establish the internal and external validity of a particular clustering solution before one can say that a typology has been established. The present investigation was directed largely to establishment of external validity for several practical reasons. First, there seemed to be little point in determining the internal validity of a solution that does not have heuristic value in terms of association with criteria external to what is contained in the cluster analysis itself. Second, the establishment of internal validity ideally involves replication of the cluster solution with a new sample, and we did not have sufficient data to accomplish that task. We therefore concentrated on the matters of determining the number of meaningful clusters generated in our sample by LNNB data, and determining whether cluster membership could be associated with two external sets of criteria, one derived from the Wechsler Adult Intelligence Scale-Form

R (WAIS-R) and the other from the Wide Range Achievement Test (WRAT). Thus, the major point of the study was that of determining whether cluster membership was differentially associated with various performance patterns on standard, established tests of intelligence and academic achievement. If such relationships were established, that would argue for the external validity of the cluster solution found, as well as for the utility of the LNNB with regard to providing neuropsychological correlates of different types of learning disability. We also examined selected LNNB factor scales for characteristics that might distinguish among the subtypes derived.

Subjects

The subjects were the same as those utilized in McCue et al. (1984). Briefly summarizing, they had all received the DSM III, Axis II (APA, 1980) diagnosis of one or more of the specific developmental disorders, with mental retardation and adult acquired structural brain damage ruled out. There were 19 males and six females. The mean age was 24.2 (SD=8.1) with a mean of 11.9 (SD=2.2) years of regular education.

Procedure

The subjects were administered the LNNB, the WAIS-R and the WRAT by a neuropsychologically trained psychologist. Each case was also independently reviewed by the senior author and a physician in order to confirm the specific developmental disability diagnoses and to ascertain the absence of mental retardation or adult acquired structural brain damage. The LNNB data were analyzed with a combination of hierarchical agglomerative and iterative partitioning methods, utilizing two Biomedical Deck programs (Dixon, 1985);

BMDP2M and BMDPKM. A centroid clustering procedure was used, which is a form of average linkage method, and squared Euclidean distance was the similarity measure. Number of clusters was determined by direct inspection of the dendogram. Following the clustering procedures, analyses of variance were performed using cluster membership as the independent variable and WAIS-R and, WRAT derived measures as the dependent variables. The Scheffé test was used for subsequent multiple comparisons.

RESULTS

The Total Sample

Descriptive data concerning the WAIS-R, WRAT and LNNB for the total sample may be found in McCue et al. (1984). Briefly summarizing, the sample can be characterized as a group functioning at the low end of the average range of general intelligence with substantially deficient academic skills and with a LNNB profile characterized by deficiencies in attentional and a number of academic skills, but intact function in other areas.

The Cluster Analysis

As indicated, the first step in the cluster analysis procedure involved the generation of a dendogram in order to determine whether or not there was a discernible cluster structure as well as to determine the number of clusters. A schematic representation of the dendogram is presented in Figure 1. We

Figure 1 Here

noted that at an amalgamation distance of approximately 2.5, there appeared to be three readily discernible clusters. The next step involved further analysis through an iterative partitioning (K-means) method, requesting three clusters. This method requires stipulation of the number of clusters prior to performance of the analysis. The means and standard deviations by cluster are

Figure 2 Here

profiled in Figure 2. Cluster 1, containing 7 cases, obtained a profile characterized by a moderate elevation on the Rhythm and Expressive Speech scales, with marked elevations on the Writing, Reading and Arithmetic scales. Cluster 2, containing 6 cases, had elevations on the Motor and Rhythm scales with an otherwise flat profile. Mean scores on the academic scales tended to approach the impaired range, but reflected substantially less deficit than was the case for Cluster 1. It is also noteworthy that the mean scores on the Motor, Tactile, and Vision scales were higher for Cluster 2 than they were for the other two clusters. Cluster 2 members therefore appeared to have more difficulty with the nonverbal aspects of the LNNB in general than did members of the other clusters. Cluster 3, containing the remaining 12 cases, had elevations on the Writing and Arithmetic scales comparable to what was found for Cluster 2, but the Rhythm scale was not elevated, and the remaining scales were quite normal. Thus, we have a small cluster with marked impairment on the Rhythm and academic scales, another small cluster with mild impairment on the academic scales but with a substantially elevated score on the Rhythm scale and lesser elevations on the Motor, Tactile and Vision scales, and a relatively large cluster that produced a completely normal profile, but with slightly elevated Writing and Arithmetic scales.

WAIS-R and WRAT Comparisons

The ANOVA results are presented in Table 1. All comparisons made for

Table 1 Here

WAIS-R IQ and WRAT scores yielded statistically significant results, indicating that cluster membership is associated with general level of intelligence and academic achievement. Looking at the clusters individually, Cluster 1 had a lower Verbal than Performance IQ, with markedly deficient WRAT scores. Cluster 2, unlike both Clusters 1 and 3, had a higher Verbal than Performance IQ. WRAT scores were also deficient, but not to the extent found in the case of Cluster 1. Cluster 3 actually manifested evidence of learning disability only in the sense that the WRAT grade levels were below that expected on the basis of educational level, which was generally in the high school range. The Verbal and Performance IQs were within the average range, and were very close to each other.

Multiple comparisons, utilizing the Scheffé procedure yielded the following results. With regard to Verbal IQ, Clusters 2 and 3 did not differ from each other, but both differed from Cluster 1. In the case of Performance IQ, Cluster 3 was different from Cluster 2, with no other significant differences. For Full Scale IQ, Cluster 3 differed from Clusters 1 and 2, which did not differ from each other. In the case of the WRAT, Cluster 1 differed from Clusters 2 and 3, which did not differ from each other, on all three subtests. On the WAIS-R subtests, the only non-significant ANOVA was for Digit Span. In general, the multiple comparisons reflect the IQ findings, which indicated that Cluster 1 tended to do worse than the others on verbal relative to performance tests, while the reverse was true for Cluster 2. Multiple comparison results for the WAIS-R and WRAT are summarized in Table 2.

Table 2 Here

An Examination of Selected LNNB Factor Scales

In our previous study, we remarked on how the full sample was characterized by abnormal scores on some of the language and academically related LNNB factor scales. The scales of interest and their means and standard deviations for each cluster are presented in Table 3. All inter-

Table 3 Here

cluster differences were statistically significant with the exception of Rc4-Verbal-Spatial Relations, where the means for all three clusters were 60 or higher. The results of the multiple comparisons are summarized in Table 4.

Table 4 Here

In the case of all of the academically related factor scales considered, Cluster 1 members performed more poorly than did those in the other clusters. However, in the case of Rh1-Rhythm and Pitch Perception, Clusters 1 and 2 were equally deficient, with Cluster 3 producing a normal level performance. A similar relationship obtained in the case of Rc2-Relational Concepts, in which Cluster 3 was superior to the other two, but in this case, it was only significantly different from Cluster 1. These relationships would all suggest that Cluster 1 is the most deficient subgroup on these selected factor scales, Cluster 3 demonstrated the best performance level while Cluster 2 was somewhere in-between, although it was generally more similar to Cluster 3 than it was to Cluster 1.

DISCUSSION

It would appear that the major clinical scales of the LNNB classified our sample into three relatively distinct groups. The first of them demonstrated a combination of deficit areas involving both the Rhythm scale and the three academic scales. The second group did somewhat worse than the first on the Rhythm scale, but better on the academic scales, while the third group was approximately equivalent to the second with regard to the academic scales but did not show impairment on the Rhythm scale. If we interpret the Rhythm scale as a measure of nonverbal auditory attention, it would appear that the first group has a combination of substantial nonverbal attentional and academic difficulties, the second group has even greater nonverbal attentional deficits but less profound academic disability while the third group has only academic disabilities, without a significant nonverbal attention deficit. As will be shown, however, all three groups had some degree of verbal attention deficit.

When one examines the performance of the three groups on standard tests of intelligence and academic achievement, the first group demonstrates rather substantial impairment of verbal intelligence relative to performance intelligence. Its level of academic achievement is quite low, not exceeding the fourth grade level, despite the fact that the Full Scale IQ level is not in the mentally retarded range. The second group has substantially impaired performance intelligence relative to the other two groups and to its own level of verbal intelligence. However, its Full Scale IQ is comparable to that of the first group. Academically, the WRAT grade levels of this second group are depressed, but not to the extent found for the first group. The relative elevation on the Motor scale in this group may suggest that a component of their learning disability could involve some degree of lack of dexterity. The third group showed no substantial difference between levels of verbal and performance intelligence, both of which were somewhat superior to what was found for the other two groups. Academic levels also showed a lessser degree of disability from what was the case for the other groups. An examination of pertinent LNNB factor scales essentially confirmed that the first group had substantially greater academic disability than did the other two groups. It was noted that while the three clusters did not differ with regard to age ($F(2,22) = .84$, $p>.05$), they did differ with regard to educational level ($F(2,22) = 6.7$, $p<.01$), with Cluster 1 having the lowest level. It is unlikely, however, that limited education was primarily responsible for the poor academic achievement of the Cluster 1 members, since their mean level of education was 10 years (S.D.=2.1). It seems more likely that the learning disabilites, which were probably longstanding in nature, played a major role in engendering the limited educational levels of Cluster 1 members relative to the other subgroups.

Speculating on the nature of the basis for the cluster differences, one could suggest that the first group has its difficulties primarily in the language development area itself. The second group may have its developmental difficulties with those nonverbal visual-spatial and perceptual skills that support language learning. It may not be necessary to postulate any form of specific developmental difficulty in the case of the third group. Its relatively mild degree of disability might not be associated with any kind of neuropsychological deficit or asymmetry of verbal vs. performance intellectual function. Perhaps this group's learning disabilities are largely associated with psychosocial, educational or other environmental factors. Speculating further, it could be suggested that the first group has its difficulties in the area of left (language dominant) hemisphere function, while the second group has its major problems with abilities thought to be mediated largely by the right hemisphere.

The presence of an attention deficit was postulated on the basis of performance levels on the LNNB Rhythm scale and the WAIS-R Digit Span and Arithmetic subtests. The application of the latter two tests has support from factor analytic studies in which these subtests have been described as representing a "freedom from distractibility" factor (Cohen, 1957). It is commonly understood that learning disability is frequently associated with an attention deficit disorder, either with or without hyperactivity. All three of our groups demonstrated some degree of attention deficit. While the third group obtained a normal level score on the LNNB Rhythm scale, its mean score on Digit Span and Arithmetic (7.3 and 7.9 respectively) were both below average. While the three groups did not differ among themselves on Digit Span, it is noteworthy that the first group did worse than the other two on Arithmetic but not on the Rhythm scale, while the reverse pattern was noted for the second group. In other words, within the context of generalized attention deficit, the first group did relatively poorly with regard to verbal as opposed to nonverbal auditory attention, while the reverse was true for the second group.

In summary, cluster analysis of LNNB data obtained from a sample of 25 individuals with diagnosed learning disability yielded three subgroups. The first of them was characterized by a number of features on the LNNB, WAIS-R and WRAT that suggested severe, generalized academic disability, an attention deficit manifested more in the area of verbal than nonverbal auditory attention, and a substantially lower Verbal than Performance IQ. The second group had a lesser degree of academic disability than the first group. This group also showed evidence of an attention deficit, but nonverbal auditory attention was more impaired than was verbal auditory attention. This group's mean Performance IQ was substantially lower than the Verbal IQ. The third group was characterized by relatively mild academic disability, a mild degree of attention deficit and no substantial discrepancy between Verbal and Performance IQs. It was suggested that the differing patterns between the first two groups may be based to some extent on asymmetries in information processing skill levels mediated by the two cerebral hemispheres. The study therefore provides some support for the view that the LNNB has the capability of classifying learning disabled individuals with satisfactory external validity. However, the internal validity of the clustering remains to be established through the acquisition of larger samples. Furthermore, the small sample utilized here only provides suggestive evidence of the existence of the three subgroups described. These findings should not be overinterpreted in the direction of suggesting that all learning disabled adults fall into one of these subgroups.

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Figure Caption

Figure 1 Cluster Dendogram for 25 learning disabled adults.

Figure 2 Mean LNNB profiles for the three clusters

Table 1

Analysis of Variance Results for Comparisons of the Three Clusters on WAIS-R and WRAT Variables

Variable	Cluster 1 M	Cluster 1 SD	Cluster 2 M	Cluster 2 SD	Cluster 3 M	Cluster 3 SD	F	p
WAIS-R Verbal IQ	77.0	3.9	89.7	10.6	95.7	8.9	11.0	<.001
WAIS-R Performance IQ	88.6	11.4	73.5	9.1	97.8	15.4	6.8	<.01
WAIS-R Full Scale IQ	81.3	4.3	80.8	7.1	96.0	10.5	9.7	<.001
Information	5.1	1.8	8.5	1.5	8.4	2.2	7.4	<.01
Digit Span	6.0	2.5	5.8	1.0	7.3	1.6	1.7	>.05
Vocabulary	5.3	1.0	7.7	3.0	9.1	2.0	7.3	<.01
Arithmetic	5.3	.8	7.7	2.0	7.9	1.3	8.7	<.01
Comprehension	6.7	2.0	7.8	2.7	11.3	3.0	7.6	<.01
Similarities	6.3	1.5	8.7	3.6	10.3	3.2	4.1	<.05
Picture Completion	8.0	2.4	6.2	1.7	10.3	3.1	5.2	<.05
Picture Arrangement	8.4	2.3	6.5	3.7	9.9	1.8	3.8	<.05
Block Design	8.4	1.8	5.8	1.5	10.1	2.2	9.8	<.001
Object Assembly	9.7	1.9	5.8	2.0	9.7	2.1	8.2	<.01
Digit Symbol	5.7	2.2	5.2	2.3	9.0	2.5	6.9	<.01
WRAT-Reading	4.0	1.1	6.9	1.0	8.4	1.6	23.6	<.001
WRAT-Spelling	2.8	.7	6.3	2.5	7.2	1.9	13.1	<.001
WRAT-Arithmetic	3.6	.6	5.7	1.5	6.7	1.5	12.9	<.001

Table 2

Multiple Comparison Results (Scheffè Test, $p<.05$) for WAIS-R and WRAT Variables Among The Three Clusters

Variable	Comparisons[1]
WAIS-R Verbal IQ	1 2 3
WAIS-R Performance IQ	2 1 3
WAIS-R Full Scale IQ	2 1 3
Information	1 3 2
Vocabulary	1 2 3
Arithmetic	1 2 3
Comprehension	1 2 3
Similarities	1 2 3
Picture Completion	2 1 3
Picture Arrangement	2 1 3
Block Design	2 1 3
Object Assembly	2 3 1
Digit Symbol	2 1 3
WRAT Reading Grade Level	1 2 3
WRAT Spelling Grade Level	1 2 3
WRAT Arithmetic Grade Level	1 2 3

[1] Clusters sharing the same underlining do not differ from each other.

Table 3

Analysis of Variance Results for Comparisons of the Three Clusters on Selected LNNB Factor Scales

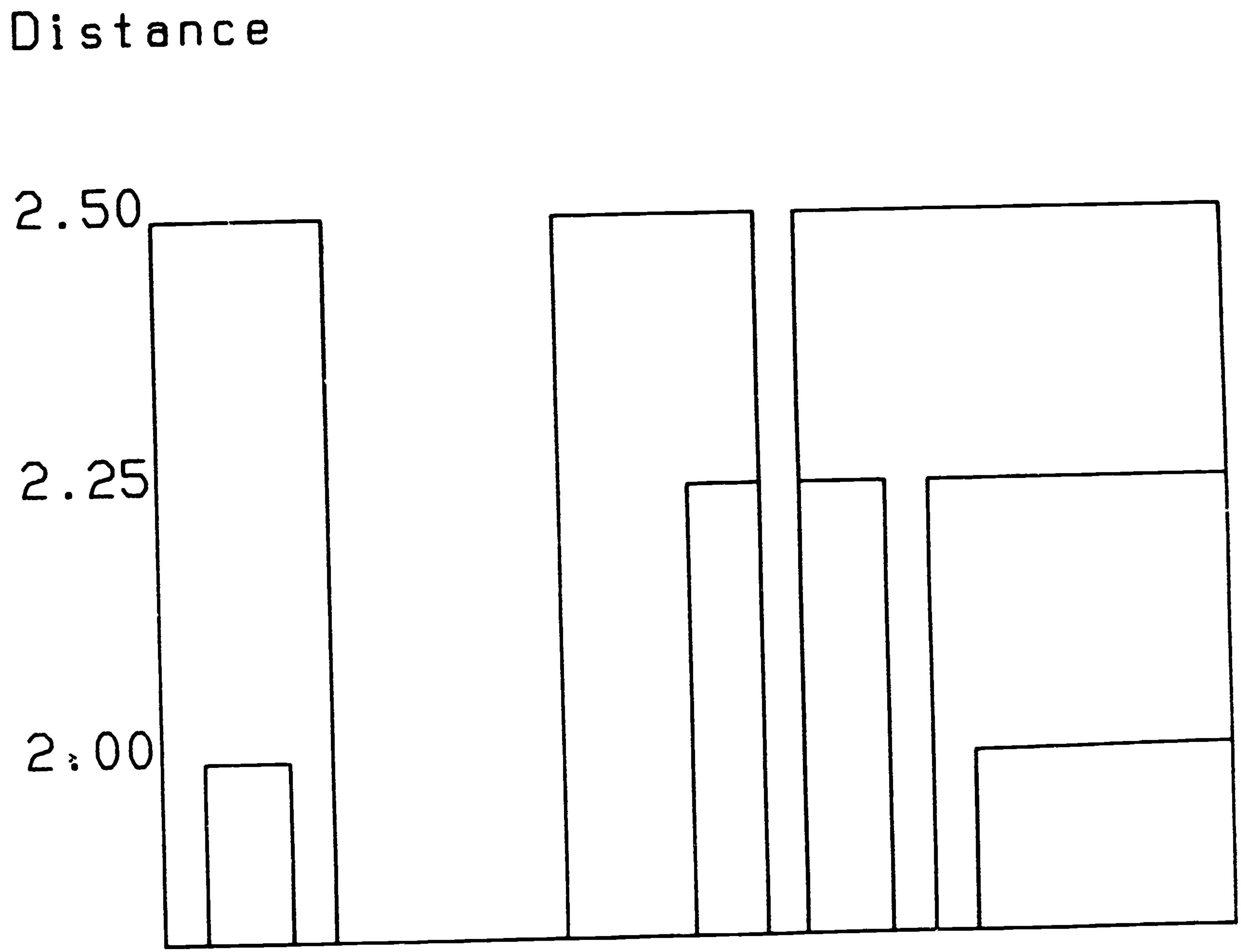
Factor Scale	Cluster 1		2		3			
	M	SD	M	SD	M	SD	F	p
Rh1-Rhythm amd Pitch Perception	61.9	7.7	69.3	5.1	48.1	9.3	15.5	<.001
Rc2-Relational Concepts	69.7	20.6	68.8	15.2	51.4	9.1	4.8	<.05
Rc4-Verbal-Spatial Relationships	69.4	39.3	81.3	25.8	60.5	31.1	.8	>.05
Rg1-Reading Complex Material	73.3	7.3	60.5	5.9	54.8	7.6	14.9	<.001
Rg2-Reading Simple Material	83.0	21.0	56.3	8.8	53.3	13.2	9.3	<.001
W1 Spelling	80.4	6.2	61.0	9.9	56.6	9.1	17.5	<.001
A1 Arithmetic Calculation	82.6	7.1	56.3	12.0	56.1	10.3	17.6	<.001
A2 Number Reading	90.9	17.3	55.3	11.4	51.0	9.6	23.9	<.001

Table 4

Multiple Comparison Results (Scheffé Test, $p < .05$) for Selected LNNB Factor Scales Among the Three Clusters

Factor Scale	Comparisons [1]
Rh1-Rhythm and Pitch Perception	3 1 2
Rc2-Relational Concepts	3 2 1
Rg1-Reading Complex Material	3 2 1
Rg2-Reading Simple Material	3 2 1
W1-Spelling	3 2 1
A1-Arithmetic	3 2 1
A2-Number Reading	3 2 1

[1] Clusters sharing the same underlining do not differ from each other.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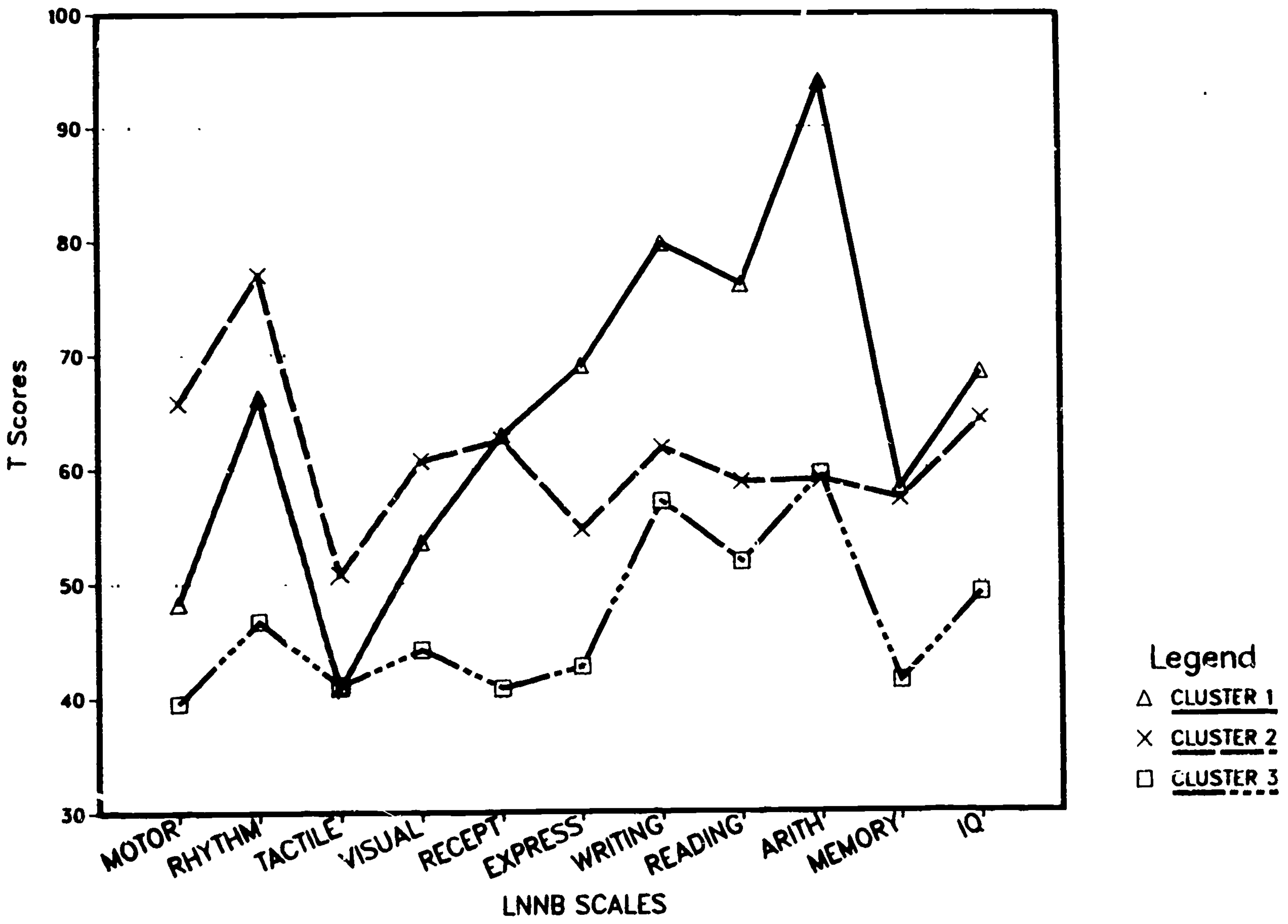

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LNNB SCALES
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CLUSTER 1
CLUSTER 2
CLUSTER 3

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