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Determination of the subtypal composition of several samples of learning-disabled children selected on the basis of WISC FSIQ IQ level: A neuropsychological, multivariate approach.

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DETERMINATION OF THE SUBTYPAL COMPOSITION OF SEVERAL SAMPLES OF LEARNING DISABLED CHILDREN SELECTED ON THE BASIS OF WISC FSIQ IQ LEVEL: A NEUROPSYCHOLOGICAL, MULTIVARIATE APPROACH

by

Gerald T. McFadden

A Dissertation
submitted to the
Faculty of Graduate Studies and Research
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I dedicate this dissertation to my loving parents, Desmond and Sophie. Their support made this work possible.

ABSTRACT

At this point, the research efforts of many investigators of learning disabled children have most often included only those children who could be considered learning disabled after excluding all other possible reasons for their academic difficulties. These studies typically exclude all children who are considered low functioning (i.e., low-IQ), emotionally disturbed, environmentally deprived, brain damaged, and hearing or visually impaired. The purpose of the present study was to investigate the subtypal composition of various samples of learning disabled (LD) children selected on the basis of WISC FSIQ level. The issue of the adequacy of the traditional exclusionary definition of LD children was investigated in the present study. Two samples of LD children were selected from a population of 4800 children referred for neuropsychological assessment. Sample A (n=1200) contained children usually excluded from LD studies (e.g., emotionally disturbed). This sample contained children who exhibited a relatively wide range of IQ values (i.e., WISC FSIQ 60-120). Sample A was initially subtyped on academic measures (i.e., WRAT subtest scores) in an attempt to provide statistically derived classifications of learning disability. This initial analysis was referred to as Phase I. The LD

children in these Phase I subtypes were then cluster analyzed on 12 measures of neuropsychological abilities in order to further delineate their adaptive strengths and weaknesses. These analyses were referred to as Phase II. In this set of analyses Lorr's (1983) procedure for clustering first for profile shape and then for profile elevation was employed. A second set of samples were constructed on the basis of WISC FSIQ ranges from Sample B (n=882). With the exception of low-IQ children all other types of unusual children were excluded from Sample B (WISC FSIQ 70-110). Four subsamples corresponding to WISC FSIQ ranges 70-80, 81-90, 91-100, and 101-110 were selected from Sample B and cluster analyzed with respect to 12 measures of neuropsychological abilities. Each subsample (n=70) was cluster analyzed to determine if differences in subtype number and subtype structure would emerge as a result of WISC FSIQ level. These analyses were referred to as Phase III in the present research.

Four WRAT subtypes emerged from the cluster analyses of Sample A (n=1200) in Phase I. WRAT subtypes #1, #2, and #4 were considered very heterogeneous with respect to the 'types' of children that they contained. The expectations for the Phase I analyses were largely unsupported. It was the case that the Phase I analyses did not yield strong evidence either for or against the utilization of an

exclusionary LD definition. Nine subtypes emerged from the Phase II analyses. Five of these subtypes contained relatively few low-IQ children. However, only one of these subtypes contained a majority of these low functioning children. Sixteen subtypes emerged from the cluster analyses of the Sample B subsamples. At least two profile shapes were found which occurred within each of these subsamples regardless of WISC FSIQ range.

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CHAPTER I

INTRODUCTION

The purpose of this paper is to investigate the subtypal composition of various samples of learning disabled (LD) children selected on the basis of WISC Full Scale IQ (FSIQ) level. This study attempted to address at least two outstanding issues in LD research. One primary issue concerns the use of an appropriate IQ level as a "cut-off" score for separating LD children from those with "below-normal" or "borderline" cognitive abilities. Many studies employing the WISC have used a FSIQ of 80 or 85 as the cut-off point (e.g., Fisk & Rourke, 1979; Petrauskas & Rourke, 1979). Children with FSIQ < 80 or FSIQ < 85 have generally been excluded from further analysis in the majority of LD investigations. This issue is most often discussed within the context of an exclusionary definition of LD children (e.g., Fletcher & Morris, 1986; Siegel & Heaven, 1986). One goal of the present study was to determine if any of these "borderline" children would be statistically classified into a subtype whose members would generally be considered simply as either LD or "low-functioning" children. A second goal of the present study was to investigate the effect of variation in IQ level (psychometric intelligence) on subtype structure. One might infer that subtype variations will also occur as IQ changes; however, it may be that some subtype variations (e.g., number of members, number of subtypes) may not be as significant as changes that could result with respect to patterns of neuropsychological abilities. In other words, if IQ changes significantly affect subtypal structure, then one would expect some variation in the neuropsychological abilities of members of particular (new) subtypes. The hypotheses arising from these two general issues which are investigated in the present study are outlined following a selective review of learning disability classification studies to date.

As research in learning disabilities has progressed, it has become apparent to a number of investigators (e.g., Applebee, 1971; Benton, 1975; Rourke, 1978) that learning disabilities in children do not constitute a homogeneous entity resulting from some underlying single factor. Instead, many contemporary researchers have attempted to delineate homogeneous subtypes from within the large heterogeneous population of LD children.

The search for reliable subtypes of learning disabilities is the point of departure for the present paper. An attempt is made to provide a review covering three types of attempts by researchers (i.e., clinical-inferential, formation of WRAT typologies, statistical) to form homogeneous subtypes of children experiencing learning difficulties. As a first step, this paper highlights the issues in dyslexia research with regard to the traditional 'unitary deficit' approach. Problems of definition and then classification are addressed in turn, followed by a discussion of methodological issues.

For the most part, investigations of learning disabilities have concentrated on children with reading problems. Some researchers have presented cases of arithmetic disability considered as an independent learning difficulty separate from reading disabilities (e.g., Slade & Russell, 1971). In one study, Goodstein and Kahn (1974) factor analyzed a group of LD children's achievement test data and demonstrated separate factors of arithmetic computation and reading achievement. They reported that these factors were independent so that one could not reliably predict arithmetic computational skill from knowledge of reading level, and vice versa. More recently, Rourke and his associates (Rourke & Strang, 1983; Strang & Rourke, 1983, 1985a, 1985b) have presented evidence that arithmetic impaired children can be differentiated from dyslexics on the basis of neuropsychological as well as adaptive abilities. Therefore, attempts to investigate subtypes of arithmetic disabilities are covered in this review. Reading, spelling, and arithmetic disabilities are generally referred to as 'learning disabilities' (LD) unless otherwise noted.

Unitary Deficit Approach and Definitional Problems

As Benton (1975) noted in his thorough review, much of the previous research in dyslexia attempted to uncover a single underlying cause for the disorder. Various researchers have postulated a large variety of underlying defective processes such as the following: improper control of eye movements (Pavlidis, 1981); motivational characteristics (Torgeson, 1977); cross-modal sensory integration (Birch & Belmont, 1964); and verbal mediation deficiencies (Vellutino, 1977, 1978). Implicit in these research attempts is the notion that childhood reading disability is a homogeneous entity and that by comparing LD children with normals the underlying deficient component or process will become apparent. However, as Fisk and Rourke (1983) have indicated, it is possible to show differentiated performances between LD children and normals on most measures of linguistic, perceptual, and cognitive functioning.

While the research representing this 'unitary deficit approach has generated a large 'catalogue' of variables which distinguish the performances of LD and normal children (Rourke, 1978) these investigators have not determined that any of these variables actually cause reading, spelling, or arithmetic disorders and instead have demonstrated correlational relationships (Ownby, 1985). This unsystematic exploration of all the ways LD children are supposedly different from normals is considered by several authors (e.g., Applebee, 1971; Benton, 1978; Rutter, 1978) to have resulted from the tendency of earlier researchers to view children with learning disabilities and dyslexia in particular as a homogeneous group, differing only in the degree or severity of their learning problem. Although some investigators (e.g., Applebee, 1971; Maliphant, Supramaniam, & Saraga, 1974; Vernon, 1977; Wiener & Cromer, 1967) have suggested that LD children may differ in terms of multiple dimensions, such as an inability to automatize appropriate grapheme-phoneme correspondences or a difficulty with proper sequencing of visual and auditory information, few early studies were designed to uncover differences between different groups or types of poor readers.

These early methodological problems are also related to the issue of defining such subtypes of LD children directly in terms of easily recognizable characteristics or behaviours. Children have most often been identified as learning disabled only after other possible (assumed) causes of reading failure, such as low IQ, emotional disturbance and lack of adequate educational opportunities, have been ruled out. This constitutes an exclusionary definition of learning disability and does not specify why children are performing poorly.

As Fletcher and Morris (1986) have indicated, exclusionary definitions have varied widely between studies and, therefore, so have the sample characteristics. These earlier research efforts failed to exploit the variability occurring within their selected samples as indications of an underlying multiple taxonomy. In the following sections, attempts by more recent researchers to uncover the taxonomic structure of learning disabilities are illustrated. Several representative studies of each approach are described. The problems associated with defining learning disabilities are addressed in more detail following the review of subtype attempts.

Classification by Clinical-Inferential Methods

Several researchers attempted to form homogeneous subtypes of LD children on the basis of theoretical, a priori considerations and visual inspection of test performance (Lyon, 1983). For example, Johnson and Myklebust (1967) proposed at least three main subtypes of learning disorders: a group experiencing problems with visual discrimination, letter reversals, and reading inversions; a group exhibiting difficulty with phonetic analysis, synthesis, and auditory sequencing; and a group deficient in visual-spatial organization and integration who experienced problems with arithmetic but with good reading skills. These authors were also very astute in describing a nonverbal disorder of learning where children were deficient in social perception. Although very much in the forefront of learning disabilities theorizing, these authors did not provide explicit directions for determining subtype membership. However, their pioneering attempts served as heuristics for future research efforts.

In one of the very first studies investigating the existence of LD subtypes, Kinsbourne and Warrington (1963) demonstrated that two groups of poor readers constructed on the basis of WISC VIQ-PIQ discrepancies of 20 points or more show different patterns of impairment on a variety of clinical tests. Kinsbourne and Warrington (1963) selected subjects to form two groups (Group 1: n=6, VIQ<PIQ; and Group 2: n=7, VIQ>PIQ). These subjects were assessed on tasks of constructional skill, finger differentiation and order, and judged on writing ability, receptive and expressive language use, and right/left orientation. All members of Group 1 (VIQ<PIQ) evidenced impairment on tests of naming and verbal learning, and three of these subjects exhibited problems with speech reception. None of the Group 2 subjects evidenced problems with the naming and verbal learning tests. All of the children in Group 2 (VIQ>PIQ) experienced difficulty on the constructional tasks while none of the subjects in Group 1 were considered impaired on these tasks. Although Kinsbourne and Warrington (1963) proposed that their Group 1 and Group 2 children experienced underlying difficulties with language and sequential ordering, respectively, their study can be criticised on several grounds.

First, the sample size was quite small (n = 13) and the experimental groups were not constructed to control for possible sex differences. All of Group 1 subjects were male and five of the seven Group 2 subjects were female. Although the influence of the sex variable in learning disabilities research is disputed (e.g., Canning, Orr, & Rourke, 1980; Witelson, 1976, 1977) it is possible that Kinsbourne and Warrington (1963) may have been measuring sex differences in visual-spatial and verbal skills (Hier, 1979). Finally, there were no control groups of normal readers or poor readers with more equivalent levels of verbal and nonverbal abilities. These methodological issues limit the generalizability of this study.

Ingram, Mason, and Blackburn (1970) used exclusionary criteria (Stanford-Binet IQ $\geq$ 80, adequate schooling and home environment, no emotional disturbance) to select 82 LD children (66 boys, 16 girls) from a total of 206 clinic referrals. These children were further divided into a "specific dyslexic" group (n = 62, mean IQ=108, range 81-165), and a "general learning disabilities" group (n = 20, mean IQ=107, range 81-131). The specific dyslexics exhibited difficulties with reading and spelling but performed satisfactorily in mechanical arithmetic. The general learning disabilities group were deficient in all three academic areas. These groups were compared in terms of historical information and neurological status. The specific dyslexics showed less evidence of brain dysfunction than the general group when parental accounts of birth and developmental histories were arbitrarily judged by the authors. The children were also rated in terms of the outcome of an EEG and neurological examination. Again, the general group was thought to exhibit more evidence of brain dysfunction. However, the authors reported that the specific dyslexic made significantly more "audio-phonic" errors (e.g., confusion of vowel sounds) than the general group.

Ingram et al., (1970) also noted that a larger number of the specific dyslexic children exhibited more severe IQ-reading achievement discrepancies than did children in the general learning disabilities group. They concluded that severe specific reading difficulty could be present without any clinical evidence of brain abnormality, but that general educational difficulties may be associated with brain dysfunction. This study is important in that it demonstrated the usefulness of comparing learning disability groups which varied in terms of the level of academic performance in arithmetic.

Motivated by their clinical observations of different deficit clusters in children with similarly severe reading difficulty, Mattis, French, and Rapin (1975) attempted to identify dyslexic subtypes by interpretation of patterns of neuropsychological test scores. They presented a variety of measures to children in three selection categories: brain damaged readers (n = 31); brain damaged dyslexics (n = 53); and developmental dyslexics (n = 29). Visual inspection of the subject profiles revealed similar performances between the developmental dyslexics and brain damaged dyslexics, and what appeared to be three symptom clusters across these two groups. Mattis et al. (1975) were able to classify 90% of the dyslexics as members of either; a Language Disorder group (anomia, comprehension and sound discrimination difficulties), an Articulatory/Graphomotor Dyscoordination group (speech articulation and sound blending difficulties, tremor on copying task), and a Visual-Perceptual Disorder group (VIQ-PIQ $\geq$ 10 points, Raven Matrices < PIQ, poor performance on the Benton Visual Retention Test). None of the dyslexic children exhibited patterns of neuropsychological performances consonant with classification in more than one symptom cluster (i.e., subtype). The importance of this study was the successful demonstration of classification of a majority of dyslexics into three mutually exclusive subtypes on the basis of visual inspection of individual profiles of neuropsychological test results.

In a cross-validation study, Mattis (1978) reported classifying 78% of 163 dyslexic children into the above three subtypes with the same criteria. However, unlike the Mattis et al., (1975) study, he found eleven subjects who could have been classified into either of two subtypes although none were placed in all three. Using the same methodology, measures, and some additional tests, Denckla (1977) was able to classify most of her dyslexic sample (92%); 65% (n = 34) into a Language Disorder group, 12% (n = 8) into an Articulatory-Graphomotor group, but only two of the 52 subjects into a Visual-Perceptual group. It is most noteworthy, however, that several of the children could be classified into more than one group. For example, both of the Visual-Perceptual dyslexics were also language-impaired and exhibited anomia. In addition, Denckla (1977) thought that the Language Disorder group could be further subdivided with respect to anomia, phonemic sequencing errors, verbal memorization, and subtle right-sided neurological signs (e.g., gait anomalies, tremor). Mattis (1978) found 16 children (10%) who could have been categorized as Denckla's "phonemic sequencing" disorder group. Mattis attributed the low incidence of Visual-Perceptual dyslexics in the Denckla study to the small sample size.

The most widely known of the clinical-inferential approaches was proposed by Boder (1971, 1973) as a "direct" means of diagnosing reading disability. By direct diagnosis, she was referring to categorization of individual LD children on the basis of the frequency of certain types of errors that these children make on an oral reading test and a written spelling test. This is to be contrasted with use of exclusionary definitions and what Boder (1973) refers to as "indirect" diagnosis where psychometric measures of cognitive abilities thought to underlie the reading process are employed.

Boder (1971, 1973) assumes that her method is tapping two basic components of the reading process: a visual-gestalt function which underlies a child's ability to develop a sight vocabulary and a auditory-analytic function which is primary to phonemic word analysis skills. In her formulation, reading disability is present when a child's reading and spelling performance yields evidence of deficiencies in either the visual-gestalt function or the auditory-analysis function, or both. Based on these conceptions Boder (1973) proposed that there were three subtypes of developmental dyslexia:
(1) a dysphonetic dyslexia, identified by poor decoding ability, reading errors that are typically word substitutions, and phonetically inaccurate spelling errors; (2) a dyseidetic dyslexia characterized by a limited sight vocabulary, phonetically accurate spelling errors, and letter and word reversals in both reading and writing; and (3) a mixed dysphonetic-dyseidetic type where the errors reflect the

combined cognitive deficits of the previous two groups.

In Boder's (1973) procedure the child is presented with a set of phonetic and nonphonetic words on flash cards to read. For each grade level there is a separate list of 20 words. Words read aloud within 10 seconds are 'known' words which are part of the child's sight vocabulary. Words not read or read after 10 seconds are considered 'unknown' words. The child is required to continue attempting to read sets of increasingly difficult words until 50% of the words on a list cannot be read. The examiner then constructs a spelling test of 10 'known' words. The child is required to spell these words to dictation. Inspection of the child's spelling reveals the number of correct attempts and phonetically inaccurate misspellings for the two 'types' of words.

Determination of the child's reading-spelling pattern depends on the following: reading level, type of reading errors, amount of correctly spelled sight vocabulary, number of phonetically inaccurate misspellings, presence of 'bizarre' spelling errors, number of 'known' nonphonetic words misspelled, number of correctly spelled 'unknown' phonetic words, and "other" indications (e.g., letter reversals, semantic substitutions when reading).

Boder (1973) gives descriptions of the subtypes but, unfortunately, no explicit instructions for determining subtype membership. This appears to be determined, for the most part, by the degree to which the child's spelling errors are phonetically accurate or inaccurate, and the presence of unusual or bizarre misspellings. There are no frequency expectations for these various spelling productions given by Boder (1971, 1973) for each subtype.

Holmes and Peper (1977) investigated Boder's claim that poor and good readers would differ in terms of the frequency of occurrence of qualitative types of spelling errors. They constructed nine error categories (e.g., phonetically accurate, vowel deletion, consonant deletion) and tested 25 poor readers and 25 good readers with the WRAT Spelling subtest. These two groups were found to differ significantly in terms of number of misspellings, but not in terms of any of the nine types of errors. Visual inspection of the children's spelling productions yielded no evidence of differences in the number of reversal errors between the two reader groups. Holmes and Peper (1977) concluded that there was no support for Boder's (1973) claim of distinct differences in the error patterns of normal versus poor readers.

In another study which attempted to investigate Boder's subtypes using standard lists of common words, Camp and Dolcourt (1977) experienced great difficulty distinguishing between normal readers and dyseidetic dyslexics. They compared the performance of normal (n = 34) and LD children (n = 16) on the WRAT Reading subtest and Boder test in terms of obtained grade level. These two measures were found to correlate highly (r = .95). However, 14 of the children who would be classified as dyseidetics on the basis of misspelling known nonphonetic words correctly spelled more than 50% of their sight vocabulary as would a normal reader. The nonphonetic words were discarded in the category formation process and these children were subsequently classified as normals. Of particular interest was the finding that 11 of 24 children reading at least one year below grade level on the WRAT were classified as having a normal reading-spelling pattern with the Boder procedure. These children, who were one year below grade level, made significantly more 'bizarre' misspellings and fewer phonetically accurate misspellings than did other subjects, regardless of classification. The authors also had difficulty classifying dysphonetic dyslexics separately from the dysphonetic-dyseidetic type.

Using the Camp and Dolcourt (1977) modification of the Boder procedure, Rosenthal, Boder, and Calloway (1982) reported on an attempt to evaluate the three subtypes with event-related potential (ERP) correlates. Thirty-three dyslexic adults were subtyped, resulting in the following groups: 12 dysphonetics, 11 dyseidetics, 10 mixed. Twelve control subjects were also assessed in an ERP signal recognition task. While attending to visual or auditory target stimuli, the ERPs of the dysphonetics and dyseidetics were recorded at P3 (left-parietal) and P4 (right-parietal) electrode placements. For each subject, the ERP value at the P4 recording site during attention to the visual stimulus condition was compared to the ERP value at the P3 recording site during the auditory stimulus condition. Low ERP values at P3 were correlated with high values at P4 for four of 12 dysphonetics. High ERP values at P3 were associated with low values at P4 for four of 11 dyseidetic subjects. These distributions were found to be significant with a chi-square statistic; construct validity of the Boder typology was inferred on this basis. However, no other information was presented distinguishing these two subtypes from normals or mixed dyslexics. For example, the ERP values at P4 during the auditory task were not contrasted with the ERP values at P3 during the visual stimulus condition for the dysphonetics or dsyeidetics.

More recently Boder and Jarrico (1982) have attempted to formalize the procedure for classifying children as either normal readers, nonspecific problem readers, dysphonetics, dyseidetics, or mixed dysphonetic-dyseidetic type. This new method involves classification on the basis of: (i) a derived Reading Quotient; (ii) percentage of correctly spelled known words; and (iii) percentage of unknown words spelled as good phonetic equivalents (GFE). Each list of words presented is normed for grade-level difficulty and composed of 10 phonetically regular words and 10 phonetically irregular words. Several studies employing these new procedures and materials for subtype determination are reviewed in the next section.

Telzrow, Century, Whitaker, Redmond, and Zimmerman (1983) classified a sample of 30 LD children (18 white, 12 black) using the Boder and Jarrico (1982) method. Their sample subjects ranged 7.3 to 12.7 years in age; WISC-R VIQ (84-118), PIQ (80-135), and FSIQ (83-121). Four subjects (13%) were classified as normal readers, one subject (3%) was categorized as nonspecific reading disabled, 19 (63%) as dysphonetic, two (7%) as dyseidetic, and four (13%) as the mixed type. Since the distribution of children was similar by subtype to that reported by Boder and Jarrico (1982), these authors concluded they had provided some evidence for the reliability of the new procedure.

Chi-square analyses yielded no evidence of subtype differences on some demographic variables (age, length of time in LD placement). However, all members of the normal reading subtype were black children. Unfortunately, the authors suggest from these findings, "that the Boder may be more sensitive to neurologic substrates associated with reading performance than other tests, which may be more greatly influenced by sociocultural factors" (p. 429). Since there was no control group of normal readers also classified by the Boder method, it may be just as likely that the 'normal' subtype was actually a misclassification. In any case, to argue that other tests are culture-bound and since the Boder classified four black children as having normal reading-spelling patterns, it must be more sensitive to brain functioning is illogical.

On the basis of hand writing preference, three children were considered left-handed. Two of these left-handers were located in the mixed subtype, and both performed better with their preferred hand on a test of finger tapping. This finding was interpreted with respect to Geschwind and Behan's (1982) notion of deficiency associated with left-handedness and in the present context apparently represented a confirmation of Boder's (1973) suggestion that the mixed type would show more neuropsychological impairment. However, it is unwise to conclude impairment on the basis of poor performance on one measure of neurocognitive ability (Reitan, 1974). In this regard, Satz and Soper (1986) have recently suggested that the association between dyslexia and left-handedness remains to be demonstrated as much of the empirical evidence has yielded null results. It was also the case that the two other mixed subtype members showed no hand superiority on the finger tapping test and they were right-handed. In general, the results of this study support Boder's classification scheme only to the extent that similar subtypes were replicated by independent investigators.

Nockleby and Galbraith (1984) used the revised Boder procedure to form subtypes in a sample of 26 reading disabled children (WISC-R FSIQ $\geq$ 90). Thirteen (50%) were classified as dysphonetics, nine (35%) as nonspecifics, two (8%) as dyseidetics, and two children remained undetermined. The control group, dysphonetics and nonspecifics, were then presented with a set of external measures selected to assess analytic-sequential versus simultaneous-gestalt processing. The authors predicted that the dysphonetics would perform poorly on the analytic-sequential tasks, and they expected the nonspecific group to perform as well as the controls on both types of tasks.

In general, the nonspecifics appeared to have intact processing skills in both modes as they performed as well as the controls on seven out of the eight measures. However, they performed significantly better than the dysphonetics on only one task, and as poorly as the dysphonetics on one other task, suggesting that both of these groups were experiencing some type of difficulty with the phonetic aspects of language. This finding raised the possibility that members of Boder's nonspecific subtype do not apply phonics skills in a normal manner as she has indicated, even though they obtain a normal reading-spelling pattern on her test.

According to her assessment criteria (Boder & Jarrico, 1982), the major diagnostic difference between normal readers and nonspecifics is that the former obtained a reading quotient equal to or greater than 100 and the latter less than 100. Unfortunately, no attempt was made to subtype the control group of normal readers and no test data was reported for the dyseidetics and unclassified children. This study, therefore, does not show construct validity for the Boder Test. We do not know if the normal readers would be diagnosed as members of a reading disabled subtype, and dissociation between the dysphonetic and dyseidetic subtypes on the two categories of dependent measures was not shown.

Construction of WRAT Typologies

The formation of subtypes of LD children on the basis of their patterns of performance on the reading (word-recognition) spelling, and arithmetic subtests of the WRAT has been suggested by Rourke (1975, 1978, 1982). The motivation underlying a series of WRAT typology studies by Rourke and his associates (e.g., Rourke & Finlayson, 1978; Rourke & Strang, 1978; Strang & Rourke, 1983) was to determine if a relationship between variations in patterns of academic abilities and variations in brain-related abilities could be established. In these studies, three groups of disabled learners were compared on a large variety of neuropsychological measures, covering language, motor, tactile, and visual-spatial skills. The three WRAT groups were constructed as follows:

<u>Group 1</u>. (Reading-Spelling-Arithmetic disabled) WRAT Reading, Spelling, and Arithmetic centiles $\leq$ 18 and all grade-equivalent scores were at least 2.0 years below expected grade placement. There was no more than a 0.9 year grade-equivalent discrepancy between any two of the WRAT subtests.

<u>Group 2</u>. (Reading-Spelling disabled) WRAT Reading and Spelling centiles $\leq$ 14 and the Reading and Spelling grade-equivalent scores were at least 1.8 years below the WRAT Arithmetic grade-equivalent score.

<u>Group 3</u>. (Arithmetic disabled) WRAT Reading and Spelling grade-equivalent scores were in the average range and exceeded WRAT Arithmetic grade-equivalent scores by at least 2.0 years.

These children (n = 45) were all right-handed, 9 to 14 years-old, and exhibited WISC FSIQs in the 86 to 114 range.

When Rourke and Finlayson (1978) and Rourke and Strang (1978) compared the neuropsychological performances of these three subtypes it was apparent that Group 1 children found many of the tasks problematic and experienced particular difficulty on verbal measures. Group 2 children also experienced difficulty with language-related tasks but exhibited better nonverbal skills. The Group 3 children showed well developed language abilities within the context of poorly developed tactile-perceptual, psychomotor, and visual-spatial skills.

Strang and Rourke (1983) reported further deficiencies in Group 3 children in comparison to Group 2 children on the Halstead Category Test. Of the six subtests of the Category Test, Group 3 children performed significantly poorer than the Group 2 subjects on subtests #4 and #6 as well as on the overall total score. These Group 3 children were thought to make more errors on subtests and items that required "a substantial degree of 'higher order' visual-spatial analysis" (Strang & Rourke, 1985b, p. 173). Inspection of their errors on the WRAT Arithmetic subtest revealed a wide variety of difficulties with: (a) spatial organization, (b) attention to visual detail, (c) poor judgement and reasoning, (d) ability to shift psychological set, (e) application of correct procedures, (f) deployment of graphomotor skills, and (g) memory.

Siegel and Linder (1984) compared the performance of two WRAT constructed groups on short-term memory tasks which required phonemic coding. The reading-disabled group (RD) consisted of children with WRAT Reading below the 21st centile, while the arithmetic-disabled group (AD) scored below the 21st centile on the WRAT Reading subtest. The younger RD children experienced difficulty in all task conditions while the older RD children recalled rhyming letters best although not as well as normal children. The AD children experienced difficulty with rhyming as well as non-rhyming letters when they were presented visually, but performed similar to the normal controls when the letters to be recalled were delivered via the auditory modality. This study yielded further evidence of a dissociation between AD and RD youngsters and was thereby supportive of the WRAT typology approach initiated by Rourke and associates. Unfortunately, Siegel and Linder did not report the WRAT spelling levels of their subjects so we do not know how many of the RD subjects were Rourke's Group 1 or Group 2 children.

More recently, Fletcher (1985) constructed four WRAT subtypes of disabled learners and compared their performance on nonverbal and verbal selective reminding tasks derived from Buschke's (1974) procedure. Reading-Spelling-Arithmetic (RSA) disabled children exhibited all three WRAT scores below the 31st centile. Reading-Spelling (RS) disabled children obtained reading and spelling centiles less than 31 while their arithmetic score was above the 30th centile and at least one-half standard deviation above their reading score. Spelling-Arithmetic (SA) disabled children had spelling and arithmetic scores below the 31st centile while reading scores were above the 39th centile. Arithmetic (A) disabled children exhibited reading and spelling scores above the 39th centile, while arithmetic scores were below the 31st centile and at least one standard deviation below the reading score. The results were consistent with previous research (e.g., Rourke, 1978; Siegel & Linder, 1984) in that the RSA group was deficient in both verbal and nonverbal selective reminding, the RS group found verbal material most problematic, and the A group showed poor performances with nonverbal stimuli. The SA group had not been studied prior to this research effort and Fletcher reported that they performed most like the A group of disabled learners.

Ozols and Rourke (1988) investigated the neuropsychological functioning of younger WRAT defined subtypes constructed similarly to those in the Rourke and Finlayson (1978) study. Group 1 and 2 subjects performed poorly compared to Group 3 on measures of linguistic and auditory-perceptual abilities. Group 3 children performed in an inferior manner compared to the other two groups on a majority of the visual-perceptual tasks presented. In particular, Group 3 children performed in a significantly impaired fashion on the WISC Object Assembly subtest. This study successfully demonstrated differing patterns of neuropsychological performance for WRAT subtypes of young LD children.

This approach is considered very valuable by some authors (e.g., Fletcher, 1985) due to the widespread use of the WRAT and its ease in administration and interpretation. Satz and Morris (1981) have suggested that statistical subtyping should proceed following initial categorization with the WRAT. Siegel and Heaven (1986), while supportive of the WRAT as a useful measure of achievement, have been critical of the use of grade-equivalent scores in several of these studies to define the subtypes. Irrespective of this point, it is the case that Rourke and his associates have demonstrated differences between WRAT subtypes on measures external to the subtype construction. In this sense, these studies also demonstrate external validity of the WRAT subtypes (Fletcher, 1985).

Classification by Statistical Methods

In this section, the attempts by various investigators to delineate learning disability typologies by empirical means are reviewed. These analyses have generally employed a wider variety of measures and larger sample sizes than have the clinical-inferential approaches. The use of sophisticated multivariate techniques for classification is the hallmark of these studies and is considered by many in the field (e.g., Adams, 1985; Fletcher & Satz, 1985) to be the most promising methodology for identifying distinct LD subtypes. Since different investigators have used a variety of multivariate techniques applied to various types of data (academic, neuropsychological), the research reviewed in this section is grouped according to the individuals involved (e.g., Doehring, Rourke, Lyon, Satz, & Fletcher).

There have been many different attempts at statistical determinations of LD subtypes. One of the earliest attempts at multivariate subtyping of learning disabled children was carried out by Smith and Carrigan (1969). In this study, the lowest 10% of students in grades 3 to 6 (n = 40) were tested at a paediatric clinic with a series of tests tapping a wide range of skills (e.g., Spelling, WISC Maze, Coding, & Digit Span subtests, Stanford-Binet Word Fluency). A cluster analysis categorized 32 of the children into five subtypes. The first subtype profile was interpreted as indicating deficiencies in cognitive-associational skills (vocabulary, maze test, visual blending) and the second subtype was thought poor in cognitive-perceptual abilities (visual memory, WISC Coding). No clear pattern was noted in the third subtype profile, while the fourth and fifth subtype profiles were superior in performance to all other groups. The authors also collected medical data on each child (e.g., blood type) and attempted to account for each subtype in terms of a model of cholinesterase-acetylcholine imbalance at the synaptic level.

Another early study using cluster analysis was that of Naidoo (1972). Data from psychological testing, a developmental history, and a neurological examination were subjected to a single-linkage cluster analysis. Although four subtypes were identified and represented 65 of the 94 dyslexic boys, these subtypes were not definitely separated and were thought by Naidoo (1972) to reflect a "continuum of reading backwardness" (p. 107). Another reason that the groups were difficult to distinguish is that all members performed poorly on the WISC Digit Span and Coding subtests as well as on Sound Blending, thought by other researchers (e.g., Denckla, 1977; Mattis, 1978) to reflect difficulties with sequencing abilities.

Doehring and Associates

Doehring and Hoshko (1977) were the first to attempt to derive homogeneous subtypes of reading disabled children by using Q-factor analysis of performance on measures thought to be closely related to reading ability. They identified three subtypes, successfully classifying 77% of their sample (15 out of 65 Ss were unclassified). Group 1 (n = 12) exhibited slow oral reading on tests involving words and syllables; Group 2 (n = 25) subjects tended to be slow during matching of spoken and written letters; and Group 3 (n = 12) were slow on auditory-visual word and syllable matching problems. Group 1 was thought to resemble a language disorder group similar to those found by Kinsbourne and Warrington (1963), and Mattis et al. (1975). Group 3 appeared similar to Johnson and Myklebust's (1967) auditory dyslexics and to Boder's (1973) dysphonetic dyslexics.

In a follow-up study, Doehring, Hoshko, and Bryans (1979) compared their Q-factor analysis with several cluster analyses of the same subject. They applied cluster analysis to the sample of those subjects (n = 57) which previously formed subtypes with the Q-factor analysis. Although 13 of these 57 children were now considered misclassified by the cluster technique, it was the case that six clusters were formed by the new analysis and compared to only three categories determined by the Q-technique. Any children in one of the clusters who did not correspond closely to the original three Q-factor subtypes were considered misclassified. It is possible that the 6-cluster solution was actually more meaningful, but these subtypes were not interpreted clinically in terms of their reading test performances. At any rate, these authors successfully demonstrated that a majority of reading-problem children could be classified by two different multivariate techniques with good correspondence.

In a major study, Doehring, Trites, Patel, and Fiedorowicz (1981) selected a sample of 88 reading disabled individuals. Sixty-two of them were performing at least two years below grade expectation on the WRAT; 17 were one to two years below, and nine were less than one year below grade expectation. These subjects ranged from 8 to 27 years in age, most (60) obtained Weschler IQs $\geq$ 90, four subjects had both VIQ and PIQ < 90, and 24 subjects had either VIQ or PIQ < 90. The results of testing these subjects with eight achievement measures and 39 measures of reading-related skills were then factor analyzed with the Q-technique. Three subtypes emerged from this analysis: Type O (n = 33), an oral reading deficit group, Type A (n = 22), a group with deficits in auditory-visual association, and Type S (n = 17), who experienced difficulty sequencing syllables and words compared to letters and numbers. Sixteen subjects (18%) were not classified into any of these three types; however, seven of these subjects were at normal or near normal reading levels. Therefore, the majority of reading problem individuals were classified into the three types. A cluster analysis placed all but three members of Type O into one cluster, 18 of the 22 members of Type A into a second cluster, and 12 members of Type S into a third cluster. The correspondence of classification between the Q-factor and cluster analyses was considered quite high since 79% of the subjects were similarly grouped by both methods.

A set of 22 language measures were then presented to each of these subjects and language score profiles for each of the three subtypes were compared. No distinct pattern of language deficits was found for any of the reading disorder subtypes. In general, the subjects with the most severe reading problems had the most difficulty with the language measures. These subjects performed poorest on language measures tapping phonemic segmentation-blending, serial naming, following complex instructions, and morphonemic knowledge.

The subjects in this study were also tested on a set (37) of neuropsychological measures. Clinical interpretation of the average neuropsychological profiles for each reading disability subtype revealed that Type O showed no major deficiencies relative to the other two subtypes. Type A performed poorer than the other two subtypes on the WISC, PPVT, Knox Cube, and Finger Tapping tests, but scored higher on the Category and Tactual Performance Tests. Type S performed below the level of the other two subtypes on Raven's Matrices, Right-Left discrimination, Finger Agnosia, and Grip Strength.

Clinical inspection of the individual profiles of each subtype member revealed again that Type O subjects tended to be the least impaired; however, a small subset of these subjects were found to perform deficiently on verbal short-term memory. Type A individuals were thought to be most impaired on cognitive skills, verbal skills, and finger tapping speed. A small subset of these individuals were particularly deficient in verbal skills. Type S subjects tended to be most impaired on measures of visual nonverbal conceptualization and finger localization.

Several methodological shortcomings of this study should be mentioned. Selection of subjects was done on the basis of grade equivalent--grade level discrepancies. A grade level--grade equivalent difference of two years carries a different meaning at different age levels (Siegel, Levey, & Ferris, 1985). As Gaddes (1976) has indicated, a two year deviation in grade level from grade expectation on WRAT Reading yields fewer reading retarded children at 8 years of age (approximately 7%) than at 18 years of age (25%). Siegel and Heaven (1986) concluded that the grade level discrepancy approach (as employed by Doehring et al., 1981) would not detect younger reading-disabled children. Since Doehring et al. (1981) used a sample with a wide age range (8 to 27 years), this suggests that there may be more reading-disabled children at the older age limit of their sample. Furthermore, Siegel and Heaven (1986) implied that a relatively smaller grade level--grade equivalent discrepancy in younger children may represent at least as significant a problem with reading skills as a larger absolute discrepancy (e.g., two years below grade expectation) in older children.

A Q-factor analysis performed on the neuropsychological data yielded uninterpretable results and thus did not differentiate any characteristic profiles. Unfortunately, the authors do not indicate if they attempted cluster analyses of this data. The use of Q-factor analysis has been criticized by Fleiss and Zubin (1969) because it is difficult to interpret when the subjects load on more than one factor. In the Q-factor analysis of the reading skills data which yielded the three reading Types, 23 of the 72 individuals (32%) assigned to a subtype loaded significantly on more than one factor. This study did, however, consistently replicate the subtypes initially described by Doehring and Hoshko (1977) and Doehring, Hoshko, and Bryans (1979).

Rourke and Associates

A study by Petruskas and Rourke (1979) was the first multivariate attempt at deriving subtypes of reading disabled children on the basis of their performance on neuropsychological tests. The 160 subjects in this study had age ranges of 7 to 8.9 years and WISC FSIQs in the 80 to 120 range. There were 133 reading disabled subjects who scored at or below the 25th centile on the WRAT Reading subtest and 27 normal readers at or above the 45th centile on this measure of reading achievement. The scores from 20 of the measures, which represented six skill classifications as suggested by Reitan (1974), were subjected to a Q-factor analysis.

The subjects were divided into two samples of 80 subjects each to determine if the Q-technique factor analysis could be replicated in a reliable fashion. Five subtypes emerged, but only three of them were replicated across samples. Type 1 (n = 40) subjects (3:1 male-female ratio) exhibited the largest VIQ < PIQ discrepancy on the WISC of any of the subtypes. They had relatively well-developed visual-spatial and eye-hand coordination skills; they performed at mildly impaired levels on word-blending and immediate memory for digits, and performed at moderately to severely impaired levels on verbal fluency and sentence memory. The WRAT Reading and Spelling centile scores of these subjects were somewhat poorer than their Arithmetic centile score. The authors thought that these Type 1 children exhibited evidence of a language disturbance and were similar to the dyslexic group described by Ingram et al., (1970) and to the language disorder group identified by Mattis et al., (1975).

The Type 2 (n = 26) subjects (12:1 male-female ratio) exhibited low scores on all WRAT subtests. These children performed at mildly impaired levels in verbal fluency and concept formation. They performed at moderately impaired levels on finger recognition, sentence memory, and immediate visual-spatial memory. They obtained their lowest WISC scores on the Arithmetic, Coding, Information, and Digit Span subtests of the WISC (often referred to as the 'ACID' pattern) and appeared to have some sequencing difficulties.

Type 3 (n = 13) children (2:1 male-female) exhibited mildly impaired right-hand finger recognition, immediate memory for digits, and eye-hand coordination under speeded conditions. Mild to moderate difficulties were noted on verbal fluency, sentence memory, and immediate visual-spatial memory. Moderate to severe impairments were observed on a concept-formation task which required verbal coding. These children exhibited average visual-spatial abilities, and were thought to be similar to the articulatory and graphomotor disability group identified by Mattis et al., (1975).

The other two subtypes were considered unreliable and are not interpreted in detail here. Subtype 4 contained eight children, seven of whom were from the normal reading group. Type 5 subjects (n = 21) appeared to exhibit the ACID pattern on the WISC and were most similar to Type 2.

Fisk and Rourke (1979) investigated the formation of LD subtypes with Q-factor analysis in a cross-sectional study covering three age-levels: 9-10, 11-12, and 13-14 years old. A total of 264 children, with WISC FSIQs 86 to 114, and all WRAT subtest centile scores $\leq$ 30, were subtyped. There were six subtypes formed at each of the age intervals, and they accounted for 80% of the sample. The subtypes which appeared distinctly similar in terms of visual-spatial configuration and statistical correlations across age levels were combined to form three larger subtypes; these accounted for 54% of the original sample.

Type A (n = 52) children exhibited relatively poor auditory-verbal processing, marked finger recognition difficulties, psychomotor incoordination (in the younger subjects in this group), and normal nonverbal and concept-formation skills. These children also evidenced calculation difficulties (WRAT) and were thought to be similar to the 5- and 6-year-old children described by Satz, Friel, and Rudegair (1974) and to subtype #2 in the Petrauskas and Rourke (1979) study.

Type B (n = 51) exhibited relatively intact tactile and kinesthetic-perceptual abilities, normal visual-spatial skills, and adequate nonverbal problem-solving abilities. They evidenced poor auditory-verbal processing skills and were quite deficient on tasks of sound-blending, sound-symbol relationships, and immediate memory for digits. Type B also exhibited the largest VIQ < PIQ discrepancy of the three groups. These children were thought to resemble the language disorder group of Mattis et al. (1975), Boder's (1973) dysphonetic group, and subtype #1 identified by Petrauskas and Rourke (1979).

Type C (n = 39) was distinguished by outstandingly poor performances in fingertip number-writing perception, moderate impairment in sound-symbol matching and word blending, mild impairment in immediate memory for digits, and adequate nonverbal problem-solving skills and intact visual-spatial abilities. This group was not identified at the youngest age level (9-10 years old) and was interpreted as a variation of Type A that becomes apparent only at the older age levels.

A more recent study by Deluca (1986) involved the application of multivariate analysis techniques to a group of 156 children who obtained WRAT Reading centiles > 40 and Arithmetic centiles < 27. This study was designed to discover if meaningful subtypes of arithmetic disabled children would emerge when their WRAT standard scores were cluster analyzed. All the subjects were between 9.0 and 14.9 years of age and had obtained a WISC FSIQ between 85 and 115. There were 138 males and 18 females in this sample. A variety of cluster analytic techniques (complete linkage, centroid, and Ward's method) were applied to the WRAT data. Four subtypes were derived (containing all subjects); these were compared on the basis of the group profile of performance on the neuropsychological battery.

Subtype #1 (n = 78; 69M, 9F) subjects performed within normal limits on WISC VIQ, PIQ, and FSIQ as well as on the WRAT Reading and Spelling subtests. However, their PIQ tended to be greater than VIQ by about eight points and their WRAT Arithmetic standard score was at the lower limits of the low-average range. Thirty-seven percent of these children were considered emotionally disturbed on the basis of referral information and interpretation of the neuropsychological assessment results. Information obtained from a parental assessment of emotional functioning (Personality Inventory for Children-PIC) suggested that these children were unhappy, fearful, worried, and often moody and withdrawn. These subtype #1 children obtained mild to moderatly impaired levels of performance on measures designed to assess tactile-perceptual skills, expressive language abilities, and conceptual flexibility. Inconsistent performances by these children were evident on tests requiring short-term retention and attention to auditory-verbal and visual-spatial information. Their pattern of difficulties were thought most likely the result of emotional problems rather than central processing difficulties.

Subtype #2 (n = 33; 29M, 4F) children exhibited mean WISC Full Scale, Verbal, and Performance IQs of approximately 100 points. WRAT Reading standard scores tended to be high-average; Spelling and Arithmetic were average and low-average, respectively. Forty-two percent (n = 14) of these children were considered emotionally disturbed. Their PIC elevations characterized them as restless, inattentive, impulsive, disruptive, irresponsible, easily distracted, and resistant to adult authority. They were also thought to evidence poor judgement and study skills, probable poor social and academic adjustment, as well as low frustration tolerance. These children exhibited their worst performances on measures of tactile-perceptual skills (finger agnosia and dysgraphesthesia), and complex psychomotor problem-solving (TPT). They also experienced difficulty on a measure of speeded eye-hand coordination (Pegs) and with immediate memory for sentences and phonemically-cued verbal fluency. The children of Subtypes #1 and #2 were thought to be similar with respect to their academic and neuropsychological test performances. However, they were quite dissimilar in terms of their corresponding PIC profiles, since Subtype #2 children did <u>not</u> evidence elevations on the Depression, Withdrawal, Anxiety, Psychosis and Social Skills scales often associated with 'internalized' psychopathology.

Subtype #3 (n = 8; 4M, 4F) constituted the smallest and youngest of the four subtypes. Their mean WISC FSIQ, VIQ, and PIQs were within the normal range. Their WRAT Reading and Spelling performances were superior and high average, respectively, while their Arithmetic performance was low average. With respect to the neuropsychological measure, this group exhibited poor performances on a test of Finger Agnosia and age-appropriate levels of performance on the TPT and a measure of dysgraphesthesia. Subtype #3 children performed somewhat poorly on measures designed to assess conceptual flexibility, verbal mediation, and symbolic shifting. They also experienced difficulties on several measures of visual-spatial skills (e.g., Target test, WISC Block Design) which were more pronounced than the other subtypes in this study.

Three (40%) of the children in Subtype #3 were considered to be emotionally disturbed. PIC elevations were noted on the Intellectual Screening, Development, Somatic Concern, Depression, Anxiety, Psychosis, and Social Skills scales. These children were thought to be as emotionally disturbed as the Subtype #1 children. Parental concerns regarding these children included difficulties in understanding instructions, forming lasting friendships, withdrawal, and emotional lability.

Subtype #4 (n = 37; 36M, 1F) children were the oldest of the four subtypes (mean age of 12.25 years). WISC Full Scale, Verbal, and Performance IQs were all within the average range; however, there was a 10-point VIQ-PIQ discrepancy in favour of PIQ. They performed worse than the other subtypes on a test of dysgraphesthesia. A test of Finger Agnosia and the third trial of the TPT also proved problematic for these children. They also exhibited difficulties with verbal expression and simple visual-spatial sequencing ability.

Thirty-eight percent (n = 14) of the Subtype #4 children were considered to be emotionally disturbed on the basis of referral information. On the PIC, elevations occurred for the

Achievement, Intellectual Screening, Development, Depression, Delinquency, Anxiety, Psychosis, and Social Skills scales. Parental concerns seemed to be most focused on poor school performance, difficulty with concentrating, clumsiness, and concrete thinking. These children were also depicted as worried, unhappy, and socially isolated. They were thought similar to children described by Levine, Oberklaid, and Meltzer (1981) who exhibited "developmental output failure," characterized by difficulties with tactile-perceptual skills, expressive language problems, and attentional deployment.

This study is important as the first major attempt to apply cluster analytic techniques to children considered primarily arithmetic-disabled. It is also the first investigation to demonstrate external validity for arithmetic subtypes on the basis of personality factors (PIC).

Lyon and Associates

Lyon and Watson (1981) employed cluster analysis to identify subtypes of LD children selected from special education classes. The reading disabled children in this study were cluster analyzed on the basis of their performances on eight measures representing a range of neuropsychological abilities. The LD subtypes which emerged from these analyses were then compared on two measures of reading achievement.

A group of normal readers (NR, n = 50) were selected from regular classes and matched for mean age and mean WISC-R FSIQ with the LD subjects. The reading-disabled children (RD, n = 100, age range 11 to 12.5 years, mean WISC-R FSIQ = 105.7) all exhibited poor performances on the PIAT word recognition and reading comprehension subtests.

The performances of these two groups were compared on eight tests thought to tap a range of language-related and visual-spatial abilities. The measures included the following: the Naming Test employed by Mattis et al., (1975), the Wepman Auditory Discrimination Test, the Token Test, an Auditory Attention Span measure for related syllables from the Detroit Tests of Learning Aptitude (DTLA), the Beery Test of Visual-Motor Integration, the Sound Blending subtest from the Illinois Test of Psycholinguistic Abilities (ITPA), Raven's Matrices, and the Graham-Kendall Memory-for-Designs Test (MFD). Standard scores were derived by subtracting each RD child's raw score from the mean of the NR group's performance on that particular test and then dividing this value by the standard deviation of the NR group.

When the raw scores and derived standard scores were cluster analyzed separately, both types of data yielded six subtypes. The authors reported that neither profile shape nor subtype membership differed as a function of type of data. The six subtypes consisted of 94% of the RD children, with six discarded as outliers. A discriminant function analysis of the RD subtype data for the eight diagnostic measures (predictor variables) yielded two discriminant functions accounting for 94% of the variance between the six subtypes. The first discriminant function was thought to represent a language and visual-motor integration dimension. One pole of this dimension was due to better performances on language-related measures characterized by a strong positive weighting on the Token Test. The other end of this dimension was due to poorer performances on visual-spatial skills characterized by a large negative weighting on the VMI. Relatively high loadings on this dimension were obtained by subtypes characterized by better performances on language-related measures compared to more poorly developed visual-spatial skills. This first discriminanat function appeared to efficiently separate subtypes #1 and #4 from subtype #5. The second discriminant function was thought to separate the subtypes on the basis of visual-motor-integration skill versus deficit. All subtypes were separated from each other along this second dimension with the exception of subtypes #2 and #5.

Subtype #1 (n = 10) exhibited their most pronounced difficulties on measures of visual-motor integration, visual MFD, and sound-blending. They also performed below average on the other tests of receptive language, auditory memory, and discrimination. These children were also the poorest readers, evidencing minimal sight vocabulary and deficient word-attack skills. They were thought to resemble Boder's (1973) mixed dysphonetic-dyseidetic subtype. Subtype #2 (n = 12) also exhibited mixed deficits in language comprehension, auditory memory, and visual-motor skills. However, they performed within the average range on measures of visual memory (MFD), visual-spatial skill (Raven Matrices) and sound-blending. These authors thought that the subtype #2 children were most similar to a "mild" form of Boder's (1973) mixed type.

On the other hand, Subtype #3 (n = 12) appeared to exhibit pronounced deficits on the Auditory Attention subtest of the Detroit Tests of Learning Aptitudes (DTLA), the Token Test, and on the sound blending subtest of the Illinois Test of Psycholinguistic Abilites (ITPA). These children generally exhibited good performances on tests requiring the processing of visual information (e.g., Raven's Matrices and the Graham-Kendell Memory for Designs Test). They were considered most like the dysphonetic subtype described by Boder (1971) and the language-disorder group of Mattis et al. (1975).

Children in Subtype #4 (n = 32) performed very well on the Token test and in an impaired fashion on the visual-motor integration test. All other scores were within the average range; however, it was apparent they had some difficulty (albeit mild) with Raven's Matrices, sound-blending, and auditory attention. It was thought that their reading difficulties were due primarily to visual-perceptual deficiencies, similar to Boder's (1971) dyseidetic subtype. The rather large size of this subtype (34% of RD sample) was unexpected. Studies employing statistical classification methods most often report finding a language problem subtype which contains the most members.

Subtype #5 (n = 12) children exhibited severe impairment on the Token test and performances well below average on sound blending and auditory attention. The degree and pattern of their deficiencies were thought indicative of problems with the retention, synthesis, and expression of sound and word sequences. These children exhibited the next to lowest scores on the PIAT reading subtests and were considered similar to the Mattis et al., (1975) language disorder group.

Subtype #6 (n = 16) was unexpected since they evidenced levels of performance within the average range on all measures. Lyon and Watson (1981) suggested that social and/or emotional factors were responsible for the poor reading performances of these children. They concluded that their study successfully demonstrated the existence of subtypes within an RD population. The appearance of Subtype #5 was considered supportive of other researchers' (e.g., Denckla, 1977; Luria, 1975) recognition of the importance of sequencing abilities in reading behaviour.

In a re-analysis of this data, including four subtests of the Porch Index of Communication Ability in Children (PICAC), Lyon, Reitta, Watson, Porch, and Rhodes (1981) compared the six subtypes on the basis of developmental, family, and school history information. The six subtypes were significantly different only in terms of number of female siblings, which was considered an unusual and unexplainable result by these authors. None of the other historical data differentiated between subtypes. An ANOVA revealed that the six subtypes were significantly different with respect to the four PICAC subtests employed to assess spelling skills (i.e., Graphic Function, Graphic Names, Graphic Dictation, and Graphic Spelling). Significantly more spelling errors were made by children in subtypes #1, #3, and #5 on the Graphic Function, Graphic Names, and Graphic Dictation subtests than by children in subtypes #2, #4, and #6. Overall, subtype #1 children were the worst spellers and Subtype #6 the best. In general, poor PIAT reading was observed to be associated with poor PICAC spelling. All children experienced greater difficulty spelling words within sentences, as opposed to spelling single words.

In another study, Lyon, Stewart, and Freedman (1982) employed cluster analysis to determine the presence of subtypes in a sample (n = 75) of younger children (aged 6.4 to 9.75 years) with reading difficulties. These RD children evidenced normal WISC-R FSIQs (mean 102.9) and were significantly deficient compared to their same-aged peers on measures of word recognition and reading comprehension (PIAT). A NR group matched for age and IQ was employed in order to derive standard scores on a variety of measures as was done in the Lyon and Watson (1981) study. These measures were identical to those used previously, with the addition of the Benton Visual Retention test (BVRT), the ITPA Grammatic Closure subtest (GC), and the Motor Free Visual Retention test (MFVR).

Cluster analysis revealed five subtypes that included 64 RD children (85%), with 11 subjects discarded as outliers. A discriminant function analysis revealed that the measures most responsible for differentiating the subtypes were, in order of importance, the Token test, Grammatic Closure, and the Visual-Motor Integration test.

Subtype #1 (n = 18) exhibited a pattern of deficits in visual perception, visual-motor integration, and visual-spatial skills within the context of relative linguistic strengths. These children were thought most similar to Lyon and Watson's (1981) Visual-Motor Integration group (i.e., subtype 4), Johnson and Myklebust's (1967) Visual Dyslexic group, Boder's (1971) Dyseidetic type, and Satz and Morris' (1981) Visual-Perceptual-Motor subtype.

Subtype #2 (n = 10) exhibited selective deficiencies in morphological-syntactical knowledge, sound blending, receptive language abilities, auditory memory and discrimination, and naming ability. There were no apparent deficits in visual-perceptual skills. In sum, this was considered a language-disordered group similar to Lyon and Watson's (1981) subtype #3, to Boder's Dysphonetic group, to Mattis et al.'s (1975) language group, to Petrauskas and Rourke's (1979) subtype #1, and to Johnson and Myklebust's Auditory dyslexic type.

Subtype #3 (n = 12) exhibited a normal diagnostic profile on the various test measures. Subtype #4 (n = 15) evidenced deficits in sound blending, receptive language comprehension, auditory memory, and naming ability. These children were most like other subtypes reported in the literature (e.g., subtype 2 in Petrauskas & Rourke, 1979) thought to have some type of sequencing difficulty with auditory-verbal information. Finally, subtype #5 (n = 9) was a mixed deficit group, exhibiting problems with sound blending, visual-perceptual skills, and visual memory ability.

Satz, Fletcher, and Associates

Satz and Morris (1981, 1983), as well as Fletcher and Satz (1985) reported the results of using agglomerative clustering techniques to identify subtypes of children on the basis of their WRAT performances. What makes this study particularly interesting is the attempt to avoid exclusionary criteria in the initial subject selection. These children (n = 236) were part of a larger ongoing longitudinal study (Fletcher, Satz, & Morris, 1984) of normal and learning problem youngsters within a Florida school system. Although not included in the Satz and Morris (1981) study on the basis of academic achievement, socioemotional status, or presence of emotional problems, all of these children exhibited PPVT IQs ranging from 90 to 116 (i.e., within normal limits). Their WRAT Reading, Spelling, and Arithmetic performances were converted to discrepancy scores by comparing each child's grade-equivalent subtest score with their actual grade level. The cluster analyses were then applied to these derived discrepancy scores.

Nine subtypes emerged containing 230 of the 236 subjects (6 outliers were discarded). Two subtypes (n = 89) were impaired in all three areas of academic achievement as measured by the WRAT subtests. Lower socioecomomic status and "soft" neurological signs were more often associated with these subtypes. Data derived from the performances of these children on four neuropsychological measures (WISC Similarities, Verbal Fluency, Recognition-Discrimination, and the Beery Visual-Motor Integration Test) were then cluster analyzed using four different procedures. Regardless of the cluster method, five separate subtypes were uncovered.

Subtype #1 (n = 27) was defined as a global language deficiency group due to impairment on WISC Similarities and Verbal Fluency measures. Subtype #2 (n = 14) was considered to be a specific language-naming impairment type due to poor performance only on the Verbal Fluency measure. Subtype #3 (n = 10) was labelled a global language and perceptually impaired group due to their severely deficient performances on all measures. Subtype #4 (n = 23) was considered to be a visual-perceptual-motor subgroup due to their impairment on the more 'visually' dependent measures and good performances on the language measures and the PPVT. Subtype #5 (n = 12) children were not impaired on any of the neuropsychological measures and were labelled an 'unexpected' LD group.

These five subtypes were not distinguished in terms of WRAT achievement levels which was thought to confirm the original cluster solution for subtypes #8 and #9. Compared to previously reported subtype studies, Satz and Morris's (1983) results were supportive of the general findings of language, perceptual/visual-spatial, and mixed subtypes of disabled learners. However, the finding of no neuropsychological impairment in subtype #5 was unexpected. Since this subtype emerged regardless of the cluster method employed, the authors argued that this group did not represent a measurement of statistical artifact. However, no specific personality characteristics were associated with the subtype #5 children as determined by the Children's Personality Questionnaire (CPQ); so the authors were unable to argue strongly for motivational or emotional factors underlying the poor academic performances of these children. In addition, the finding that 40% of the children in the five LD subtypes did not evidence any language-related impairment was considered nonsupportive of the results of other researchers, such as Vellutino (1978), who posit that a single unitary language deficit underlies reading disability.

This study is also important due to the successful cross-cultural replication of their cluster analytic approach as reported by Van der Vlught and Satz (1985). In this investigation, a sample of a similar number of children matched for age and sex were administered a Dutch translation of the WRAT. Discrepancy scores were calculated and cluster analyzed as in the Satz and Morris (1981) report. Nine subtypes emerged from the WRAT data and subtypes #5 to #9 were again clustered on the basis of the WISC Similarities subtest, Verbal Fluency Test, Visual-Motor Integration Test, and the Recognition-Discrimination Test.

Seven subtypes resulted and the authors concluded that all children, except for one subtype (#2 in the Dutch study, n=15), belonged to subtypes that were comparable to those found in the Florida study. The different Dutch subtype #2 exhibited specific deficiencies on the Visual-Motor

Integration test and the WISC subtest. In general, 82% of the Dutch subtype members were thought to be similar to the children successfully categorized in the Florida study.

Another important aspect of the Dutch part of these analyses was the inclusion of low IQ children. Forty-two subjects with IQs < 90 were included in the cluster analyses. Unfortunately, however, the authors do not indicate from what measure this IQ score was derived nor do they report what happened to these children in terms of subtype membership following the statistical procedures. In this sense, their strong claim that this study is a 'test' of the exclusionary definition of dyslexia would seem out of place.

More recently, Morris, Blashfield, and Satz (1986) employed a longitudinal cluster analytic technique to classify a reading disabled (RD) and a normal reading (NR) group into different subtypes. The children were classified on the basis of their performances on the measures reported previously (Satz & Morris, 1981), with the addition of PPVT IQ, combined ear Dichotic Recall, Embedded Figures Test, and the Auditory-Visual Integration test used by Birch and Belmont (1964). There were 200 children in the sample that was cluster analyzed, of which the authors report approximately 35% were considered RD on the basis of deficient word recognition in grade 2 and teacher judgement of reading level. Five clusters were derived and interpreted in terms of the children's performances across time on the eight neuropsychological measures. The children were assessed at three different times, once during kindergarten, grade 2, and grade 5.

Cluster Types A, B, and C were composed of poor readers, while Types D and E were good readers. Each cluster Type showed a different pattern of skills and deficits across the eight verbal and visual-spatial tests. Type E (n = 20) was considered a group of above average readers, while Type D children (n = 59) were thought to represent the average reader. Type C subjects (n = 24) were consistently below average on all tests at the three grade levels. The performances of children in these three subtypes were stable and could be ordered as E > D > C at each grade level (where ">" indicates superior test results). These children tended to develop their visual-perceptual and verbal skills in an even and uneventful manner On the other hand, there was a dissociation in skill development noted with the other two subtypes.

Type A (n = 45) children initially exhibited deficiencies in both ability areas. However, their visual-perceptual abilities progressed from below-average levels in kindergarten to above-average levels by fifth grade. Their verbal skills remained deficient across all three grade levels. The Type B (n = 41) children exhibited deficient visual-perceptual abilities initially, which remained impaired, while their verbal skills were quite average during kindergarten and became increasingly more deficient by grade five. These findings were supportive of theoretical developmental models which predict that visual-perceptual-motor factors are most important during initial reading acquisition, after which reliance on verbal skills becomes primary for increased reading ability (Bakker, 1979; Rourke, 1978, 1982). Type B children exhibited visual-perceptual-motor deficits at an early age and impairment in both skill categories five years later. According to teacher ratings, there were more poor readers in Type B compared to Type A.

These studies represent the major ongoing research efforts in the multivariate identification of LD subtypes. The studies by Satz, Fletcher, and their co-workers are generally characterized by attempts to subtype unselected samples of normal and poor readers and to avoid exclusionary subject selection criteria. Unfortunately, they do not demonstrate directly that exclusionary criteria are unnecessary or irrelevant for subtype determination.

Doehring and his associates have most often attempted to form reading disability clusters on the basis of performance on measures considered related to actual reading behaviour. A major study (Doehring et al., 1981) was unsuccessful in differentiating their reading disability subtypes on a set of neuropsychological variables. Another aspect of their research is the reliance of Q-factor analysis to demonstrate RD subtypes.

The studies by Lyon and his associates employed cluster analysis as the main statistical technique to identify subtypes on the basis of several measures of language-related and visual-perceptual abilities. Of note is their effort to relate subtype membership to external variables such as family and developmental information.

Rourke and his associates have utilized both Q-factor techniques as well as a variety of cluster analytic methods. These statistical procedures have also been used in combination (Del Dotto & Rourke, 1985) to demonstrate convergent validity for particular subtype solutions. These investigators have also tended to use large numbers of neuropsychological variables and subjects. Another characteristic of Rourke's studies is the attempt to focus on well-defined groups of academically impaired children in order to respond to particular issues in the literature. For example, Joschko and Rourke (1985) identified subtypes within a selected sample of children all exhibiting the ACID pattern on the WISC. Del Dotto and Rourke (1985) demonstrated that similar subtypes could be derived from left- and right-handed children. Most recently, Deluca (1986) identified subtypes distinguished by neuropsychological performance and personality factors within a large group of children all deficient in WRAT Arithmetic.

Other investigators have attempted to identify LD subtypes by employing multivariate statistical analyses. Their efforts are summarized in the next section.

Other Attempts at Statistical Classification

Watson, Goldgar, and Ryschon (1983) cluster analyzed the performances of 65 reading disabled children on a wide variety of measures representing six skill areas. These children ranged in age from 7.0 to 14.9 years and evidenced either a VIQ or PIQ above 90 on the WISC-R. Several novel statistical techniques derived for the evaluation of clusters were applied to determine the homogeneity and separation of the obtained clusters. Three subtypes were found: Subtype #1 (n = 20) children exhibited a visual-processing disorder with poor short-term auditory memory; Subtype #2 (n = 17) exhibited a generalized language disorder and impairment on all memory tasks; Subtype #3 (n = 28) had minimal impairments except on auditory short-term memory and visual-motor integration, which were both below average.

The internal statistical validation procedures employed in this study suggested that the clusters were neither compact nor well separated. Although the obtained clusters were determined to be more homogeneous than clusters generated from simulated data sets, it was apparent that the reading disability clusters were relatively heterogeneous. The authors suggested three possible sources of error in their study which could have affected the cluster solution. The criteria for determining reading disability (Reading Age/Chronological Age $\leq$ 0.85) allowed for inclusion of children with milder reading difficulties than intended. The range of ages was considered too broad and all subjects were forced to belong to one of the three clusters.

In a further study, Watson and Goldgar (1988) attempted to improve the previous cluster solution by limiting the analysis to more severely disabled readers. Sixty-three moderately to severely reading impaired children were cluster analyzed based on their performances on the PPVT, the WISC-R Digit Span and Coding subtests, and tests of sound blending and visual-motor integration. Four subtypes emerged: Subtype #1 (n = 13) was deficient in auditory processing; Subtype #2 (n = 21), a mixed disorder group, exhibited an average performance only on the PPVT; Subtype #3 (n = 22) appeared to be a language disorder group; and Subtype #4 (n = 7), another mixed disorder group, exhibited good performances on the PPVT and sound blending. These clusters were considered more compact and well separated than clusters derived from simulated data sets. However, significant variation was present within the individual subtypes so that the within cluster homogeneity of the these subtypes and their corresponding simulated clusters was considered equivalent.

These two studies are important for introducing internal statistical validation as a procedure in determining the appropriateness of the cluster solution.

Summary and Methodological Issues

One author, surveying the complexity of research results on learning disability subtypes, was tempted to ask, "How many types of reading disability are there?" (Harris, 1982). This question strikes at the centre of much of the effort to illuminate "the typology" of LD types with which most researchers can readily agree. Comparing the results of the clinical-inferential and statistical studies, there are several subtype categories which have been replicated by more than one author: (1) a global language impairment group; (2) a visual-perceptual disorder; (3) a group with a mixture of impairments in the language and visual-perceptual domains; (4) children exhibiting a naming disorder; (5) children exhibiting sequencing and finger localization difficulties; and (6) poor readers who evidence minimal or no neuropsychological impairment (Lyon, 1983; Satz & Morris, 1981; Watson & Goldgar, 1986). Generalizations between studies is considered by some to be hazardous since few studies in different laboratories employ the same measures, subject selection criteria, and classification techniques

(Satz & Morris, 1983).

Apart from the identification of these five subtypes across various studies, there are three other unanticipated findings in the subtype literature. One is the demonstration by Morris et al. (1986) of developmental changes in the pattern of abilities and deficits in two subtypes of poor readers. Age-related changes in those two groups were both striking and dissociable. Another is the illustration by Rourke and associates of subtype structure within single areas of academic skill (i.e., arithmetic) as well as within subjects selected on the basis of patterns of performance (e.g., ACID pattern subtypes). A third outcome of subtype research is the unexpected finding in several studies (e.g., Satz & Morris, 1981; Watson et al., 1983) of groups of poor readers showing minimal or no neuropsychological impairment. Interestingly, all three of these results were obtained through statistical classification research. Although some studies investigating the Boder (1973) typology have found normal reading-spelling patterns in some poor readers, these results may have been due to misclassification.

Several authors, particularly Siegel, Levey, and Ferris (1985) and Siegel and Heaven (1986) have been very critical of the selection criteria used to define learning or reading disability. Siegel et al. (1985) criticized the use of reading comprehension measures in this context due to difficulties in generalizability between measures. They also suggested that researchers attempt to avoid utilizing IQ in their subject selection procedures since it could be adversely affected in LD children with language impairment.

Utilization of IQ scores to formulate exclusionary definitions of learning disabilities would seem to be one important issue that could be addressed thoroughly. Indeed, several studies have attempted to address this issue to varying degrees. The study most often cited as a direct assessment of this issue is the report by Taylor, Satz, and Friel (1979). Two groups of poor readers (dyslexic, nondyslexic disabled readers) were compared on a variety of dependent measures (e.g., frequency of reversal errors, math skills, patterns of neuropsychological performance). No significant differences were found between the two groups. The dyslexic group (n = 40) met the following three exclusionary criteria: PPVT IQ $\geq$ 90; average or above average SES rating; no serious emotional, neurological, or sensory problems. The nondyslexic disabled readers (n = 40) failed at least one of these three criteria. Close examination of the authors' description of this group revealed that 12 subjects failed more than one criteria; 28 subjects (70%) failed only one of the criteria. Of these 28 subjects, six had PPVT IQ < 90, 17 were categorized 'low SES', three were known to have emotional difficulties, and two exhibited sensory problems. Therefore, there were at least 22 nondyslexic disabled readers in this study with PPVT IQ ≥ 90. These 22 subjects represent 55% of the nondyslexic disabled readers. The nonsignificant finding between these two poor reading groups could have resulted due to between-group similarity in PPVT IQ level. If this were the case, then these authors have not demonstrated that exclusionary definitions of learning disabilities should be discarded.

There are three other studies that did not use an exclusionary definition: Satz and Morris (1981); Van der Vlugt and Satz (1985); and Spreen and Haaf (1986). All employed cluster analytic techniques and included low IQ children in their samples.

Satz and Morris (1981) used the WRAT grade-equivalent scores and converted them into discrepancy scores by comparison (subtraction) with each child's grade level in reading, spelling, and arithmetic. Use of grade-equivalent scores to identify LD children has been criticized by Siegel and Heaven (1986), and with specific reference to this study by Siegel, Levey, and Ferris (1985).

Satz and Morris (1981) do not report the IQ levels of their subjects before clustering; although they claim this is a study which does not adhere to exclusionary criteria, they do not demonstrate it. Neither is the input PPVT IQ level reported by Fletcher and Satz (1985) nor by Fletcher and Morris (1986) in their discussions of this study. Satz and Morris (1981) do report that "the PPVT IQ scores ranged from 90 (Subtype 9) to 116 (Subtype 1) with an overall sample mean of 103" (p. 131). Therefore, it appears that all subjects had PPVT IQ $\geq$ 90 since 230 out of 236 subjects were placed in one of nine subtypes.

In the Van der Vlugt and Satz (1985) report, 61 subjects had IQ $\geq$ 90 and 43 subjects had IQ $\leq$ 90 in the Dutch replication study. As in the previous study, WRAT grade discrepancy scores based on the grade-equivalent minus actual grade-level difference were employed in the subtypal analyses. Nine subtypes were derived on the basis of the WRAT discrepancy scores. The Dutch learning disability subtypes (5 to 9) were then cluster analyzed on the basis of neuropsychological performance. What happens to the IQ $\leq$ 90 subjects (n = 42, in the WRAT clusters) which are subtyped on the neuropsychological variables is not reported. It is also noteworthy that only four neuropsychological variables were used in this subtype phase. In addition, Van der Vlugt and Satz (1985) do not report the subtype membership of the low IQ subjects.

The other study to include low IQ subjects in subtype classification is that of Spreen and Haaf (1986). They indicate that subjects with "Verbal or Performance > 69"

(p. 172) were included in the analysis but do not reveal how many there were with 69 < IQ < 84, so that the reader does not know how many low IQ subjects were in the study. In this study, Cluster #5 seemed to be a severe deficiency group with mean IQ = 69, but with only five members. They do not report the IQ levels of the other subtypes, including Cluster #4 which seemed the least impaired. In this particular analysis, 53 of the 63 subjects are reported as members of subtypes, but the IQ level of the 10 remaining 'unclustered' subjects is not reported and it is unclear what became of them.

The Van der Vlugt and Satz (1985) investigation appears to be the most reliable with respect to the issue of exclusionary criteria. However, it did not directly address this issue as the primary focus of the study. They do not inform the reader as to which IQ measure was used (probably the PPVT).

Statistical classification of these low IQ children could result in the formation of separate homogeneous subtypes or they may not belong anywhere (i.e., outliers) within the generated typology. On the other hand, it may be the case that some children who would normally be excluded from consideration as learning disabled will, nevertheless, exhibit patterns of performance similar to types of LD children on selected neuropsychological measures. In this respect, the initial subtyping analysis of the data in the current study was carried out as a test of the adequacy of the traditional exclusionary definition of learning disabilities.

In order to investigate this issue, 1624 children were selected from a population of 4800 children referred for neuropsychological assessment at a metropolitan clinic. Children were not excluded from this sample on the basis of the usual criteria eployed in most learning disability studies. In the present study, the sample contained some relatively 'low IQ' and 'high IQ' children (WISC FSIQ 60-120). Also present in this sample were children thought to be emotionally disturbed or suffering from visual or hearing anomalies. This sample was subtyped initially on academic measures (i.e., WRAT subtest scores) in an attempt to provide statistically derived classifications of learning disability. All children found to be in subtypes evidencing impairment on the academic measures were then cluster analyzed on measures of neuropsychological abilities. The purpose of this second analysis was to examine the subtype structure in terms of patterns of neuropsychological abilities of children previously classified as LD on the basis of cluster analytic methodology.

A related and important issue has to do with the relationship between mild mental retardation and learning disability. At lower IQ levels, children would be expected to show similarly broad levels of deficiency; however, as IQ increases, one would expect variations in the patterns of performance of children depending on whether they could be construed as more "low functioning" or more "LD." In order to address these possibilities, a second sample of children was selected and partitioned into smaller subsamples corresponding to restricted FSIQ ranges (e.g., 70-80, 81-90) which were subtyped on the basis of their neuropsychological test performances. Subtypes formed at these levels of the data should reveal changes in the ability structure of low-functioning versus LD children in more detail than was possible with the initial statistical classification of all subjects.

At this point, one is tempted to ask how further increases in WISC FSIQ are related to possible changes in subtype composition with respect to patterns of neuropsychological abilities. Therefore, subsamples of the children in the "normal" range of intelligence were formed on the basis of restricted FSIQ ranges (e.g., 91-100, 101-110) and subjected to multivariate cluster analytic techniques as before. Since the variable of prime interest here is FSIQ level, children in these subsamples were selected according to the usual exclusionary criteria (except for IQ level).

The main purpose of the present study was to investigate the effect of WISC FSIQ level on the formation of subtypes of

LD children. Several samples of children were selected for this purpose. Sample I (n=1624) consisted of children varying from 60 to 120 in WISC FSIQ. This large sample contained not only low IQ children but also children thought to be emotionally disturbed, or suffering from hearing or visual anomalies, or some form of brain pathology. Several issues regarding the usual 'exclusionary definition' of LD children were addressed with this sample. First, an attempt was made to generate subtypes on measures of academic ability which could be considered as LD, low-functioning, or "normal". It was thought that this initial analysis would provide statistically determined (rather than "a priori") classifications of LD, "normal" academic achievers, and other types of children. Second, it was considered important to determine if the low IQ children (i.e., WISC FSIQ < 80) and other children (e.g., emotionally disturbed) typically excluded from LD studies could be classified into one subtype, or distributed across several subtypes. Third, the learning-disabled WRAT subtypes emerging from the analysis of Sample I were again clustered on the measures of neuropsychological skills and abilities. The application of this cluster analytic methodology, it was thought, would provide a more detailed view of the neuropsychological abilities of LD children.

To further investigate the effect of WISC FSIQ on subtype structure, a second sample (i.e., Sample B n=882) was selected. Sample B exhibited a WISC FSIQ range of 70 to 110 points. Except for low IQ children, all other types of children were excluded from this sample. Four subsamples of these Sample B children were then chosen according to WISC FSIQ levels as was previously described. Each subsample was cluster analyzed to determine if differences in subtype number and subtype structure would emerge as a result of WISC FSIQ level.

Expectations:

Many aspects of this study were exploratory in nature and it is therefore difficult to delineate exact hypotheses for all aspects of the present research. However, several studies (e.g., Fisk and Rourke, 1979; Deluca, 1986; Ozols and Rourke, 1988; Petrauskas and Rourke, 1979; Rourke and Finlayson, 1978; Satz and Morris, 1981; Strang and Rourke, 1983a,b) suggested that a number of subtypes would emerge similar to the following:

Sample I: Academic Measures (WRAT Subtypes)

Hypothesis 1. It is hypothesized that the cluster analysis of the largest sample of children with respect to the WRAT scores will yield six distinct but somewhat overlapping subtypes.

Hypothesis 2. Each of these six subtypes will exhibit uniquely different patterns of performance on 12 variables selected from a large battery of neuropsychological test measures.

Hypothesis 2A. Subtype #1 will consist of children exhibiting at least average (i.e., "normal") performances on all WRAT subtests, and average or above-average WISC FSIQ and PPVT IQ levels. This group will also evidence at least average performances on most of the neuropsychological measures. Subtype #1 will have the smallest percentage of children with impairment on neuropsychological abilities. It is expected that subtype #1 will contain the fewest number of low IQ children (e.g., WISC FSIQ < 80).

Hypothesis 2B. Subtype #2 will consist of children exhibiting severly depressed performances on all WRAT subtests. This subtype will contain the greatest number (or group percentage) of low IQ children, with mean WISC and PPVT IQ levels all well below-average. Subtype #2 will also exhibit more impaired performances on the neuropsychological measures and evidence the highest percentage of children with neuropsychological impairment.

Hypothesis 2C. Subtype #3 will consist of children exhibiting below-average performances on all WRAT subtests but not as severely depressed as subtype #2. The performances of subtype #3 subjects on the neuropsychological measures are expected to be similar to those characterizing Rourke's Group 1 LD children. In particular, subtype #3 children should exhibit below-average performances on the WISC Information subtest, and impaired performances on the Sentence Memory Test. Obtained scores on the WISC Vocabulary, Block Design, and Object Assembly subtests should fall within the average range. An average score is anticipated on the WISC PIQ while the WISC VIQ and PPVT IQ should be at the low end of the average range. These children are expected to exhibit better performances on visual-spatial-organizational tasks, simple motor tests, and complex psychomotor tasks. Age-appropriate performances were also expected on tasks involving nonverbal problem-solving skills.

Hypothesis 2D. Subtype #4 will consist of children evidencing below-average WRAT reading and spelling within the context of better developed (perhaps above-average) arithmetic scores. These children will be similar to Rourke's Group 2 children and the Group 4 type discussed by Ozols and Rourke (1988). Subtype #4 children are expected to evidence patterns of neuropsychological skills and abilities similar to subtype #3.

Hypothesis 2E. Subtype #5 will consist of children exhibiting relatively intact reading and spelling, and poor performances in arithmetic. These children should be most similar to Rourke's Group 3 type. Their general pattern of neuropsychological abilities should consist of poor performances on some motor, visual-spatial and nonverbal problem-solving tasks in conjunction with relatively good performances on verbal and language-related tasks. Subtype #5 is also expected to contain the highest group percentage of children thought to be emotionally disturbed (Strang & Rourke, 1985a,b). Due to the suspected low frequency of occurence of these children (Rourke, Fisk, & Strang, 1986), subtype #5 is also expected to be the smallest subtype to emerge from the cluster analysis.

Hypothesis 2F. Subtype #6 will consist of children exhibiting average reading, depressed spelling, and impaired arithmetic. Children similar to this type have been identified by Van der Vlugt and Satz (1985) and by Deluca (1986). WISC Verbal, Performance, and Full Scale IQs are expected to fall within the average range, although there will be a VIQ-PIQ discrepancy in favour of the latter. These children are expected to evidence good auditory-verbal skills on simple language tasks (e.g., WISC Information, Vocabulary) and below-average performances on more complex language-related tasks (e.g., Verbal Fluency, Sentence Memory).

Visual-spatial and nonverbal problem-solving skills are expected to be at least average, while low-average performances are anticipated on complex motor tasks (e.g., Grooved Pegboard, Maze Test).

Sample I: Neuropsychological Measures (NEURO Groups)[1]

Hypothesis 3. It was expected that at least five subtypes, some corresponding to those found by other investigators (e.g., Fisk & Rourke, 1979; Petrauskas & Rourke, 1979) would emerge from the cluster analysis of Sample I with respect to the neuropsychological measures.

Hypothesis 4. Since all subtypes evidencing 'normal' WRAT subtest scores have been removed following the initial subtyping of Sample I, it was expected that no subtype would be found with average or above-average WRAT Reading scores and evidence minimal impairment on the twelve measures of neuropsychological abilities.

Hypothesis 5. Subtype #1 will consist of children exhibiting at least average performances on most of the neuropsychological measures. However, these children are expected to perform somewhat poorly on the WRAT reading subtest. Poor readers evidencing minimal or no neuropsychological impairment have been found by several investigators (e.g., Lyon, 1983; Satz & Morris, 1981;

Watson & Goldgar, 1986).

Hypothesis 6. Subtype #2 will consist of children exhibiting severely depressed performances on most of the neuropsychological measures. This subtype will contain the greatest number (or group percentage) of low IQ children, with mean WISC and PPVT IQ levels all well below-average. Subtype #2 children will exhibit severely impaired performances on all WRAT subtests. Subtype #2 will also exhibit more impaired performances on the neuropsychological measures and evidence the highest percentage of children with neuropsychological impairment.

Hypothesis 7. Subtype #3 will consist of children exhibiting relatively poor language-related abilities in the context of well-developed motor, visual-spatial, and nonverbal problem-solving skills. Performances should be below-average on WISC Information, near-average on WISC Vocabulary, and moderately to severely impaired on Verbal Fluency and Sentence Memory. Subtype #3 should exhibit the largest VIQ-PIQ discrepancy (in favour of the latter) of any subtype. WRAT reading and spelling scores should be somewhat below arithmetic.

Hypothesis 8. Subtype #4 will exhibit relatively intact language-related abilities in conjunction with poor performances on complex motor, visual-spatial, and nonverbal problem-solving tasks. Children in this subtype are expected to perform better on the WRAT reading and spelling subtests than on the arithmetic subtest. Subtype #4 will evidence a WISC VIQ-PIQ discrepancy in favour of VIQ. This subtype is expected to contain a higher group percentage of children considered emotionally disturbed, and will be similar to Rourke's Group 3 type children.

Hypothesis 9. Subtype #5 will consist of children exhibiting below-average performances on many of the neuropsychological measures. However, these performances will not be as severely depressed as expected for subtype #2. The pattern of neuropsychological skills and abilities of subtype #5 children will most closely resemble a 'mixed-deficit' subgroup reported in the literature (e.g., Boder, 1973; Lyon & Watson, 1981). Subtype #5 is expected to contain more low IQ children than the other groups, but not as many as in subtype #2.

Sample B Subsamples (Neuropsychological Measures)

As regards the four subsamples selected from Sample B, it may be the case that the number and type of subtypes identified are similar across the different FSIQ ranges. However, there is no evidence in the literature reviewed so far to suggest that the subtype structure should change with different levels of psychometric intelligence. If it were proposed that IQ influenced subtype composition, it is difficult to determine exactly what type of a prediction could be suggested which would accurately describe such changes. Therefore, for the purposes of this investigation, a 'conservative' position that changes in IQ level will not affect subtypal number or subtype structure was adopted for the subsamples with WISC FSIQ ranges 81-90, 91-100, and 101-110. However, for the subsample with WISC FSIQ range 70-80, it was expected that the clusters which emerged would be different from all others in at least two ways: (1) there would be fewer numbers of clusters, and (2) these subtypes would evidence much more impaired performances on the neuropsychology variables than would subjects in any other subtypes.

CHAPTER TWO

METHOD

Subjects

The subjects in the present study were selected from a population of 4800 children referred to the Regional Children's Centre of Windsor Western Hospital in Windsor, Ontario. These children were primarily referred for neuropsychological assessment due to academic difficulties, although this database contains a variety of children; some were referred due to behavioral difficulties, or suspected neurological dysfunction. The majority of the children selected for this study were referred by school authorities (n=592, 49%). Family physicians referred 28% (n=339), community psychologists and social workers referred 19% (n=225), while psychiatrists were the source of 77 referrals (6%), and neurologists referred 6 (0.5%) of the children in this study.

There were two samples of subjects selected for this study from the neuropsychology database as depicted in Figure 1. Sample I consisted of children selected without the 'typical' exclusionary criteria. This sample was so selected to address the issue of the relevance of the exclusionary definition of learning disabilities. Sample B, on the other

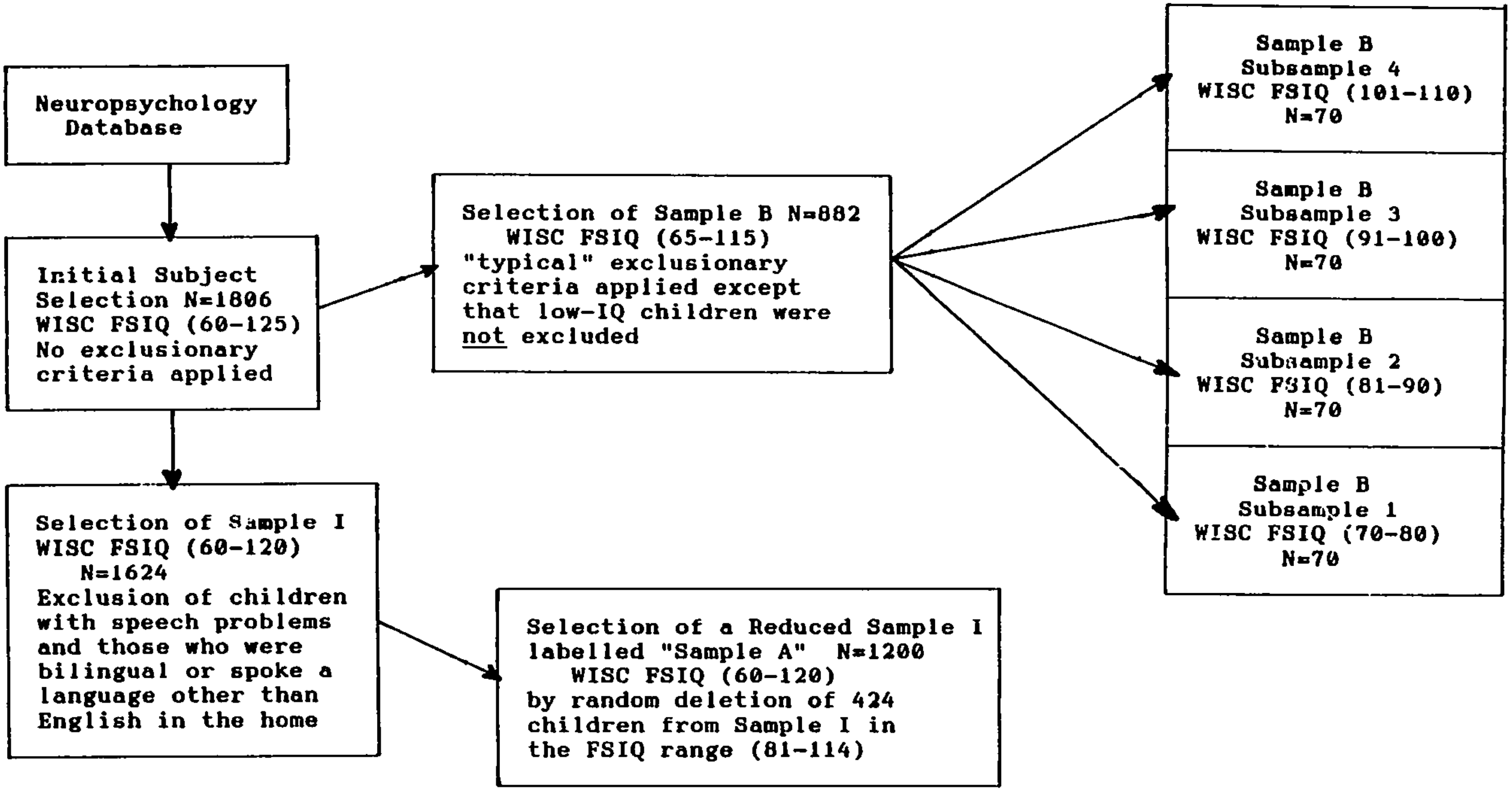
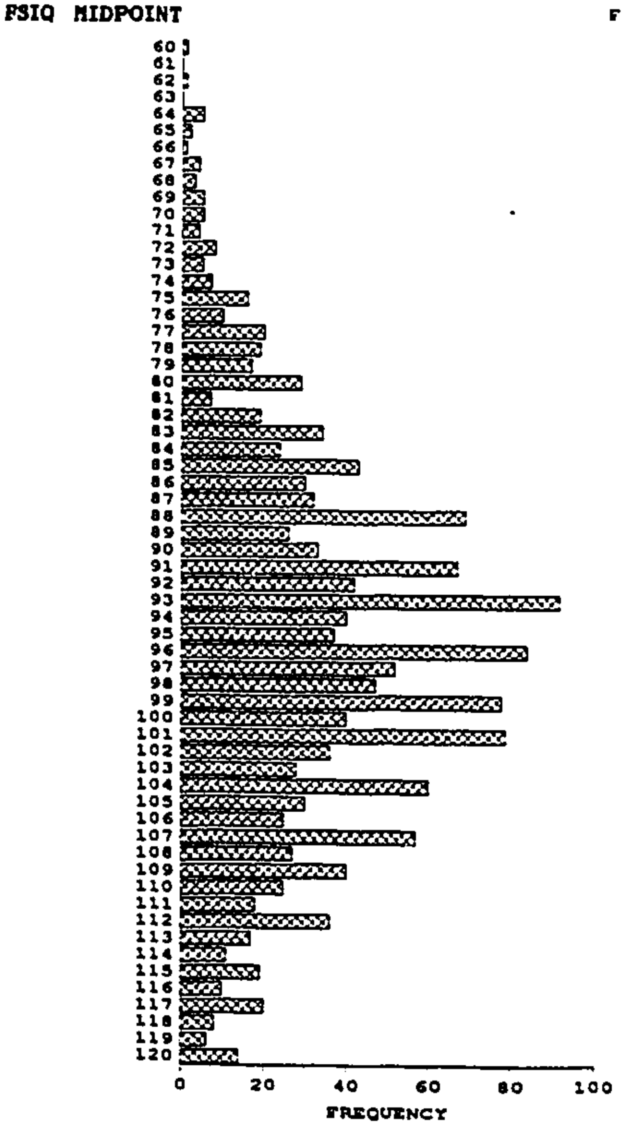


Figure 1. Illustration of subject selection procedure.

hand, was selected on the basis of the usual exclusionary criteria; however, low IQ children were included in this sample. This was done in order to investigate the relevance of the IQ variable on the formation of subtypes of 'low functioning' and LD children.

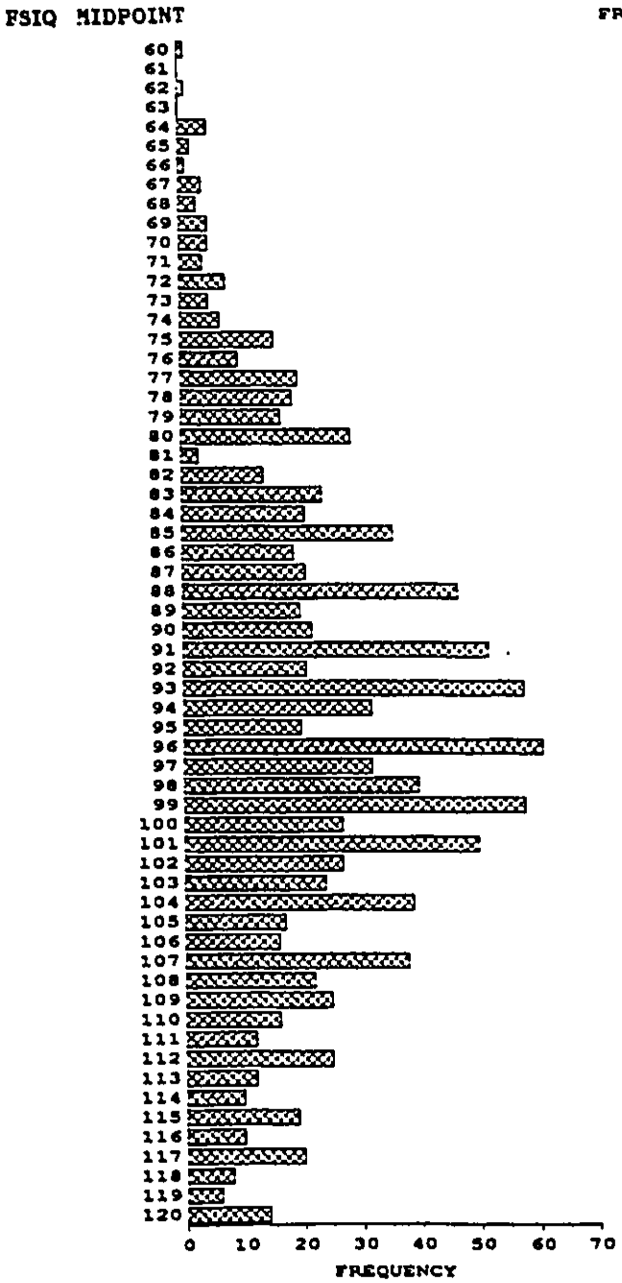
It was necessary to reduce the large size of Sample I due to limitations in the computing resources available. First, it was determined that the SAS clustering procedures could be implemented with a sample size of approximately 1200 cases. Then, subjects from Sample I with a FSIQ range of 81 to 114, and who were either impaired on the Sweep Hearing Test or who would be considered only LD on the basis of a typical learning disability exclusionary definition (e.g., as applied to Sample B below) were selected at random until 424 were chosen. These 424 subjects were then deleted from the original Sample I to form a new sample called 'Sample A', n=1200. The frequency distributions of FSIQ in Sample I and Sample A are depicted in Figures 2 and 3. The distribution of subjects in Sample A with emotional difficulties and brain lesions are depicted in Figures 4 and 5. The distribution of children in Sample A thought to be environmentally deprived, or evidencing hearing and visual anomalies or showing impairment on the Sweep Hearing Test are depicted in Figures 6 through 10, respectively.

The inclusion of subjects for Sample A and Sample B was



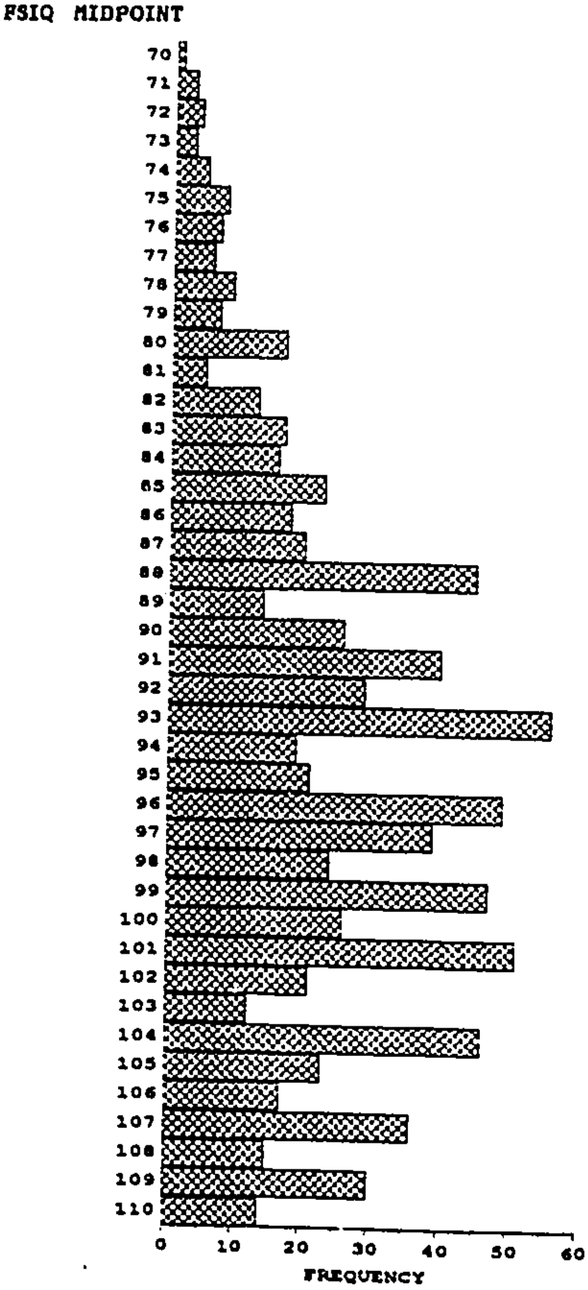
FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
60	1	1	0.06	0.06
61	0	1	0.00	0.06
62	1	2	0.06	0.12
63	0	2	0.00	0.12
64	5	7	0.31	0.43
65	2	9	0.12	0.55
66	1	10	0.06	0.62
67	4	14	0.25	0.86
68	3	17	0.18	1.05
69	5	22	0.31	1.35
70	5	27	0.31	1.66
71	4	31	0.25	1.91
72	8	39	0.49	2.40
73	5	44	0.31	2.71
74	7	51	0.43	3.14
75	16	67	0.99	4.13
76	10	77	0.62	4.74
77	20	97	1.23	5.97
78	19	116	1.17	7.14
79	17	133	1.05	8.19
80	29	162	1.79	9.98
81	7	169	0.43	10.41
82	19	188	1.17	11.58
83	34	222	2.09	13.67
84	24	246	1.48	15.15
85	43	289	2.65	17.80
86	30	319	1.85	19.64
87	32	351	1.97	21.61
88	69	420	4.25	25.86
89	26	446	1.60	27.46
90	33	479	2.03	29.50
91	67	546	4.13	33.62
92	42	588	2.59	36.21
93	92	680	5.67	41.87
94	40	720	2.46	44.33
95	37	757	2.28	46.61
96	84	841	5.17	51.79
97	52	893	3.20	54.99
98	47	940	2.89	57.88
99	78	1018	4.80	62.68
100	40	1058	2.46	65.15
101	79	1137	4.86	70.01
102	36	1173	2.22	72.23
103	28	1201	1.72	73.95
104	60	1261	3.69	77.65
105	30	1291	1.85	79.50
106	25	1316	1.54	81.03
107	57	1373	3.51	84.54
108	27	1400	1.66	86.21
109	40	1440	2.46	88.67
110	25	1465	1.54	90.21
111	18	1483	1.11	91.32
112	36	1519	2.22	93.53
113	17	1536	1.05	94.58
114	11	1547	0.68	95.26
115	19	1566	1.17	96.43
116	10	1576	0.62	97.04
117	20	1596	1.23	98.28
118	8	1604	0.49	98.77
119	6	1610	0.37	99.14
120	14	1624	0.86	100.00

Figure 2. Number of Subjects by WISC FSIQ Level in Sample I (n=1624).



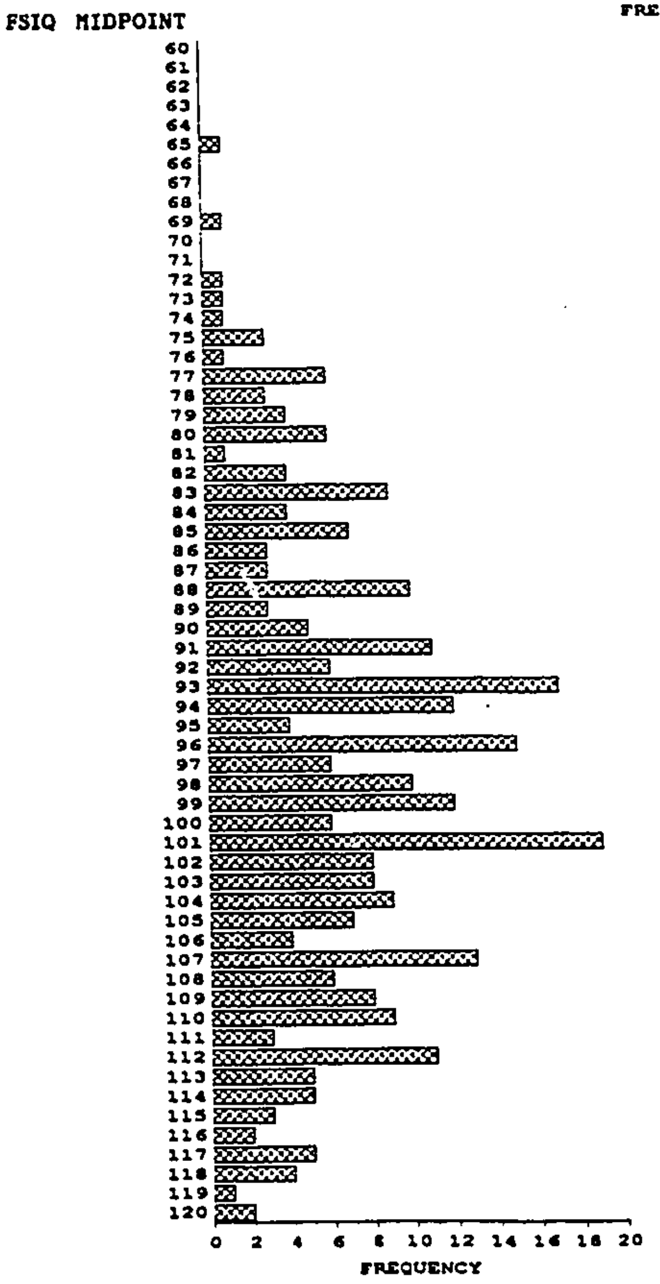
FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
60	1	1	0.08	0.08
61	0	1	0.00	0.08
62	1	2	0.08	0.17
63	0	2	0.00	0.17
64	5	7	0.42	0.58
65	2	9	0.17	0.75
66	1	10	0.08	0.83
67	4	14	0.33	1.17
68	3	17	0.25	1.42
69	5	22	0.42	1.83
70	5	27	0.42	2.25
71	4	31	0.33	2.58
72	8	39	0.67	3.25
73	5	44	0.42	3.67
74	7	51	0.58	4.25
75	16	67	1.33	5.58
76	10	77	0.83	6.42
77	20	97	1.67	8.08
78	19	116	1.58	9.67
79	17	133	1.42	11.08
80	29	162	2.42	13.50
81	3	165	0.25	13.75
82	14	179	1.17	14.92
83	24	203	2.00	16.92
84	21	224	1.75	18.67
85	36	260	3.00	21.67
86	19	279	1.58	23.25
87	21	300	1.75	25.00
88	47	347	3.92	28.92
89	20	367	1.67	30.58
90	22	389	1.83	32.42
91	52	441	4.33	36.75
92	21	462	1.75	38.50
93	58	520	4.83	43.33
94	32	552	2.67	46.00
95	20	572	1.67	47.67
96	61	633	5.08	52.75
97	32	665	2.67	55.42
98	40	705	3.33	58.75
99	58	763	4.83	63.58
100	27	790	2.25	65.83
101	50	840	4.17	70.00
102	27	867	2.25	72.25
103	24	891	2.00	74.25
104	39	930	3.25	77.50
105	17	947	1.42	78.92
106	16	963	1.33	80.25
107	38	1001	3.17	83.42
108	22	1023	1.83	85.25
109	25	1048	2.08	87.33
110	16	1064	1.33	88.67
111	12	1076	1.00	89.67
112	25	1101	2.08	91.75
113	12	1113	1.00	92.75
114	10	1123	0.83	93.58
115	19	1142	1.58	95.17
116	10	1152	0.83	96.00
117	20	1172	1.67	97.67
118	8	1180	0.67	98.33
119	6	1186	0.50	98.83
120	14	1200	1.17	100.00

Figure 3. Number of Subjects by WISC FSIQ Level in Sample A (n=1200).



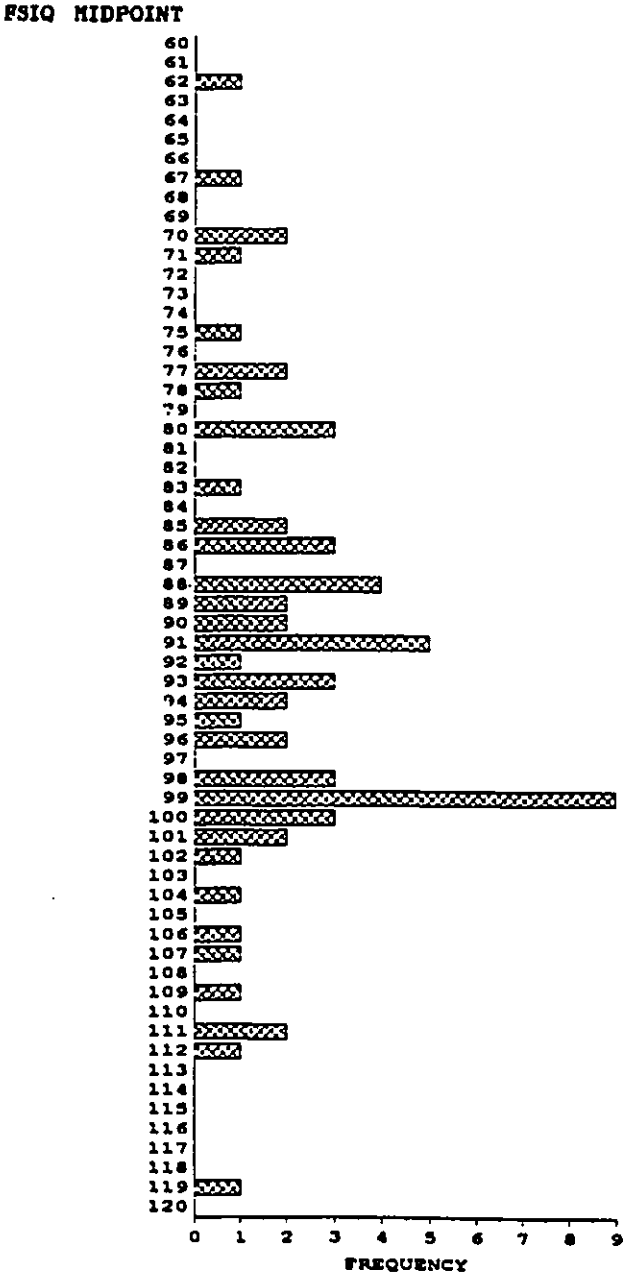
FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
1	1	0.11	0.11
3	4	0.34	0.45
4	8	0.45	0.91
3	11	0.34	1.25
5	16	0.57	1.81
8	24	0.91	2.72
7	31	0.79	3.51
6	37	0.68	4.20
9	46	1.02	5.22
7	53	0.79	6.01
17	70	1.93	7.94
5	75	0.57	8.50
13	88	1.47	9.98
17	105	1.93	11.90
16	121	1.81	13.72
23	144	2.61	16.33
18	162	2.04	18.37
20	182	2.27	20.63
45	227	5.10	25.74
14	241	1.59	27.32
26	267	2.95	30.27
40	307	4.54	34.81
29	336	3.29	38.10
56	392	6.35	44.44
19	411	2.15	46.60
21	432	2.38	48.98
49	481	5.56	54.54
39	520	4.42	58.96
24	544	2.72	61.68
47	591	5.33	67.01
26	617	2.95	69.95
51	668	5.78	75.74
21	689	2.38	78.12
12	701	1.36	79.48
46	747	5.22	84.69
23	770	2.61	87.30
17	787	1.93	89.23
36	823	4.08	93.31
15	838	1.70	95.01
30	868	3.40	98.41
14	882	1.59	100.00

Figure 4. Number of Subjects by WISC FSIQ Level in Sample B (n=882).



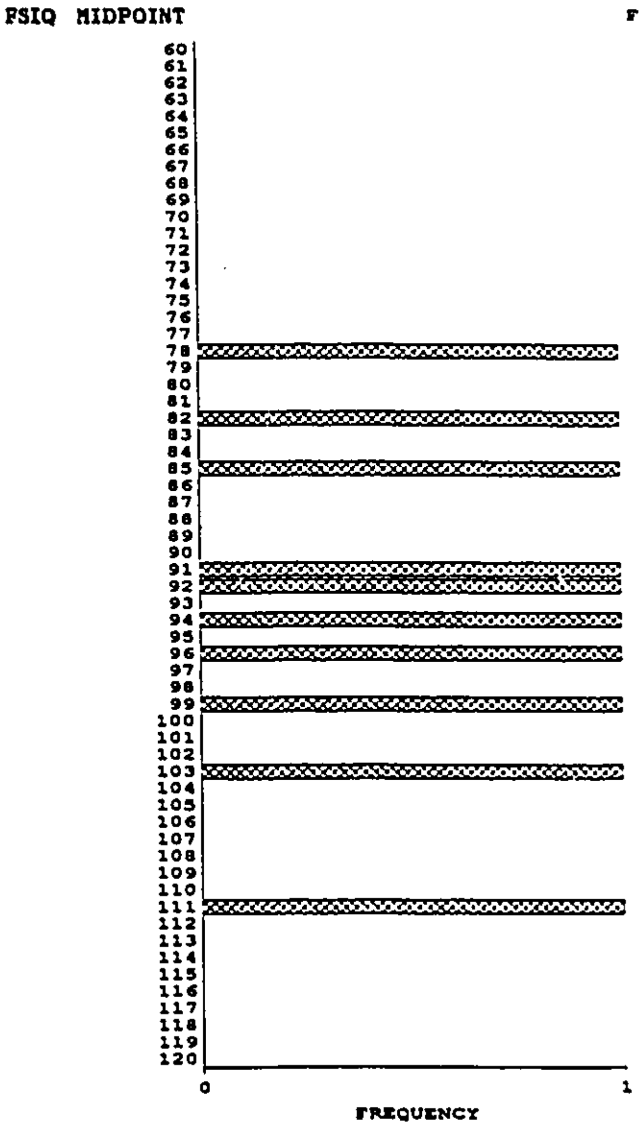
FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
60	0	0	0.00	0
61	0	0	0.00	0
62	0	0	0.00	0
63	0	0	0.00	0
64	0	0	0.00	0
65	1	1	0.32	0
66	0	1	0.00	0
67	0	1	0.00	0
68	0	1	0.00	0
69	1	2	0.32	1
70	0	2	0.00	1
71	0	2	0.00	1
72	1	3	0.32	1
73	1	4	0.32	1
74	1	5	0.32	2
75	3	8	0.97	3
76	1	9	0.32	3
77	6	15	1.95	5
78	3	18	0.97	6
79	4	22	1.30	7
80	6	28	1.95	9
81	1	29	0.32	9
82	4	33	1.30	11
83	9	42	2.92	14
84	4	46	1.30	15
85	7	53	2.27	17
86	3	56	0.97	18
87	3	59	0.97	19
88	10	69	3.25	22
89	3	72	0.97	23
90	5	77	1.62	25
91	11	88	3.57	29
92	6	94	1.95	31
93	17	111	5.52	36
94	12	123	3.90	40
95	4	127	1.30	41
96	15	142	4.87	46
97	6	148	1.95	48
98	10	158	3.25	51
99	12	170	3.90	55
100	6	176	1.95	57
101	19	195	6.17	63
102	8	203	2.60	66
103	8	211	2.60	69
104	9	220	2.92	71
105	7	227	2.27	74
106	4	231	1.30	75
107	13	244	4.22	79
108	6	250	1.95	81
109	8	258	2.60	84
110	9	267	2.92	87
111	3	270	0.97	88
112	11	281	3.57	91
113	5	286	1.62	93
114	5	291	1.62	94
115	3	294	0.97	95
116	2	296	0.65	96
117	5	301	1.62	98
118	4	305	1.30	99
119	1	306	0.32	99
120	2	308	0.65	100

Figure 5. Subjects Considered Emotionally Disturbed in Sample A by WISC FSIQ Level.



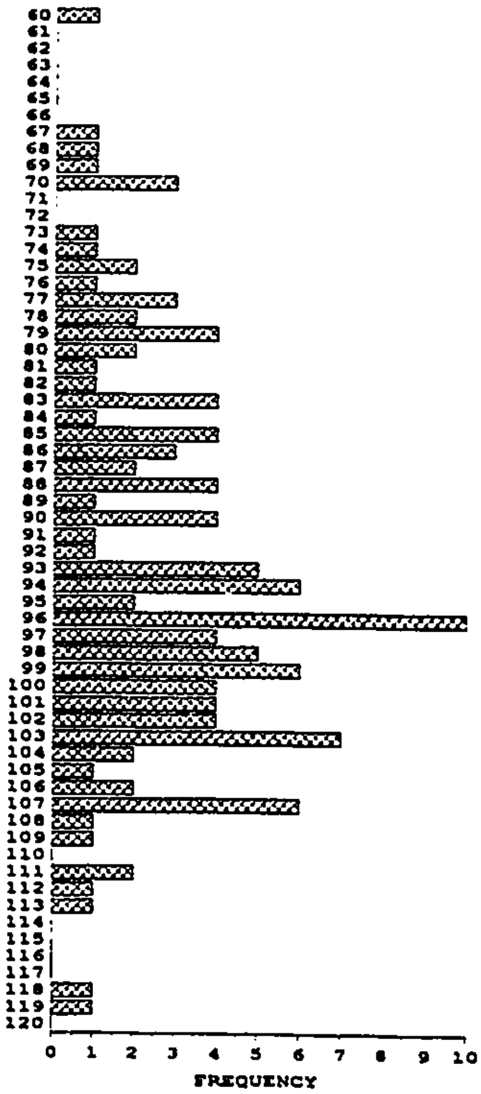
FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
60	0	0	0.00	0
61	0	0	0.00	0
62	1	1	1.52	2
63	0	1	0.00	2
64	0	1	0.00	2
65	0	1	0.00	2
66	0	1	0.00	2
67	1	2	1.52	3
68	0	2	0.00	3
69	0	2	0.00	3
70	2	4	3.03	6
71	1	5	1.52	8
72	0	5	0.00	8
73	0	5	0.00	8
74	0	5	0.00	8
75	1	6	1.52	9
76	0	6	0.00	9
77	2	8	3.03	12
78	1	9	1.52	14
79	0	9	0.00	14
80	3	12	4.55	18
81	0	12	0.00	18
82	0	12	0.00	18
83	1	13	1.52	20
84	0	13	0.00	20
85	2	15	3.03	23
86	3	18	4.55	27
87	0	18	0.00	27
88	4	22	6.06	33
89	2	24	3.03	36
90	2	26	3.03	39
91	5	31	7.58	47
92	1	32	1.52	48
93	3	35	4.55	53
94	2	37	3.03	56
95	1	38	1.52	58
96	2	40	3.03	61
97	0	40	0.00	61
98	3	43	4.55	65
99	9	52	13.64	79
100	3	55	4.55	83
101	2	57	3.03	86
102	1	58	1.52	88
103	0	58	0.00	88
104	1	59	1.52	89
105	0	59	0.00	89
106	1	60	1.52	91
107	1	61	1.52	92
108	0	61	0.00	92
109	1	62	1.52	94
110	0	62	0.00	94
111	2	64	3.03	97
112	1	65	1.52	98
113	0	65	0.00	98
114	0	65	0.00	98
115	0	65	0.00	98
116	0	65	0.00	98
117	0	65	0.00	98
118	0	65	0.00	98
119	1	66	1.52	100
120	0	66	0.00	100

Figure 6. Subjects with Brain Lesions in Sample A by WISC FSIQ Level.



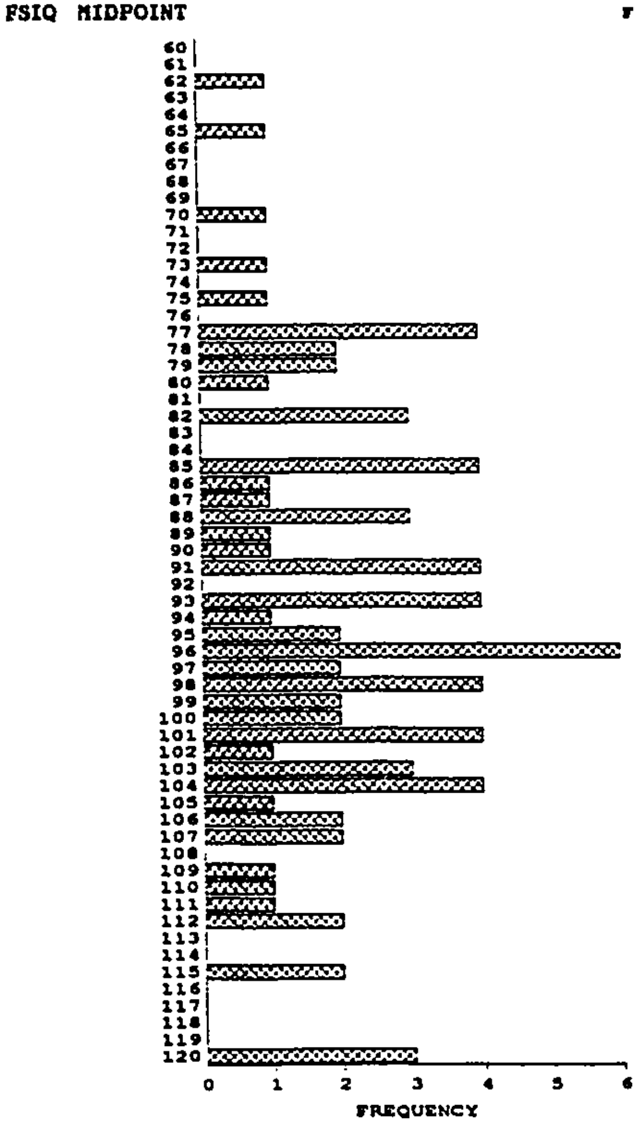
FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
60	0	0	0	0
61	0	0	0	0
62	0	0	0	0
63	0	0	0	0
64	0	0	0	0
65	0	0	0	0
66	0	0	0	0
67	0	0	0	0
68	0	0	0	0
69	0	0	0	0
70	0	0	0	0
71	0	0	0	0
72	0	0	0	0
73	0	0	0	0
74	0	0	0	0
75	0	0	0	0
76	0	0	0	0
77	0	0	0	0
78	1	1	10	10
79	0	1	0	10
80	0	1	0	10
81	0	1	0	10
82	1	2	10	20
83	0	2	0	20
84	0	2	0	20
85	1	3	10	30
86	0	3	0	30
87	0	3	0	30
88	0	3	0	30
89	0	3	0	30
90	0	3	0	30
91	1	4	10	40
92	1	5	10	50
93	0	5	0	50
94	1	6	10	60
95	0	6	0	60
96	1	7	10	70
97	0	7	0	70
98	0	7	0	70
99	1	8	10	80
100	0	8	0	80
101	0	8	0	80
102	0	8	0	80
103	1	9	10	90
104	0	9	0	90
105	0	9	0	90
106	0	9	0	90
107	0	9	0	90
108	0	9	0	90
109	0	9	0	90
110	0	9	0	90
111	1	10	10	100
112	0	10	0	100
113	0	10	0	100
114	0	10	0	100
115	0	10	0	100
116	0	10	0	100
117	0	10	0	100
118	0	10	0	100
119	0	10	0	100
120	0	10	0	100

Figure 7. Subjects Considered Evironmentally Deprived in Sample A by WISC FSIQ Level.



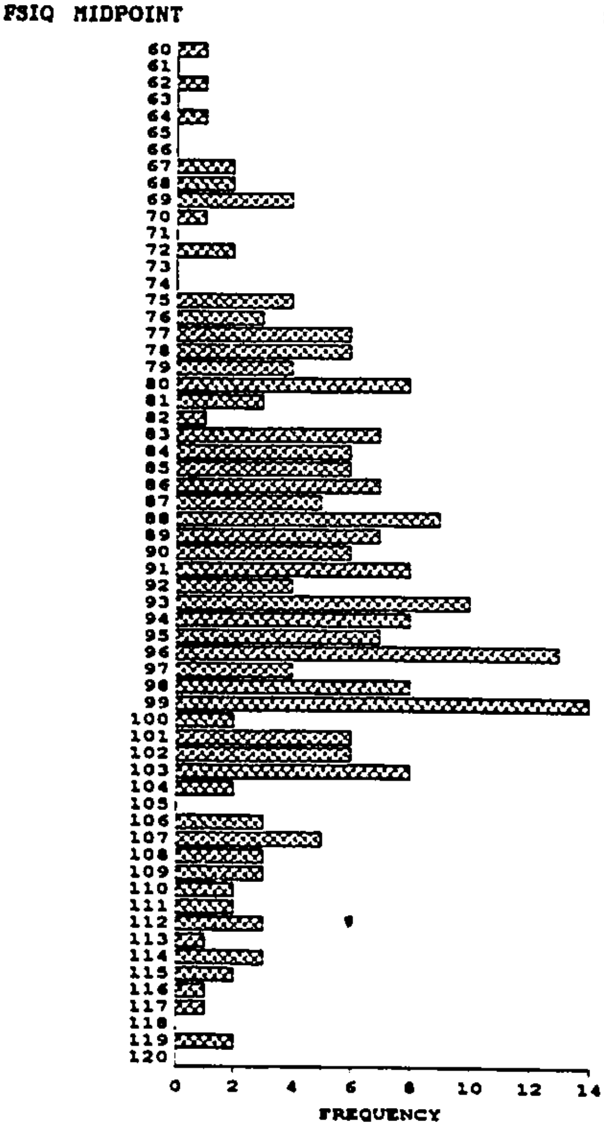
FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
60	1	1	0.79	0.79
61	0	1	0.00	0.79
62	0	1	0.00	0.79
63	0	1	0.00	0.79
64	0	1	0.00	0.79
65	0	1	0.00	0.79
66	0	1	0.00	0.79
67	1	2	0.79	1.59
68	1	3	0.79	2.38
69	1	4	0.79	3.17
70	3	7	2.38	5.56
71	0	7	0.00	5.56
72	0	7	0.00	5.56
73	1	8	0.79	6.35
74	1	9	0.79	7.14
75	2	11	1.59	8.73
76	1	12	0.79	9.52
77	3	13	2.38	11.90
78	2	17	1.59	13.49
79	4	21	3.17	16.67
80	2	23	1.59	18.25
81	1	24	0.79	19.05
82	1	25	0.79	19.84
83	4	29	3.17	23.02
84	1	30	0.79	23.81
85	4	34	3.17	26.98
86	3	37	2.38	29.37
87	2	39	1.59	30.95
88	4	43	3.17	34.13
89	1	44	0.79	34.92
90	4	48	3.17	38.10
91	1	49	0.79	38.89
92	1	50	0.79	39.68
93	5	55	3.97	43.65
94	6	61	4.76	48.41
95	2	63	1.59	50.00
96	10	73	7.94	57.94
97	4	77	3.17	61.11
98	5	82	3.97	65.08
99	6	88	4.76	69.84
100	4	92	3.17	73.02
101	4	96	3.17	76.19
102	4	100	3.17	79.37
103	7	107	5.56	84.92
104	2	109	1.59	86.51
105	1	110	0.79	87.30
106	2	112	1.59	88.89
107	6	118	4.76	93.65
108	1	119	0.79	94.44
109	1	120	0.79	95.24
110	0	120	0.00	95.24
111	2	122	1.59	96.83
112	1	123	0.79	97.62
113	1	124	0.79	98.41
114	0	124	0.00	98.41
115	0	124	0.00	98.41
116	0	124	0.00	98.41
117	0	124	0.00	98.41
118	1	125	0.79	99.21
119	1	126	0.79	100.00
120	0	126	0.00	100.00

Figure 8. Subjects with Hearing Anomalies in Sample A by WISC FSIQ Level.



FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
60	0	0	0.00	0
61	0	0	0.00	0
62	1	1	1.22	1
63	0	1	0.00	1
64	0	1	0.00	1
65	1	2	1.22	2
66	0	2	0.00	2
67	0	2	0.00	2
68	0	2	0.00	2
69	0	2	0.00	2
70	1	3	1.22	4
71	0	3	0.00	4
72	0	3	0.00	4
73	1	4	1.22	5
74	0	4	0.00	5
75	1	5	1.22	6
76	0	5	0.00	6
77	4	9	4.88	11
78	2	11	2.44	13
79	2	13	2.44	16
80	1	14	1.22	17
81	0	14	0.00	17
82	3	17	3.66	21
83	0	17	0.00	21
84	0	17	0.00	21
85	4	21	4.88	26
86	1	22	1.22	27
87	1	23	1.22	28
88	3	26	3.66	32
89	1	27	1.22	33
90	1	28	1.22	34
91	4	32	4.88	39
92	0	32	0.00	39
93	4	36	4.88	44
94	1	37	1.22	45
95	2	39	2.44	48
96	6	45	7.32	55
97	2	47	2.44	57
98	4	51	4.88	62
99	2	53	2.44	65
100	2	55	2.44	67
101	4	59	4.88	72
102	1	60	1.22	73
103	3	63	3.66	77
104	4	67	4.88	82
105	1	68	1.22	83
106	2	70	2.44	85
107	2	72	2.44	88
108	0	72	0.00	88
109	1	73	1.22	89
110	1	74	1.22	90
111	1	75	1.22	91
112	2	77	2.44	94
113	0	77	0.00	94
114	0	77	0.00	94
115	2	79	2.44	96
116	0	79	0.00	96
117	0	79	0.00	96
118	0	79	0.00	96
119	0	79	0.00	96
120	3	82	3.66	100

Figure 9. Subjects with Visual Anomalies in Sample A by WISC FSIQ Level.



FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
60	1	1	0.43	0.43
61	0	1	0.00	0.43
62	1	2	0.43	0.86
63	0	2	0.00	0.86
64	1	3	0.43	1.29
65	0	3	0.00	1.29
66	0	3	0.00	1.29
67	2	5	0.86	2.15
68	2	7	0.86	3.00
69	4	11	1.72	4.72
70	1	12	0.43	5.15
71	0	12	0.00	5.15
72	2	14	0.86	6.01
73	0	14	0.00	6.01
74	0	14	0.00	6.01
75	4	18	1.72	7.73
76	3	21	1.29	9.01
77	6	27	2.58	11.59
78	6	33	2.58	14.16
79	4	37	1.72	15.88
80	8	45	3.43	19.31
81	3	48	1.29	20.60
82	1	49	0.43	21.03
83	7	56	3.00	24.03
84	6	62	2.58	26.61
85	6	68	2.58	29.13
86	7	75	3.00	32.19
87	5	80	2.15	34.33
88	9	89	3.86	38.20
89	7	96	3.00	41.20
90	6	102	2.58	43.78
91	8	110	3.43	47.21
92	4	114	1.72	48.93
93	10	124	4.29	53.22
94	8	132	3.43	56.65
95	7	139	3.00	59.66
96	13	152	5.58	65.24
97	4	156	1.72	66.95
98	8	164	3.43	70.39
99	14	178	6.01	76.39
100	2	180	0.86	77.25
101	6	186	2.58	79.83
102	6	192	2.58	82.40
103	8	200	3.43	85.84
104	2	202	0.86	86.70
105	0	202	0.00	86.70
106	3	205	1.29	87.98
107	5	210	2.15	90.13
108	3	213	1.29	91.42
109	3	216	1.29	92.70
110	2	218	0.86	93.56
111	2	220	0.86	94.42
112	3	223	1.29	95.71
113	1	224	0.43	96.14
114	3	227	1.29	97.42
115	2	229	0.86	98.28
116	1	230	0.43	98.71
117	1	231	0.43	99.14
118	0	231	0.00	99.14
119	2	233	0.86	100.00
120	0	233	0.00	100.00

Figure 10. Subjects with Impairment on the Sweep Hearing Test in Sample A by WISC FSIQ Level.

not carried out on a case-by-case basis by examination of actual clinical files. Instead, these children were selected by using a computer to determine cases (as many as possible) which met the following criteria; (1) WISC FSIQ>60 and FSIQ<120, (2) data was present and readily available for the variables relevant to the study, (3) no apparent speech difficulties, and (4) English was the language spoken in the home. If a child's data were coded indicating a speech problem, or a language in addition to English was spoken in the home he/she was excluded from the sample. In contrast to most other LD investigations, these were the only exclusionary criteria employed for Sample A. The majority of LD studies tend to exclude children on the basis of a wide array of criteria including the following: low IQ, inadequate schooling, visual or auditory anomalies, environmental deprivation, suspected socioemotional disturbance, and known or suspected cerebral pathology. No attempt was made to exclude any children on the basis of these 'typical' criteria from Sample A. However, children were excluded from Sample B on the basis of these exclusionary criteria and only the low IQ children were not excluded.

All subjects included in Sample A (see Table 1) were between the chronological ages of 9-years, 0-months and 14-years, 11-months; they had obtained a WISC FSIQ between 60 and 120. WISC VIQ ranged from 60 to 125 while the WISC PIQ

Table 1

Sample A (n=1200)
Characteristics: Means (Standard Deviations) by Sex

	males	females	total
n	964	236	1200
Chronological Age (years)	11.42 (1.62)	11.18 (1.62)	11.37 (1.62)
WISC			
Verbal IQ	92.37 (11.21)	89.54 (11.49)	91.83 (11.32)
Performance IQ	100.78 (14.56)	97.40 (14.46)	100.14 (14.58)
Full Scale IQ	96.00 (11.97)	92.64 (12.03)	95.36 (12.04)
PPVT IQ	98.71 (14.28)	91.62 (13.60)	97.32 (14.42)
WRAT			
Reading %	28.67 (25.62)	32.49 (28.54)	29.45 (26.29)
Spelling %	18.68 (19.92)	25.56 (24.09)	20.10 (21.05)
Arithmetic %	16.67 (13.32)	19.19 (15.46)	17.16 (13.79)
HAND PREFERENCE			
Right	798	195	993
Left	166	41	207

ranged from 54 to 146. PPVT IQ ranged from 57 to 140. There were 964 males (80%) and 236 females (20%) in Sample A. A majority (83%, n=994) of the children were considered right-handed on the basis of hand preference for name writing, while 17% (n=206) were considered left-handed. Table 1 also displays the composition of Sample A in terms of age, sex, WISC variables, and the WRAT Reading, Spelling, and Arithmetic mean centiles.

The number of subjects in Sample A belonging to categories of children usually excluded from learning disability studies are listed in Table 2. Overall, there were 493 children in Sample A within these five categories; Emotionally Disturbed, Brain Lesioned, Environmentally Deprived, Hearing Anomalies, and Visual Anomalies.

All subjects included in Sample B (see Table 3) were between the chronological ages of 9-years, 0-months and 14-years, 11-months; they obtained a WISC FSIQ between 70 and 110. WISC VIQ ranged from 61 to 123 while WISC PIQ ranged from 58 to 133. PPVT IQ ranged from 57 to 138. There were 730 males (83%) and 152 females (17%) in Sample B. A majority (82%, n=760) were considered right-handed on the basis of hand preference for name writing, while 18% (n=162) were considered left-handed. Table 3 also displays the composition of Sample B in terms of age, sex, WISC variables, and the WRAT Reading, Spelling, and Arithmetic mean centiles.

Table 2

Number of Children in Sample A Fitting a Typical Exclusionary Category

1. Emotionally Disturbed (n=308)
   These children were considered emotionally disturbed on the basis of referral information (n=168) or as a result of the neuropsychological examination (n=120).

2. Brain Lesioned (n=66)
   There are 48 children in this category who are known to have epilepsy. Seven children have medical confirmation of a brain lesion, and for eleven others the weight of medical evidence suggests neurological dysfunction. However, these last 18 children were not diagnosed as epileptic at the time of referral. The presence of these neurological problems was determined on the basis of the referral information.

3. Environmental Deprivation (n=10)
   On the basis of the referral information, eight children in Sample A were considered to lack adequate food, shelter, and/or clothing.

4. Hearing Anomalies (n=86)
   According to the information available, eight-six children in Sample A had hearing difficulty at some point prior to the neuropsychological evaluation. This was determined on the basis of referral information or parental report.

5. Visual Anomalies (n=82)
   A total of eighty-six children in Sample A were considered to have experienced some type of visual difficulty prior to the neuropsychological evaluation. This was determined on the basis of the referral information or parental report.

6. Impairment on a standardized Sweep Hearing Test (n=233)
   This measure was given during the neuropsychological examination. Impairment was defined as evidence of a hearing loss greater than 25 decibels with either ear within a frequency range of 500 to 8000 Hz.

Table 3

Sample B (n=882)
Characteristics: Means (Standard Deviations) by Sex

	males	females	total
n	732	152	882
Chronological Age in years	11.26 (1.53)	11.08 (1.56)	11.23 (1.54)
WISC			
Verbal IQ	91.18 (8.90)	89.63 (8.60)	90.91 (8.86)
Performance IQ	100.30 (12.15)	98.48 (12.46)	99.99 (12.21)
Full Scale IQ	95.08 (9.02)	93.25 (8.73)	94.76 (8.99)
PPVT IQ	98.39 (12.99)	92.13 (11.17)	97.31 (13.00)
WRAT			
Reading %	23.99 (22.35)	29.18 (25.19)	24.88 (22.93)
Spelling %	15.86 (16.69)	22.84 (21.25)	17.06 (17.74)
Arithmetic %	16.31 (12.65)	18.12 (13.33)	16.62 (12.78)
HAND PREFERENCE			
Right	589	131	720
Left	141	21	162

The subjects in Sample B were subdivided into smaller subsamples according to the WISC FSIQ levels illustrated in Figure 11. These subsamples were equated for size so that the results of the data analyses (cluster algorithms) could be compared between each of the five IQ levels in Figure 11. With this procedure, any influence that sample size may have on the formation of subtypes at the various IQ levels was controlled. Each of the five subsamples consisted of 70 children since this was the smallest number of subjects occuring in the WISC FSIQ range 70 to 80 apparent in Figure 11. The relevant characteristics of the children in each of the Sample B Subsamples 1 to 4 are depicted in Tables 4 through 7, respectively. The distribution of children according to WISC FSIQ within each Sample B Subsample are depicted in Figures 12 through 15, respectively.

Procedure

In order to address the issues of; (1) relevance of exclusionary definitions, and (2) the effect of FSIQ level on subtypal composition, the sample data was analyzed at the 'levels' as indicated in Figure 11. Initially, the Sample A subjects were subtyped together on the basis of their WRAT Reading, Spelling, and Arithmetic subtest scores. This was done to provide some indication of the subtypal composition of a large heterogeneous group of children without reliance on exclusionary criteria. Of interest here was the degree to

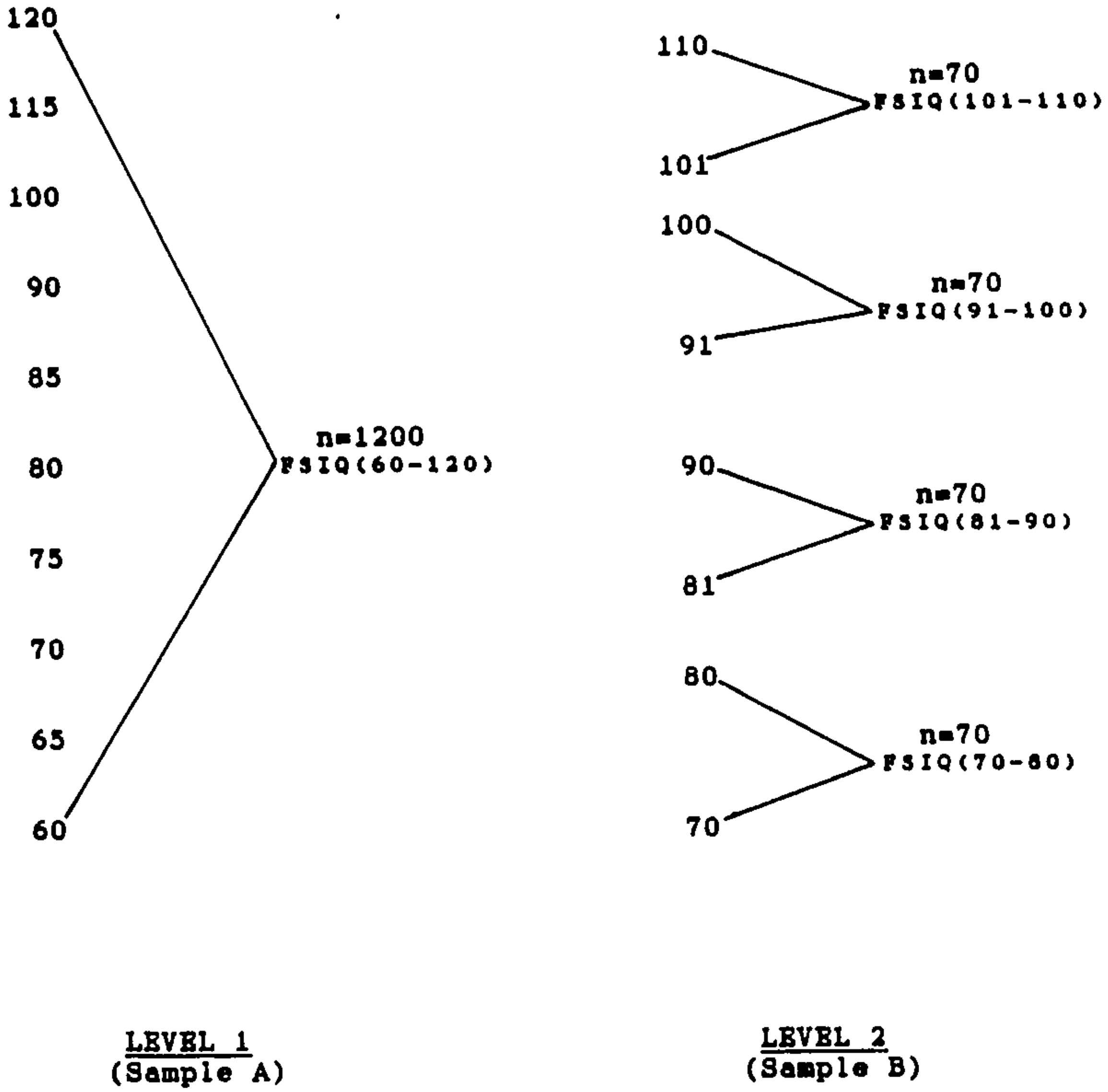


Figure 11. The first and second levels of subtypal analysis.

Table 4

Sample B Sub-Sample 1 (n=70) WISC FSIQ (70-80) Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	57	13	70
Chronological Age in years	11.45 (1.63)	11.97 (1.53)	11.55 (1.62)
WISC			
Verbal IQ	78.77 (6.13)	77.77 (7.45)	78.59 (6.35)
Performance IQ	79.10 (7.10)	79.53 (8.80)	79.19 (7.38)
Full Scale IQ	76.75 (2.38)	76.46 (3.20)	76.70 (2.88)
PPVT IQ	85.57 (11.72)	84.85 (12.50)	85.44 (11.78)
WRAT			
Reading %	16.47 (23.79)	21.54 (19.29)	17.41 (22.98)
Spelling %	10.67 (13.95)	15.00 (13.67)	11.47 (13.90)
Arithmetic %	8.11 (6.18)	11.31 (13.47)	8.70 (8.01)
HAND PREFERENCE			
Right	43	13	56
Left	14	0	14

Table 5

Sample B Sub-Sample 2 (n=70) WISC FSIQ (81-90) Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	56	14	70
Chronological Age in years	11.51 (1.66)	11.11 (1.52)	11.43 (1.63)
WISC			
Verbal IQ	84.88 (6.50)	87.43 (6.64)	85.39 (6.56)
Performance IQ	90.45 (8.06)	87.50 (7.87)	89.86 (8.05)
Full Scale IQ	86.59 (2.50)	86.43 (2.85)	86.56 (2.55)
PPVT IQ	93.82 (11.79)	89.36 (8.41)	92.93 (11.29)
WRAT			
Reading %	19.98 (19.82)	31.71 (32.49)	22.33 (23.12)
Spelling %	13.48 (15.00)	28.14 (29.01)	16.41 (19.31)
Arithmetic %	11.64 (8.01)	11.50 (7.70)	11.61 (7.90)
HAND PREFERENCE			
Right	41	9	50
Left	15	5	20

Table 6

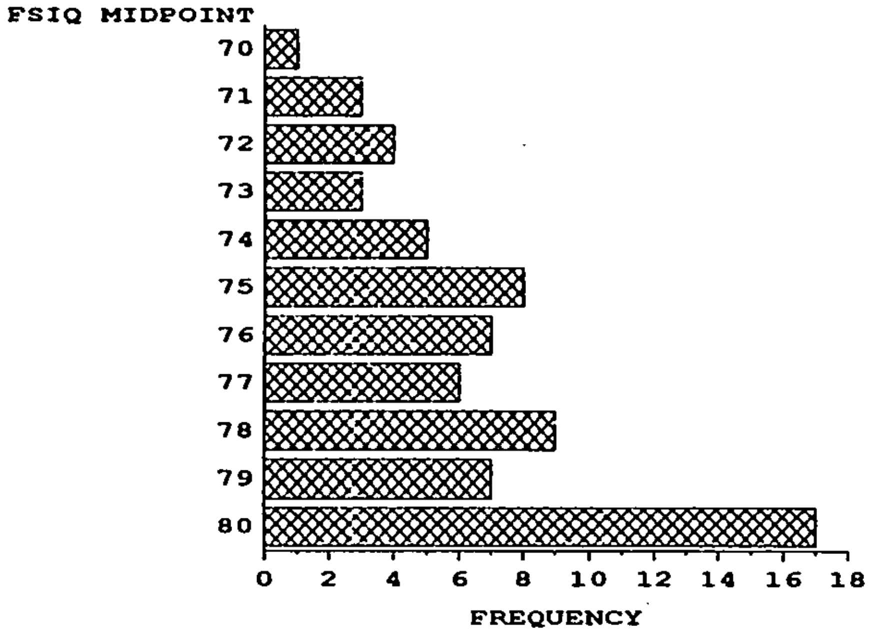
Sample B Sub-Sample 3 (n=70) WISC FSIQ (91-100) Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	60	10	70
Chronological	11.15	10.11	11.00
Age in years	(1.59)	(1.02)	(1.52)
WISC			
Verbal IQ	91.12 (6.63)	93.80 (6.44)	91.50 (6.63)
Performance IQ	100.83 (7.56)	95.40 (9.82)	100.06 (8.07)
Full Scale IQ	95.37 (2.79)	94.20 (3.01)	95.20 (2.83)
PPVT IQ	99.03 (10.35)	93.90 (13.95)	98.30 (10.97)
WRAT			
Reading %	22.92 (21.59)	45.90 (24.31)	26.20 (23.26)
Spelling %	15.88 (16.07)	38.00 (25.71)	19.04 (19.18)
Arithmetic %	17.10 (12.49)	33.80 (19.89)	19.49 (14.82)
HAND PREFERENCE			
Right	50	10	60
Left	10	0	10

Table 7

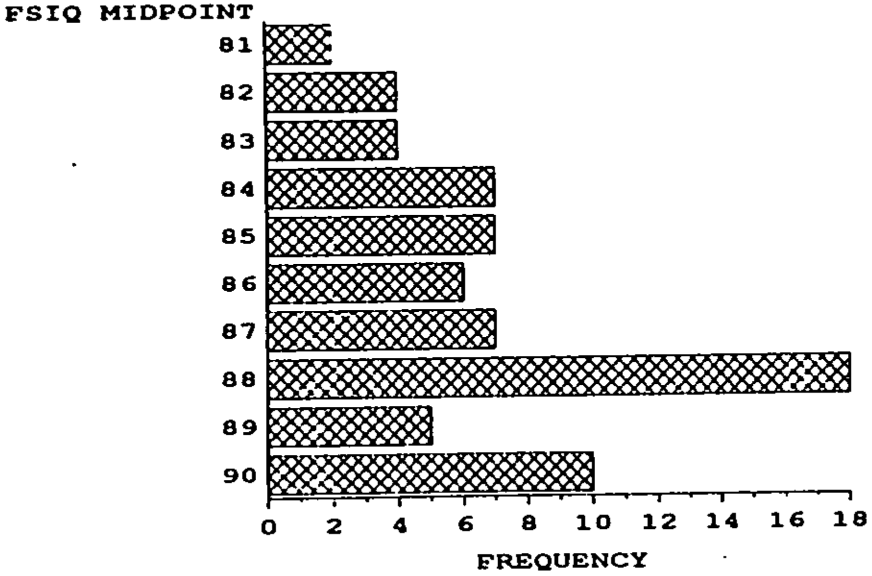
<u>Sample B Sub-Sample 4 (n=70) WISC FSIQ (101-110) Characteristics: Means (Standard Deviations) By Sex</u>

	males	females	total
n	61	9	70
Chronological Age in years	11.06 (1.41)	11.16 (1.68)	11.07 (1.44)
WISC			
Verbal IQ	99.23 (6.36)	100.22 (5.97)	99.36 (6.28)
Performance IQ	111.00 (7.70)	107.33 (7.95)	110.53 (7.78)
Full Scale IQ	105.28 (3.03)	104.11 (3.44)	105.13 (3.09)
PPVT IQ	106.57 (11.55)	98.56 (13.54)	105.54 (12.02)
WRAT			
Reading %	31.72 (25.29)	40.00 (35.45)	32.79 (26.64)
Spelling %	19.87 (20.92)	30.22 (24.06)	21.20 (21.44)
Arithmetic %	21.95 (17.46)	26.22 (15.65)	22.50 (17.19)
HAND PREFERENCE			
Right	51	8	59
Left	10	1	11



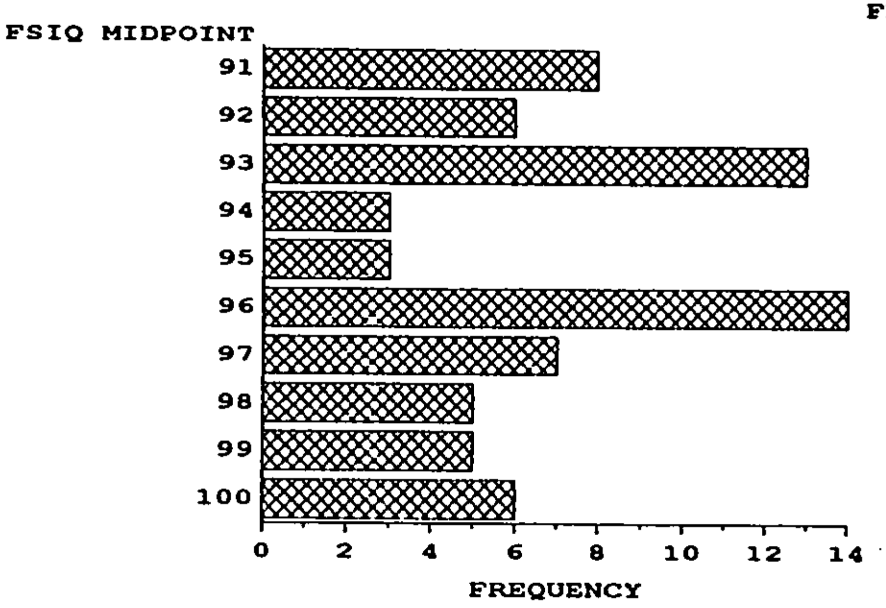
FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
1	1	1.43	1.43
3	4	4.29	5.71
4	8	5.71	11.43
3	11	4.29	15.71
5	16	7.14	22.86
8	24	11.43	34.29
7	31	10.00	44.29
6	37	8.57	52.86
9	46	12.86	65.71
7	53	10.00	75.71
17	70	24.29	100.00

Figure 12. Number of Subjects by WISC FSIQ Level in Sample B Subsample 1.



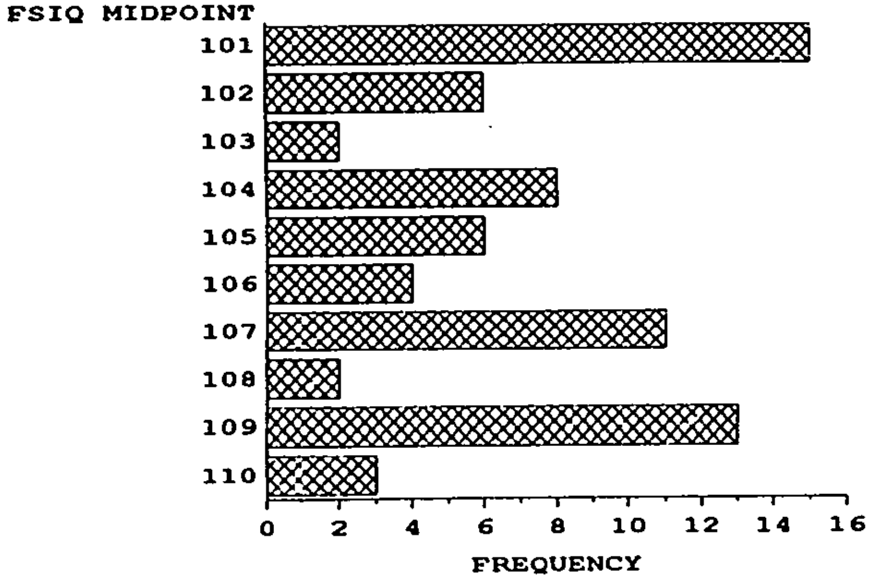
FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
2	2	2.86	2.86
4	6	5.71	8.57
4	10	5.71	14.29
7	17	10.00	24.29
7	24	10.00	34.29
6	30	8.57	42.86
7	37	10.00	52.86
18	55	25.71	78.57
5	60	7.14	85.71
10	70	14.29	100.00

Figure 13. Number of Subjects by WISC FSIQ Level in Sample B Subsample 2.



FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
8	8	11.43	11.43
6	14	8.57	20.00
13	27	18.57	38.57
3	30	4.29	42.86
3	33	4.29	47.14
14	47	20.00	67.14
7	54	10.00	77.14
5	59	7.14	84.29
5	64	7.14	91.43
6	70	8.57	100.00

Figure 14. Number of Subjects by WISC FSIQ Level in Sample B Subsample 3.



FSIQ MIDPOINT	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
101	15	15	21.43	21.43
102	6	21	8.57	30.00
103	2	23	2.86	32.86
104	8	31	11.43	44.29
105	6	37	8.57	52.86
106	4	41	5.71	58.57
107	11	52	15.71	74.29
108	2	54	2.86	77.14
109	13	67	18.57	95.71
110	3	70	4.29	100.00

Figure 15. Number of Subjects by WISC FSIQ Level in Sample B Subsample 4.

which relatively reliable, well-separated, and homogeneous subgroups emerge. In particular, the subgroup membership of children with WISC FSIQs in the below 90 range were noted since they fall within the IQ scores generally used to exclude subjects from further participation in the research at hand. Children who do not appear to fit into any subgroup (outliers) were also be reported on in detail.

Cluster methodology was selected for detecting the presence of subgroups since it does not rely on a priori assumptions regarding the structure of the data (Massart & Kaufman, 1983). Instead of deleting subjects such as those described in Table 2, it was thought that cluster techniques could be employed to determine if these children formed natural subgroups separate from the other subjects, or whether they would 'share' subtype membership with children usually identified as LD. Therefore, the subtype membership of the individual children who belong to the categories in Table 2 were reported in detail.

The subjects in Sample A were initially cluster analyzed according to their performance on the WRAT Reading, Spelling, and Arithmetic subtests (Jastak & Jastak, 1965). Some authors (e.g., Fletcher & Satz, 1985; Satz & Morris, 1981) have suggested that subtypes derived from cluster analyses of measures of academic achievement be identified prior to analysis of neuropsychological data. This is done in order to determine which groups of children are deficient in one or more areas of academic achievement. Subgroups of children found who are 1 SD below the mean on at least one WRAT subtest are considered 'learning disabled' and are compared on their neuropsychological performance. Satz and Morris (1981) suggest that this procedure provides a statistical rather than a priori definition of learning disability. This procedure was utilized in the present study and the subtypes found deficient in at least one WRAT subtest were then cluster analyzed on the basis of their neuropsychological performances.

Other researchers, most notably Rourke and associates (e.g., Ozols & Rourke, 1988; Rourke & Finlayson, 1978) have demonstrated there are differences in neuropsychological abilities and impairment between groups of children categorized according to the patterns of their score profiles on the WRAT subtests. For example, one subtype (i.e., classification) of children exhibited average or above-average performances on the WRAT Reading and Spelling subtests while evidencing a deficient performance on WRAT Arithmetic. This 'configurational' approach was also applied in the present study to define which WRAT subtypes resulting from the cluster analysis could be considered LD. In this case, a subtype of children was designated learning disabled if there was a difference of at least one-half a standard deviation (with respect to T-scores) between any two WRAT subtest scores. The proposed course of data analysis for Sample A is represented in Figures 16 and 17.

As depicted in Figure 11, at the second level of analysis Sample B was partitioned at several levels of WISC FSIQ. This was done in order to address the effect of WISC FSIQ on the formation of subtypes. Separate cluster analyses were applied to the five sections of the data created by this partition. Comparisons were made in terms of number of subtypes formed and similarities or differences in ability structure based on interpretation of the subgroup profile on the neuropsychological variables. The subtyping of the subjects in Sample B proceeded according to the steps illustrated in Figure 17, starting with a T-score transformation and then a z-score transformation (Lorr, 1983) of each child's performance on the neuropsychology variables. It was thought that inspection of the neuropsycholgy variable profiles would yield evidence for or against the assumption of no differences in subgroup composition due to variations in WISC FSIQ level between the Sample B subsamples.

Cluster Analysis

The statistical techniques known as cluster analysis are generally useful for two purposes; (1) devising a strategy for grouping similar objects into categories so 'like' objects occur in the same class, and (2) reducing a large set

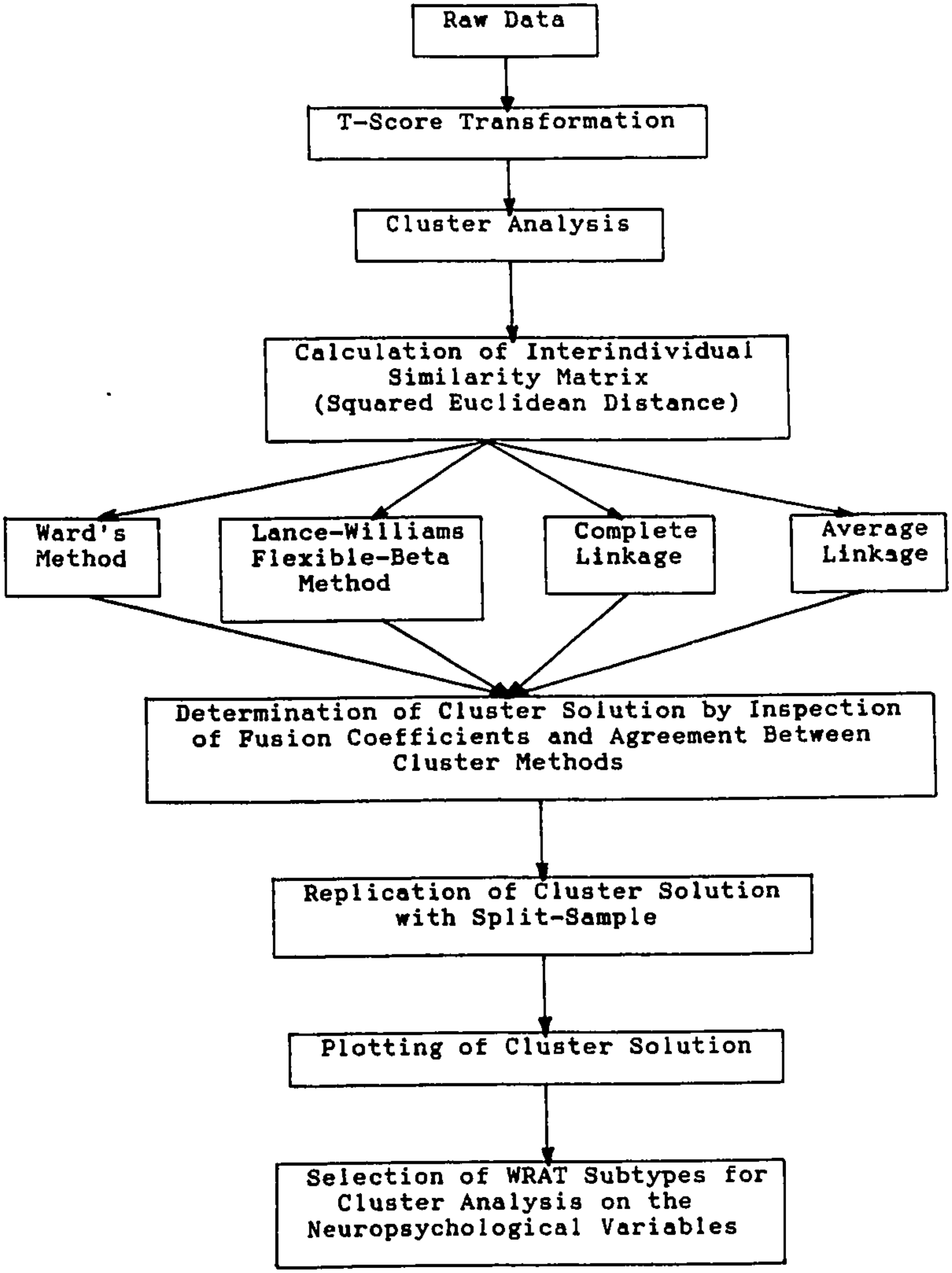


Figure 16. Illustration of the cluster analytic procedure for the WRAT variables.

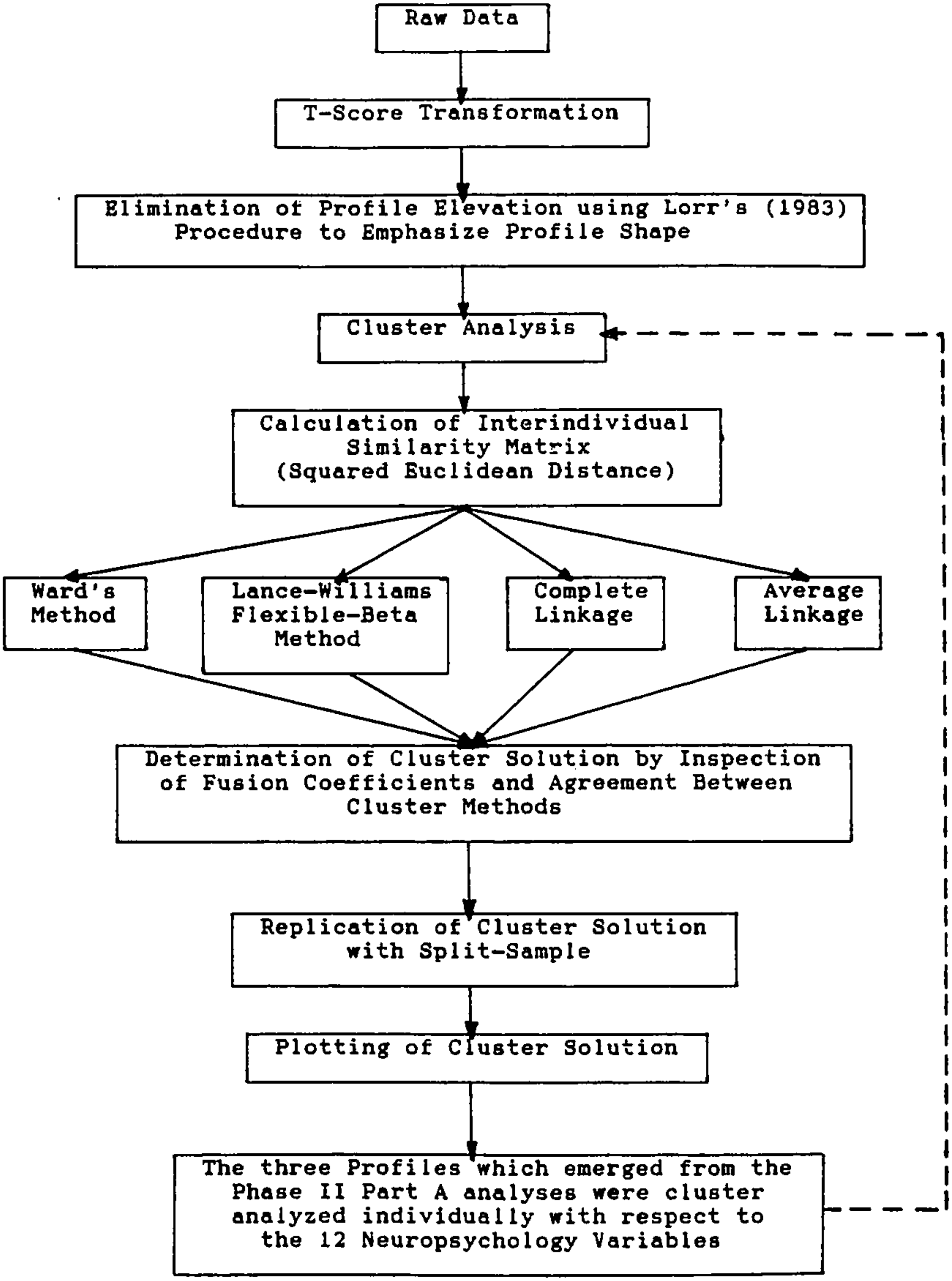


Figure 17. Illustration of the cluster analytic procedure for the Neuropsychological Variables.

of data into smaller more manageable parcels (Manly, 1986). Cluster analytic algorithms operate mainly by dividing a large data set into smaller portions, each of the members sharing more in common with their portion than with the rest of the data, or by starting with every individual case in the data and deriving subgroups by agglomerations. In each instance the data can be transfered into and out of a group in a series of successive iterations until there is an optimal or logically consistent (i.e., meaningful) pattern of subtype structure (Massart & Kaufman, 1983).

It is well known that there are a large variety of cluster analytic techniques and software packages for their implementation (Blashfield & Aldenderfer, 1978). In a review of software packages, Blashfield, Aldenderfer, and Morey (1982) recommended the use of Wishart's (1975) CLUSTAN (Version 1C2) due to its documentation and flexible options. The SAS Institute Inc. has more recently offered a large variety of clustering algorithms within its SAS Statistics package (Version 5 Edition; 1985). Although the clustering procedures of this version of SAS have not been as widely utilized or reviewed as has the CLUSTAN package, they were chosen for use in the present study. There were three primary reasons for this decision; (a) the CLUSTAN package was not readily available, (b) the SAS software package allows for relatively flexible operations on large data sets, and (c) it is very well documented.

A majority of cluster investigations of LD data (e.g., Doehring, Hoshko & Byrans, 1979; Deldotto & Rourke, 1985) have employed variations of the agglomerative hierarchical clustering techniques with good success. This type of cluster analysis begins with computation of an inter-individual similarity matrix (Everitt, 1980; Manly, 1986). Following this calculation, subjects are grouped together by successively merging those individuals most alike. This process continues until all subjects belong to one large group. The crucial variable for determining how the technique carries out assembling groups of 'like' members is the measure of similarity introduced into the analysis.

Measures of similarity in cluster analytic procedures group together individuals on the basis of their test score profiles. According to Cronbach and Gleser (1953) there are three basic elements of any subject's profile: the 'shape' is the pattern formed by the changes in magnitude of the individual scores across the profile; the 'elevation' is the average of all the individual's test scores; and the profile 'scatter' refers to the dispersion of each score about the mean score.

Massart and Kaufman (1983) considered three separate types of similarity measures: (1) distance, (2) correlation coefficients, and (3) information content. This last type of similarity coefficient is derived from the probability of measuring or detecting a given signal or event. Other types of similarity measures, such as association coefficients, have also been employed (Aldenderfer & Blashfield, 1984). However, for the present study only the distance and correlation coefficients were considered. Measures of similarity using a correlation coefficient tend to emphasize profile shape and minimize elevation (Fleiss & Zubin, 1969). On the other hand, measures that emphasize distance between subjects (euclidean, squared euclidean) tend to minimize profile shape. With correlation coefficients as similarity measures, two individuals who differ in terms of levels of performance (elevation) can exhibit similar profile shapes (Aldenderfer & Blashfield, 1984).

Skinner (1978) discussed a research strategy for determining the differential contributions of shape, scatter, and elevation to the formation of clusters of test score profiles. This three-stage process was an elaboration of Guertin's (1966) two-step strategy that involved the grouping of 'like' profiles on the basis of shape with a correlation similarity measure. Each of these 'shape groups' is then cluster analyzed on the basis of scatter and elevation using a distance measure of profile similarity. Most recently, Lorr (1983) has explicitly delineated this two-step clustering strategy and proposed a modification for using a distance measure of similarity at both stages. The first and second steps of this strategy were employed in the cluster analysis of the neuropsychology variables with the Sample A data.

Morris, Blashfield and Satz (1981) have cautioned that different cluster analytic techniques may yield rather different cluster solutions with the same data set. The strategy for using cluster analysis in the present study was to employ several variations of one particular class of methods which have been utilized by several researchers in the field of learning disabilities.

In the present study, the initial cluster analysis of the Sample A subjects using the WRAT data was conducted with a similarity matrix determined by squared Euclidean distance. This was done to emphasize elevation and separate groups of children on the basis of levels of performance on the academic measures. However, in the next step of the cluster analysis the degree to which the shapes of the profiles of the subtypes on the neuropsychological measures was considered most important. Unfortunately, the SAS clustering methods used in this study do not allow for similarity matrices composed of correlation coefficients. Therefore, the procedure suggested by Lorr (1983) to eliminate profile elevation from the data was employed. In this procedure, each subject's 12 scores on the neuropsychological variables were standardized across the subject's profile. The standard score transformation used by Lorr (1983)[1] is $z= X-x/SD$, where x is the subject's raw score, X is the mean of that subject's profile and SD is the standard deviation of the subject's profile. The mean and SD are calculated across the 12 neuropsychology variables for each subject and z is the resultant standard score. Following the identification of profile 'shapes' in the Sample A data, the second step of Lorr's (1983) strategy was applied. Each profile shape was clustered on the basis of shape and profile elevation using squared Euclidean distance as a similarity measure (see Figure 17). This was done to emphasize elevation and separate subtypes of children on the basis of performance on the neuropsychological measures.

Massart and Kaufman (1983) provide descriptions of several types of clustering algorithms including the following: hierarchical agglomerative, divisive methods, graph-theoretical methods, density linkage, and fuzzy clustering. Several of the hierarchical agglomerative methods were chosen for the present study. The other techniques are discussed in more detail by other authors (e.g., Everitt, 1980; Lorr, 1983; Morris, Blashfield, & Satz, 1981) and will not be addressed here.

The SAS statistical software package (SAS Institute, Version 5, 1985) offers a variety of the hierarchical agglomerative techniques (e.g., average linkage, density sorting, complete linkage, single linkage). Although single linkage is considered the most mathematically rigourous of these procedures (Jardine & Sibson, 1971), it was not chosen for the present study since it is known to be highly sensitive to 'chaining' and 'noise' in the data (Edelbrock, 1979; Everitt, 1980). The single linkage (also called nearest neighbour) method attempts to join individuals to existing clusters if at least one member of the group shares a certain degree of similarity with the object considered for membership. In this manner, successive 'fusions' of individuals who are less and less similar to a majority of the members can occur forming a 'chain' and distorting the cluster shape to appear elongated. If there are distinct homogeneous clusters within the data but some individuals lie in the space between them, the single linkage technique may join these 'noise' elements to the distinct clusters actually present in the data, thereby distorting the cluster solution (Massart & Kaufman, 1983).

Complete linkage (or furthest neighbour) attempts to include other individuals within already formed clusters only if they share a certain level of similarity with all other individuals in the group. It is considered the logical opposite of the single linkage technique and tends to form cohesive clusters of highly similar individuals (Aldenderfer

& Blashfield, 1984).

In the average method, all the elements of the clusters about to be fused are considered independently of the size of the clusters. Clusters are fused to form new groups and individuals are added to clusters when the similarity of the new observations achieve a given level compared to the average similarity of the existing cluster (Massart & Kaufman, 1983).

Ward's method (error sum of squares, minimum variance method) involves the calculation of the sum of the squared distance of each member to its cluster centroid. This sum represents the heterogeneity of that cluster. Ward's algorithm allows for the fusion of clusters or individuals which increase this heterogeneity by the least amount (Massart & Kaufman, 1983). Although Ward's method has been criticized as prone to the formation of spherical equal-sized groups (Aldenderfer & Blashfield, 1984), it has been found to be the most accurate method for recovering known cluster structure in several studies (e.g., Edelbrock, 1979; Morey, Blashfield, & Skinner, 1983).

Cluster analysis techniques can be compared in terms of how well they recover known cluster structure (i.e., accuracy), how much of the data they are able to categorize (i.e., coverage), and how well they generate the same cluster structure (i.e., reliability) when the data is manipulated by adding or deleting members (Everitt, 1980). There is considerable disagreement on which cluster analytic method provides the best recovery of cluster structure within the data.

Recently, Milligan (1981) reveiwed the studies assessing the accuracy of cluster recovery when the various techniques were applied to artificially generated data sets. The underlying assumption of this effort is that cluster algorithms which do not recover the subgroups from created data sets could not be counted on to recover the 'true' clusters (unknown) during exploratory data analyses.

In one of these studies, Blashfield (1976) compared the single linkage, complete linkage, average linkage, and Ward's method for recovery of known cluster structure in 50 multivariate data sets. Ward's technique was found to be the most accurate, complete linkage was second best, and single linkage was the poorest. In a second study, Blashfield and Morey (1980) generated data sets to resemble the MMPI profiles for psychotic, neurotic, and personality disorder groups. Ward's method provided 100% coverage and only 12 misclassifications between the three patient groups. Kuiper and Fisher (1975) also found Ward's minimum variance method produced the best solutions in terms of coverage and accuracy of classification. However, average linkage has also been reported to generate the best solutions with data sets analyzed by Edelbrock (1979), and Milligan and Isaac (1980).

As a result of these studies, some authors (e.g., Everitt, 1980; Lorr, 1983) recommend using several cluster methods and looking for agreement between the techniques in order to determine the best cluster solution. This 'cross-method' procedure was employed in the present study to ensure detection of 'good' clustering. There are few learning disability studies in the literature that employ any cross-method criteria to determine an optimal solution.

Doehring, Hoshko, and Bryans (1979) found that 23% of the children in their sample were misclassified between Q-factor and cluster analytic procedures. More recently, Fuerst, Fisk, and Rourke (1989) reported only 10% of their sample was misclassified between Q-factor analysis and Ward's cluster method. In their study, the cross-method agreement between Q-factor analysis and a K-means cluster procedure yielded no misclassifications.

In the present study, an acceptable misclassification rate of 30% was employed between Ward's method and the other three cluster analytic techniques. This misclassification rate was set arbitrarily high for the following reasons: (1) due to the exploratory nature of the present study, using a very large and heterogeneous sample, it was anticipated that cross-method agreement would be more difficult to demonstrate at an (arbitrarily) lower (e.g., 10%)

misclassification rate; and (2) there are no common guidelines in the literature for establishing such criteria; however, it is obvious that the fewer misclassifications the more confidence that an optimal cluster solution has been achieved.

Ward's method, average linkage, and complete linkage were employed in the present study due to their accuracy (Edelbrock, 1979), coverage (Kuiper & Fisher, 1975), and ability to detect group structure within psychological data (Mezzich, 1978). As mentioned previously, these methods have also been used in studies of LD populations. To date, the flexible-beta method (Lance & Williams, 1967) has been successfully employed in one published cluster-analytic study of psychosocial functioning in LD children (i.e., Feurst, Fisk, & Rourke, 1989). In this study, the flexible-beta method (compared with four other clustering techniques) produced the second fewest number of misclassified subjects that were assigned to subtypes with a Q-Factor analytic procedure. In recent studies comparing various cluster algorithms (Milligan, 1980; Milligan & Cooper, 1987; Scheilber & Schneider, 1985) the flexible-beta technique was found to provide excellent recovery of artificial cluster structure when outliers were not present in the data. Since outliers were removed from the data set in the present study with the SAS TRIM option (discussed below) prior to cluster analysis the flexible-beta technique was selected for use in the present research effort. Due to the large number of studies (see Milligan, 1981) that have indicated Ward's method to be superior in terms of cluster recovery, coverage, and accuracy it was decided to use Ward's as the target method. Cluster-analytic results that yielded 'good' correspondence (i.e., 30% or less misclassified subjects) between Ward's method and at least one of the other three cluster analytic techniques were considered good cluster solutions for the data sets in the present study. In general, Ward's minimum variance technique is thought to give the best recovery when overlapping clusters are present in the data and when a Euclidean distance similarity measure is used (Lorr, 1983).

There are three other outstanding issues with cluster methodology that should be addressed at this point. The first concerns which initial diagnostic procedures to rely on in order to detect the number of clusters present in the data. The second issue is the problem of what to do with the outliers that are present in the data set. Outliers are subjects whose test score profiles may not belong in any of the clusters within the data. They are thought to represent unique individuals or error due to measurement (Aldenderfer & Blashfield, 1984). Lastly, there is the problem of demonstrating the validity of the cluster solution.

Although there is no accepted method of determining the number of clusters, the plotting of various 'fusion' coefficients against the number of clusters reveals the amount of variance accounted for by successive cluster fusions (Everitt, 1980). When there are rapid or dramatic peaks or drops in these fusion plots, there is evidence of good clustering (Sarle, 1985). Several recent studies with simulated data sets have assessed the accuracy of these fusion coefficients in indicating the presence of cluster structure. Most notable of these efforts are the studies by Cooper and Milligan (1984), and Milligan and Cooper (1983), where the performance of 30 different methods for estimating the number of clusters present were compared. The two best fusion coefficients were reported to be a 'pseudo F' statistic first developed by Calinski and Harabasz (1974), and a 'pseudo T' statistic developed by Duda and Hart (1973). Both of these measures are provided with the SAS clustering algorithms and were utilized in the present study. Following Sarle's (1985) recomendation, cluster solutions were investigated when there was a consensus between these two coefficients.

In general, there is no consensus on how to determine which subjects are outliers, but there is agreement on the need for removing them from the data (Everitt, 1980). Fortunately, the SAS cluster software allows for a TRIM option which deletes a specified percentage of the most extreme observations prior to the analysis. Sarle (1985) recommends using a TRIM percentage of 10% with large data sets. However, inspection of the actual subjects deleted from the present data set with such a large TRIM value revealed that many children typically considered 'arithmetic disabled' on the basis of the WRAT subtests were deleted. For the purposes of this study, it was thought desirable to retain as many of the data points (i.e., children) as possible. Therefore, whenever feasible the smallest TRIM value which appeared to produce good clustering was employed. The TRIM option was used to remove outliers for all the data sets analyzed in this study. The SAS TRIM option must be used in conjunction with another parameter referred to as 'K'. Wong (1982) recommends using a K value which is the cubed root of the number of observations in the data set. This convention was applied in the present study.

Aldenderfer and Blashfield (1984) discussed several methods for assessing the validity of a cluster solution. They considered the three most powerful methods to be as follows: (1) statistcal demonstration of between-cluster differences on variables not used in the cluster analysis; (2) demonstrating that the cluster solution is not present in simulated data sets that are generated randomly; and (3) replication of the cluster solution with split-samples and/or different samples drawn from the same initial data set.

The first method involves showing the uniqueness of the derived clusters on measures external to the cluster analysis with statistical techniques such as multivariate analysis of variance (Morris, Blashfield, & Satz, 1981). In the second method, a data set is randomly constructed which matches the general characteristics of the original sample; however, this simulated data set contains no clusters. Since most clustering methods will 'find' clusters even within random data, the solutions from the actual data and the random data can be compared in terms of cluster homogeneity, and visually with respect to the cluster profiles. Obviously, if cohesive meaningful clusters can be obtained from random data then the validity of the solution derived from the actual data would be questionable. Probably the most common means of assessing the validity of a cluster solution is to demonstrate that it can be recovered repeatedly across different data sets (Lorr, 1983). The replication data sets are generally split samples or reduced samples of the original data (Morris, Blashfield, & Satz, 1981). This was the method of choice in the present study. Attempts were made to demonstrate the replicability of the cluster solutions for Sample A using samples of various sizes (N=1000, N=800, N=600) that were selected randomly from Sample A. The stability of cluster solutions derived from the Sample B Subsamples was also demonstrated with split samples drawn from the original data sets. In this case, two replication samples were selected for each of the four Subsamples (split sample sizes N=50 and N=35).

Selection of Neuropsychological Variables

The group of measures known as the Halstead-Reitan neuropsychology battery (Reitan & Davidson, 1974) served as the source for the variables employed in the present study. These measures are well known and have been reviewed extensively with regard to their discriminant validity and the coverage of brain-related abilities that they provide (e.g., Golstein & Shelley, 1972; Newby, Hallenbeck, & Embritson, 1983; Reitan & Davidson, 1974; Rourke & Adams, 1984). There are 42 measures generally associated with this battery and these measures are thought to represent areas of abilities and adaptive skills as delineated by Reitan (1974). These categories are comprised of the following:
(1) perceptual and kinesthetic tactile abilities, (2) simple motor and complex psychomotor abilities, (3) verbal and language-related abilities, (4) visual-spatial and sequential processing abilities, (5) academic ability (WRAT Reading, Spelling & Arithmetic), and (6) concept-formation or 'higher order' executive functions.

The measures in the neuropsychology battery were given to all children in the present study, and the variables selected for analysis are listed in Table 8. The categorization of these measures differs somewhat from

Table 8

List of Variables by Category

Variable	Category
1 Tactile Imperception & Suppression-Right Hand	Simple Tactile Perceptual
2 Tactile Imperception & Suppression-Left Hand	
3 Tactile Finger Recognition-Right Hand (FAGR)	
4 Tactile Finger Recognition-Left Hand (FAGL)	
5 Tactile Finger Recognition-Mean (FAGM	
6 Fingertip Number Writing-Right Hand (FTWR)	Complex Tactile Perceptual
7 Fingertip Number Writing-Left Hand (FTWL)	
8 Fingertip Number Writing-Mean (FTWM)	
9 Tactile Coin Recognition-Right Hand (ASTR)	
10 Tactile Coin Recognition-Left Hand (ASTL)	
11 Tactile Coin Recognition-Mean (ASTM)	
12 Finger Tapping Test-Right Hand (TAPR)	Simple Motor Skill
13 Finger Tapping Test-Left Hand (TAPL)	
*14 Finger Tapping Test-Mean (MTAP)	
15 Foot Tapping Test-Right Foot (FTAPR)	
16 Foot Tapping Test-Left Foot (FTAPL)	
17 Dynomometer-Right Hand (GRIPR)	
18 Dynomometer-Left Hand (GRIPL)	
*19 Dynomometer-Mean (MGRIP)	
20 Grooved Pegboard Test-Right Hand (PEGSRT)	Complex Motor Skill
21 Grooved Pegboard Test-Left Hand (PEGSLT)	
*22 Grooved Pegboard Test-Mean (MPEGS)	
23 Maze Time-Right Hand (MAZERT)	
24 Maze Counter-Right Hand (MAZERC)	
25 Maze Speed-Right Hand (MAZERS)	
26 Maze Time-Left Hand (MAZELT)	
27 Maze Counter-Left Hand (MAZELC)	
28 Maze Speed-Left Hand (MAZELS)	
*29 Maze Time-Mean (MMAZE)	
30 Maze Counter-Mean (MAZECM)	
31 Maze Speed-Mean (MAZESM)	
32 Holes Time-Right Hand (HOLERT)	
33 Holes Counter-Right Hand (HOLERC)	
34 Holes Time-Left Hand (HOLELT)	
35 Holes Counter-Left Hand (HOLELC)	
36 Holes Time-Mean (HOLETM)	
37 Holes Counter-Mean (HOLECM)	
38 Name Writing Speed-Right Hand (NAMER)	
39 Name Writing Speed-Left Hand (NAMEL)	

Table continued

Table 8 continued

Variable		Category
40	WISC Picture Completion Subtest (PICCOM)	Visual Spatial Skills
41	WISC Picture Arrangements Subtest (PICARR)	
*42	WISC Block Design Subtest (BLKDES)	
*43	WISC Object Assembly Subtest (OBJASS)	
44	Visual Imperception & Suppression-Right	
45	Visual Imperception & Suppression-Left	
46	Target Test (TARGET)	
47	Trails A (TRSAT)	
48	WISC Arithmetic Subtest (ARITH)	Sequencing Abilities
49	WISC Digit Span Subtest (DIGITS)	
50	WISC Coding Subtest (CODING)	
51	Seashore Rhythm Test (SEARYM)	
*52	WISC Information Subtest (INFO)	Simple Language Abilities
53	WISC Comprehension Subtest (COMP)	
54	WISC Similarities Subtest (SIMIL)	
*55	WISC Vocabulary Subtest (VOCAB)	
56	Peabody Picture Vocabulary IQ (PPVTIQ)	
57	Auditory Imperception & Suppression-Right	
58	Auditory Imperception & Suppression-Left	
59	Speech-Sounds Perception Test (SSPT)	Complex Language Skills
60	Auditory Closure Test (AUDCLO)	
*61	Sentence Memory Test (SENMEM)	
*62	Verbal Fluency Test (VFLU)	
63	WRAT Reading Subtest (READSS)	Academic Skills
64	WRAT Spelling Subtest (SPELSS)	
65	WRAT Arithmetic Subtest (ARITSS)	

Table continued

Table 8 continued

Variable	Category
66 Tactual Performance Test-Right Hand (TPTDT)	Concept Formation or "Executive Functioning"
67 Tactual Performance Test-Left Hand (TPTNDT)	
68 Tactual Performance Test-Mean (TPTM)	
69 Tactual Performance Test-Both Hands (TPTBT)	
70 Tactual Performance Test-Total Time (TPTTOT)	
*71 Tactual Performance Test-Mean Total Time (MTPTTOT)	
72 Tactual Performance Test-Memory (TPTMEM)	
73 Tactual Performance Test-Location (TPTLOC)	
*74 Category Test (CATTOT)	
75 Trails B Test (TRSBT)	

*indicates variables chosen for analyses

Reitan (1974); it flows from recent analyses by Francis (1985, 1988). Using confirmatory factor analysis Francis (1985, 1988) has developed structural models that distinguished between simple and complex skill factors. These divisions are reflected in the classifications apparent in Table 8. In addition, Francis (1985) reported that several of the sensori-motor measures were fully equivalent across their right and left hand scores (simple tactile imperception, finger agnosia, finger dysgraphesthesia, astereognosis, finger tapping, grip strength, grooved pegboard, and mazes). Therefore, he recommended combining the right hand and left hand scores for these measures to increase the reliability of these tests. In the present study, composite scores for the sensori-motor measures (Simple, Complex) were derived from a mean of the right and left hand T-score conversions.

The twelve neuropsychology variables employed were selected according to criteria suggested by Fisk and Rourke (1979). Most important, these variables were thought to provide a sufficient amount of coverage across different skill categories to provide for clinically useful interpretation of group profiles. Although the Tactual Performance Test (TPT) probably taps a variety of skill areas, including tactile-form discrimination and psychomotor abilities, it also relies on spatial reasoning and problem-solving skills (Thompson & Parsons, 1985). Therefore, for the purposes of the present study, it was classified as a measure of "executive functioning" and concept formation as indicated in Table 8. A mean of the TPT total time across the three trials (in T-score conversion) was the measure derived for the current analyses.

CHAPTER III

RESULTS

The results of the cluster analyses of the various samples in the current study will be presented in three sections. The first section contains the results of the cluster analysis of Sample A with respect to the measures of academic ability (i.e., WRAT subtest scores). This first section in the presentation of the analyses will be referred to as Phase I. The next section will be referred to as Phase II; it contains the findings of the cluster analyses of Sample A with respect to the 12 measures of neuropsychological abilities. The third section is Phase III; it consists of the cluster analyses of the four Sample B Subsamples with respect to the 12 measures of neuropsychological abilities. In Phase I and Phase II, the data presentation consists of graphical and tabular displays of the various clusters which emerged from the analysis. Due to the large amount of data to be described in Phase III, only graphical representations of the cluster analysis results for the four Sample B Subsamples are shown.

Cluster Analyses

Phase I: Academic Measures (Sample A)

In this part, the findings of the cluster analytic methods are reported as follows: (1) the cluster fusion coefficients 'pseudo T and F' for WARD's minimum variance technique (which was employed as the target method) are depicted graphically and a particular solution is suggested; (2) then the cross-method agreement between the four cluster analysis techniques for this solution is displayed; (3) the WRAT T-score profiles are calculated and plotted for the cluster solution determined by at least two methods; (4) a MANOVA between the four WRAT groups is presented using the 12 neuropsychology variables as external criterion measures; (5) the split-sample replication attempts are graphically displayed; and (6) each of the Sample A WRAT clusters and outliers (unique individuals) are presented in terms of their performance on the academic and neuropsychological variables. Finally, the types of children (i.e., low IQ, emotionally disturbed) occuring in the WRAT subtypes and outliers are described.

The standard scores of the WRAT academic measures (i.e., Reading, Spelling, Arithmetic) were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The standard score and T-score means and standard deviations for the Sample A WRAT variables are presented in Table 9. The classifications for various levels of performance with respect to standard scores on the WRAT suggested by Jastak and Jastak (1978) and the corresponding T-score equivalents are shown in Table 10.

The plots of the pseudo F and T cluster coefficients for Ward's minimum variance technique are presented in Figure 18. These cluster coefficients were developed to indicate changes in the within-cluster variance resulting from the 'fusion' of clusters at each stage of the analysis (Morris, Blashfield, & Satz, 1981). The pseudo F coefficient was developed by Calinski and Harabasz (1974) so that 'peaks' or 'jumps' to higher values were indicative of small within-cluster variance and thus good (i.e., homogeneous) cluster formation. The pseudo T coefficient was developed by Duda and Hart (1973) so that good cluster formation would be found with 'drops' to lower values. Following Sarle's (1985) recommendation, the plots of these cluster coefficients were overlayed so that a consensus between local peaks of pseudo F and local drops of pseudo T could be determined by visual inspection. Sarle (1985) cautions that the pseudo T cluster coefficient may not be appropriate for correlated variables. Since the WRAT variables are known to be highly correlated (Jastak & Jastak, 1978), greater emphasis was placed on the pseudo F statistic in determining a probable cluster solution.

Table 9

Phase I:
Means and Standard Deviations of WRAT Standard Scores and T-Score Conversions for Sample A (n=1200)

	Mean (n=1200)	Standard Deviation	Minimum Value	Maximum Value
WRAT (Standard Scores)[1]				
Reading	89.42	14.60	56.00	156.00
Spelling	83.99	12.38	50.00	146.00
Arithmetic	83.47	8.89	57.00	120.00
WRAT (T-Scores)[2]				
Reading	42.94	9.74	20.67	87.33
Spelling	39.33	8.25	16.67	80.67
Arithmetic	38.98	5.93	21.33	63.33

Note 1: WRAT Standard Score Mean = 100, standard deviation = 15, and range = 40-160. Adapted from Jastak and Jastak (1978).

Note 2: WRAT T-Score Mean = 50, standard deviation = 10, and possible T-score range = 10-90.

Table 10

Phase I:
Classifications of Levels of Performance for WRAT Standard Scores and T-Score Conversions

Classifications	WRAT Standard Scores[1]	T-score Conversions[2]
Very Superior	130 - 160	70.00 - 90.00
Superior	120 - 129	63.33 - 69.33
High Average	110 - 119	56.67 - 62.67
Average	90 - 109	43.33 - 56.00
Low Average	80 - 89	36.67 - 42.67
Inferior	70 - 79	30.00 - 36.00
Defective	40 - 69	10.00 - 29.33

Note 1: WRAT Standard Score Mean = 100, standard deviation = 15, and range = 40-160. Adapted from Jastak and Jastak (1978).

Note 2: WRAT T-Score Mean = 50, standard deviation = 10, and possible T-score range = 10-90.

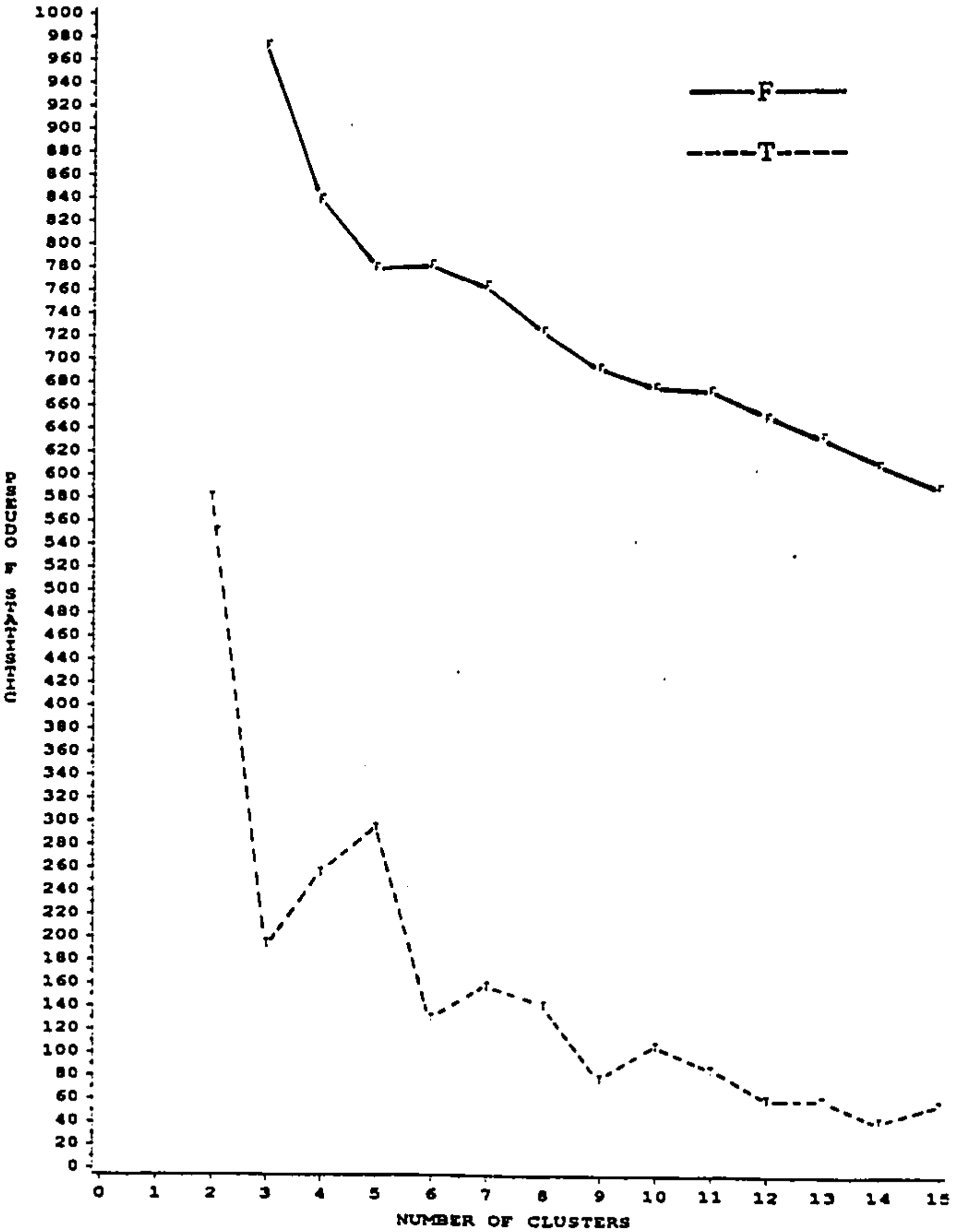


Figure 18. Phase I: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Sample A (n=1200) with TRIM=4, K=11.

Apparent in Figure 18 are several possible choices for a cluster solution. For example, there appears to be a small peak in pseudo F and a small drop in pseudo T at 11 clusters. However, the cross-method agreement was very poor at this level and it was rejected as a solution. There appears to be very good clustering at the six-cluster level, but again there was limited agreement amoung the various cluster methods employed. Plots of the cluster coefficients for the flexible-beta, complete linkage, and average linkage methods are displayed in Figures 19 to 21. Inspection of these plots revealed that the various cluster methods offer several different possible solutions between 7 and 13 clusters. These solutions were investigated and discarded due to a lack of agreement between the four cluster methods. The values of the pseudo F and pseudo T cluster coefficients for each cluster level are presented in Tables 11 and 12, respectively.

The graph of the cluster coefficients in Figure 18 suggested a four-cluster solution with Ward's method. This solution was most apparent with the pseudo F coefficient while the pseudo T coefficient indicated a three-cluster solution. A four-cluster solution was also apparent from inspection of the pseudo F coefficient plots generated by the flexible-beta (Figure 19), complete linkage (Figure 20), and average linkage (Figure 21) methods. The pseudo T

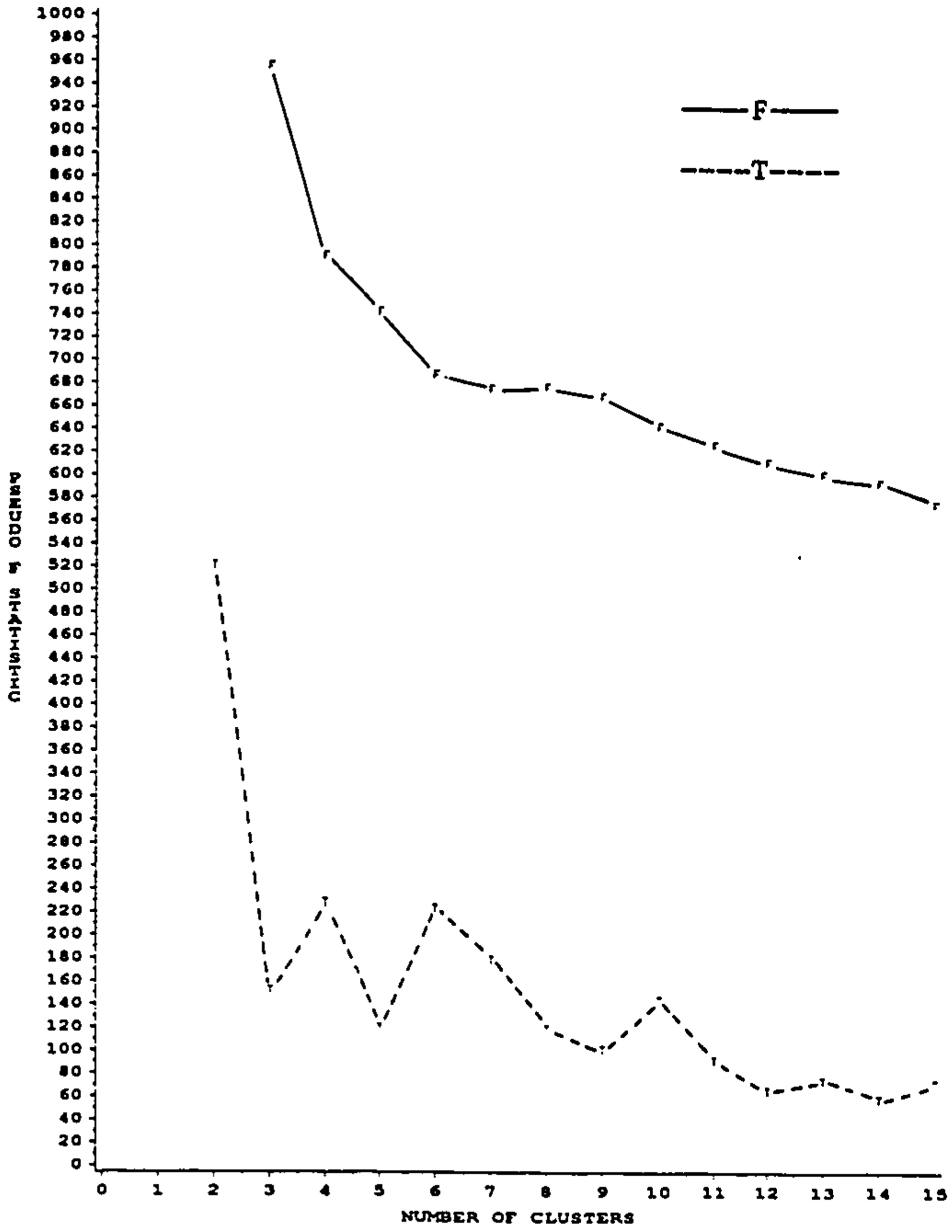


Figure 19. Phase I: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Sample A (n=1200) with TRIM=4, K=11.

Figure 20. Phase I: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Sample A (n=1200) with TRIM=4, K=11.

Figure 21. Phase I: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Sample A (n=1200) with TRIM=4, K=11.

Table 11

Phase I:
Psuedo F Cluster Fusion Coefficients for Each Cluster Method using Squared Euclidean Distance as a Similarity Measure: Sample A WRAT T-Scores

number of clusters	Ward's Method	Flexible Beta	Complete Linkage	Average Linkage
15	591.73	573.84	547.86	436.40
14	610.93	592.62	541.48	411.09
13	635.33	599.53	574.96	439.47
12	652.27	609.97	580.45	467.97
11	674.73	624.48	573.78	504.50
10	677.55	640.42	606.97	554.22
9	693.46	666.29	587.12	538.86
8	724.99	674.28	634.41	433.48
7	764.59	673.50	666.19	480.57
6	782.30	686.00	731.86	492.85
5	779.54	740.89	745.90	603.85
4	838.23	790.03	869.25	727.35
3	971.93	945.42	1031.09	816.21
2	1042.37	1079.92	1206.83	275.63
1	--	--	--	--

Table 12

Phase I:
Psuedo T Cluster Fusion Coefficients for Each Cluster Method using Squared Euclidean Distance as a Similarity Measure: Sample A WRAT T-Scores

number of clusters	Ward's Method	Flexible Beta	Complete Linkage	Average Linkage
15	56.75	70.94	72.15	108.22
14	42.05	57.61	115.22	165.95
13	59.66	73.58	23.35	42.45
12	60.19	64.60	85.59	27.23
11	85.69	91.20	129.10	24.18
10	105.84	143.34	56.19	12.02
9	78.16	100.04	212.79	148.68
8	141.18	118.00	60.39	388.52
7	157.22	177.90	108.38	39.62
6	129.61	222.46	91.48	146.24
5	293.91	118.65	196.54	34.03
4	255.31	228.31	114.85	72.79
3	194.36	151.78	165.23	255.23
2	580.64	520.75	532.92	1075.46
1	1042.37	1079.92	1206.83	275.63

coefficient plots suggested a five-cluster solution for the flexible-beta (Figure 19) and average linkage (Figure 21) methods. However, the five-cluster solution produced many misclassifications between the four methods (greater than 36 percent). The relatively large drop in the pseudo T value in Figure 21 from 3 to 4 clusters also was thought indicative of a four-cluster solution. Since a four-cluster solution was suggested by all of the cluster methods with respect to the pseudo F coefficients and by at least two methods with respect to the pseudo T coefficients, the four-cluster solution was considered the best choice for further investigation in the present study.

The misclassification analysis for the four-cluster solutions are presented in Table 13. Ward's method (TRIM=4, K=11) was the target solution and resulted in a removal of 48 outliers with the remaining 1152 children classiifed into four groups. There was good agreement between the Ward's four-cluster solution and the four-cluster solutions which emerged from the flexible-beta and complete linkage methods. Only 23% of the children were misclassified by the flexible-beta method and 24% were misclassified by the complete linkage method. Average linkage produced an unacceptably high misclassification rate of 56%. With respect to the individual WRAT subtypes, the flexible-beta method misclassified 40% of the children which emerged as

Table 13

Phase I:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Sample A N=1200)

Cluster analysis method	Ward's Cluster Groups 1 (n=460)	2 (n=382)	3 (n=254)	4 (n=56)	Total (n=1152)
Flexible-Beta Method	184 (40)	37 (10)	27 (11)	15 (27)	263 (23)
Complete Linkage	64 (14)	179 (47)	17 (7)	18 (32)	278 (24)
Average Linkage	326 (71)	59 (15)	254 (100)	11 (20)	650 (56)

Group 1 (n=460) from the Ward's cluster analysis, however; an average of only 11% of the children in the other three WRAT subtypes were misclassified. The complete linkage method misclassified approximately 47% of the children identified as Ward's Group 2 (n=382), while misclassifying an average of only 13% of the children in Groups 1, 3, and 4. The average linkage method misclassified nearly all the subjects (i.e., 81%) identified as Ward's Groups 1 and 3, while misclassifying an average of 16% of the children in Ward's Groups 2 and 4. The misclassification analyses for the split-sample replication attempts will be presented next.

The three internal validation samples (N=1000, N=800, and N=600, respectively) were cluster analysed with the same methods as used previously. In order to remove the outliers, a TRIM value of 4 was used; this discarded 4% of the most extreme subjects in each sample. This TRIM value was identical to that used for the Sample A analysis; however, it was necessary to use different values of the K parameter with the different sample sizes. Following the convention suggested by Wong (1982) with the sample size N=1000, K=10 was used; for the sample size N=800, K=9; and for sample size N=600, K=8.

The misclassification analysis for Ward's four-cluster solution (TRIM=4, K=10, 9, or 8) with the internal validation samples are given in Tables 14 to 16. It is quite apparent that most of the children randomly selected from the original sample can be clustered into four groups at each level of sample selection with very good agreement between the four cluster methods.

In summary, these comparisons revealed good evidence for a four cluster solution. With respect to the Sample A analyses, (see Table 13) the number of children misclassified was less than 25% for three of the cluster methods. Secondly, the four groups were accurately reproduced across two of these methods (flexible-beta, complete linkage) while average linkage accurately reproduced two of the four Ward's groups (i.e., Group 2 and Group 4). With respect to the analyses of the three internal validation samples, it again was apparent that a four-cluster partition could be demonstrated at different sample levels and across different cluster algorithms. In the next section, the profile of the Ward's four-cluster solution and a MANOVA on 12 external criterion variables (i.e., the neuropsychological measures) are presented, followed by the split-sample replication attempts for this solution.

The four subtype profiles derived from the WRAT Reading, Spelling, and Arithmetic mean subtest scores are displayed in Figure 22. The mean T-scores of several other measures commonly used in educational settings

Table 14

Phase I:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=1000)

	Ward's Cluster Groups				
Cluster analysis method	1 (n=365)	2 (n=338)	3 (n=191)	4 (n=66)	Total (n=960)
Flexible-Beta Method	99 (27)	62 (18)	72 (38)	0 (0)	233 (24)
Complete Linkage	76 (21)	119 (35)	6 (3)	0 (0)	201 (21)
Average Linkage	25 (7)	63 (19)	63 (33)	3 (5)	154 (16)

Table 15

Phase I:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=800)

	Ward's Cluster Groups				
Cluster analysis method	1 (n=132)	2 (n=335)	3 (n=239)	4 (n=62)	Total (n=768)
Flexible-Beta Method	11 (8)	89 (27)	56 (23)	0 (0)	156 (20)
Complete Linkage	60 (45)	53 (16)	77 (32)	3 (5)	193 (25)
Average Linkage	8 (6)	34 (10)	7 (3)	5 (8)	54 (7)

Table 16

Phase I:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=600)

	Ward's Cluster Groups				
Cluster analysis method	1 (n=174)	2 (n=211)	3 (n=124)	4 (n=67)	Total (n=576)
Flexible-Beta Method	2 (1)	26 (12)	7 (6)	0 (0)	35 (6)
Complete Linkage	82 (47)	39 (18)	2 (2)	2 (3)	125 (22)
Average Linkage	21 (12)	9 (4)	15 (12)	32 (48)	77 (13)

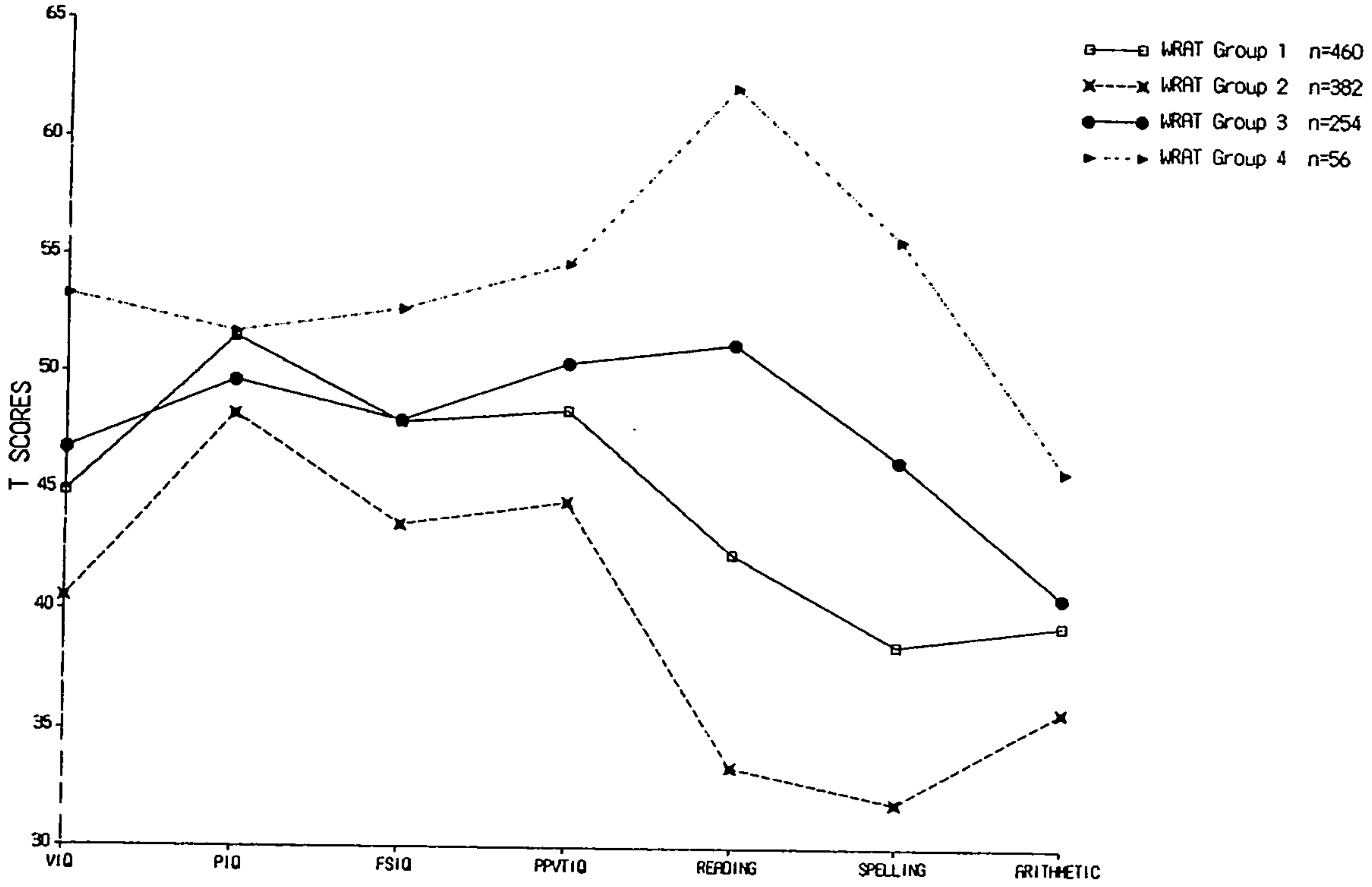


Figure 22. Mean profiles of the four WRAT Groups which emerged from Ward's cluster analysis of Sample A (n=1200).

(i.e., WISC VIQ, PIQ, and FSIQ; Peabody Picture Vocabulary Test IQ) were also included in the subtype profiles in Figure 22. It was thought these additional variables would aid subtype interpretation and so were included in the profiles of all WRAT subtypes in Phase I of the present study. In addition, the mean T-scores of the tweleve neuropsychological measures were plotted in Figure 23 for the four Sample A WRAT subtypes. These neuropsychological measures were not employed in the cluster analyses in this phase of the study. However, there do appear to be differences between the four Sample A WRAT subtypes on these external variables. It is apparent in Figure 23 that the four WRAT subtypes differed on the neuropsychological measures primarily in terms of profile elevation. For example, with respect to language-related abilities, Group 2 appeared to perform in a rather impaired manner, while Group 4 performed well within the average range.

The statistical differentiation of subtype classifications on external criterion measures is considered a rigorous demonstration of the concurrent (external) validity of cluster analytic solutions by Morris, Blashfield, and Satz (1981). Therefore, an attempt was made to demonstrate statistically that the four Sample A WRAT Groups could be differentiated on the 12 neuropsychological variables which were external to the cluster analysis. The

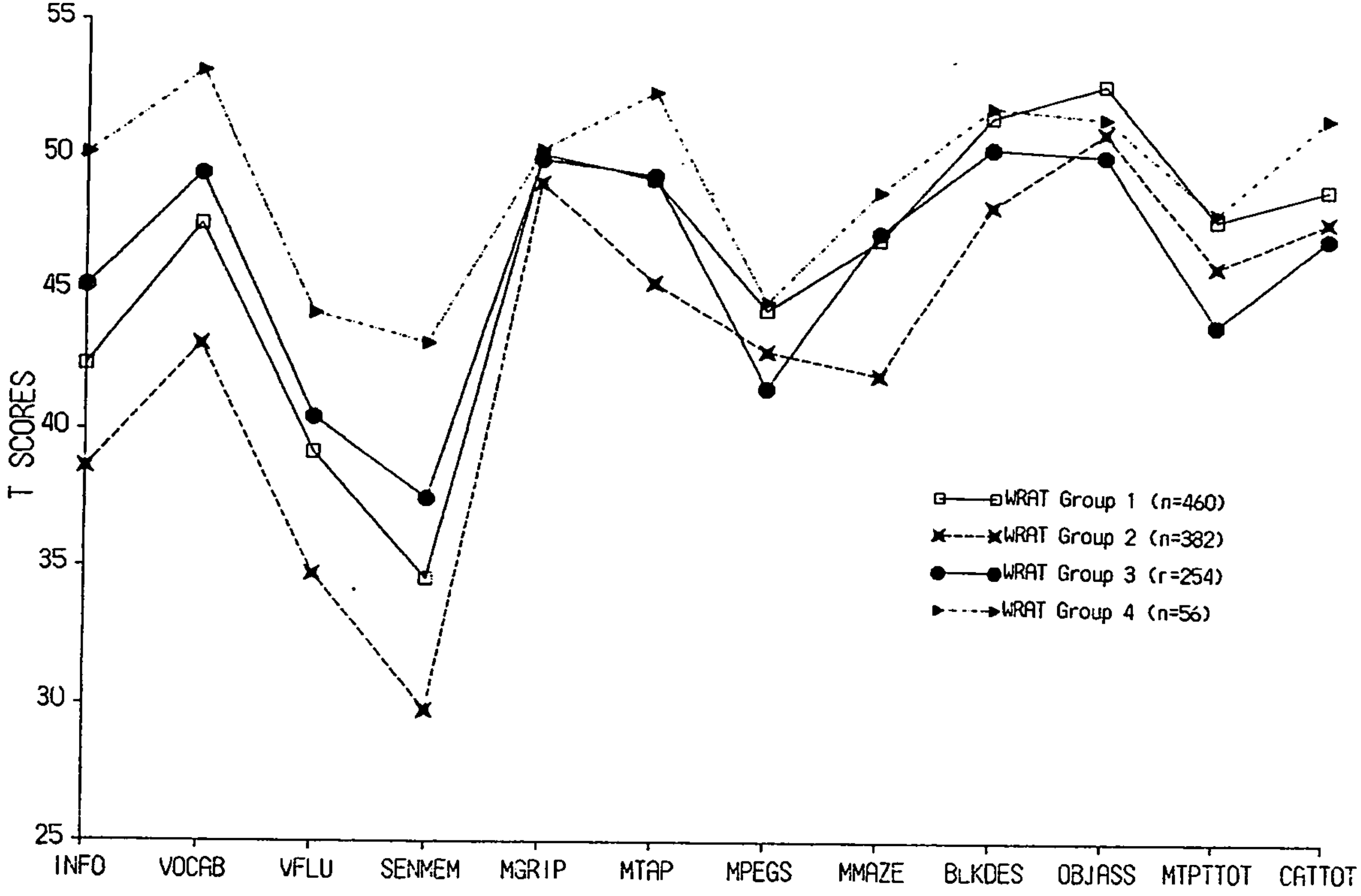


Figure 23. Mean profiles of the four WRAT Groups on the twelve neuropsychological measures.

SAS MANOVA procedure (SAS Institute Inc., 1985; PROC GLM) was employed to determine the main effects of subtype classification across the 12 neuropsychological variables chosen for this study (see Table 8). The overall main effect of subtype classification was significant: Wilk's Criterion, multivariate $\underline{F}(36,3360.12)=12.36$, $p<.0001$; Pillai's Trace, multivariate $\underline{F}(36,3417)=11.30$, $p<.0001$; Hotelling-Lawley Trace, multivariate $\underline{F}(36,3407)=13.47$, $p<.0001$. These significant MANOVA results suggested that the four WRAT subtypes which emerged from the cluster analysis of the academic measures (i.e., WRAT Reading, Spelling, Arithmetic) could also be differentiated on other measures typically considered non-academic (i.e., the 12 neuropsychological variables). With respect to the main effect for each neuropsychological measure, only three of these variables did not discriminate between the four WRAT subtypes. These variables included MGRIP, multivariate $\underline{F}(3,1148)=1.56$, $p>.05$; MPEGS, multivariate $\underline{F}(3,1148)=2.60$, $p>.05$; and OBJASS, multivariate $\underline{F}(3,1148)=3.57$, $p>.01$.

The main effects for the other 9 neuropsychological measures were all significant as follows: INFO, multivariate $\underline{F}(3,1148)=79.05$, $p<.0001$; VOCAB, multivariate $\underline{F}(3,1148)=54.22$, $p<.0001$; VFLU, multivariate $\underline{F}(3,1148)=29.97$, $p<.0001$; SENMEM, multivariate $\underline{F}(3,1148)=36.80$, $p<.0001$; MTAP, multivariate $\underline{F}(3,1148)=12.25$, $p<.0001$; MMAZE, multivariate

$\underline{F}(3,1148)=10.66$, $p<.0001$; BLKDES, multivariate $\underline{F}(3,1148)=8.40$, $p<.0001$; MTPTTOT, multivariate $\underline{F}(3,1148)=8.09$, $p<.0001$; CATTOT, multivariate $\underline{F}(3,1148)=4.80$, $p<.01$. These results demonstrated that 9 of the 12 neuropsychological measures were contributing to the overall subtype differences.

A multiple comparison procedure (MCP) was used to determine which WRAT Groups could be differentiated on the neuropsychological measures. Due to the unequal cell sizes and the use of the harmonic mean, the Tukey-Kramer modification of Tukey's 'honestly significant difference' test (SAS Institute Inc., 1985; PROC GLM) was employed. As shown in Table 17, none of the WRAT group comparisons were significantly different for the variables MGRIP, MPEGS, or OBJASS ($p>.05$). All other multiple comparisons showed significant ($p<.05$) differences between the four WRAT subtypes. These differences (see Table 17) are as follows for variable: INFO, all WRAT subtypes were significantly different; VOCAB, VFLU, and SENMEM, Group 4 vs. Group 3, Group 4 vs. Group 1, Group 4 vs. Group 2, Group 3 vs. Group 2, and Group 1 vs. Group 2; MTAP and MMAZE, Group 2 vs. Group 4, Group 2 vs. Group 3, and Group 2 vs. Group 1; BLKDES, Group 4 vs. Group 2, and Group 1 vs. Group 2; MTPTTOT, Group 4 vs. Group 3, and Group 1 vs. Group 3; CATTOT, Group 4 vs Group 2, and Group 4 vs. Group 3. The

Table 17

Tukey-Kramer Multiple Comparison Procedure: Differences between the Phase I Sample A WRAT Groups on the Neuropsychological Measures

Variable	WRAT Groups	Minimum Significant Difference[1]
INFO[2]	4 3 1 2	2.887
VOCAB	4 3 1 2	3.745
VFLU	4 3 1 2	3.768
SENMEM	4 3 1 2	4.768
MGRIP	4 1 3 2	* *
MTAP	4 3 1 2	3.832
MPEGS	4 1 2 3	* *
MMAZE	4 3 1 2	5.012
BLKDES	4 1 3 2	3.311
OBJASS	1 4 2 3	* *
MTPTTOT	4 1 2 3	3.921
CATTOT	4 1 2 3	3.855

Note 1: Critical t = 3.638, df = 1148, alpha = 0.05, harmonic mean of cell sizes = 150.456.

Note 2: The WRAT Groups (1,2,3,4) are presented in descending order (highest to lowest) according to the size of their mean for the relevant variable. Groups which are *not* significantly different are underlined.

profiles of the three internal validation samples are compared to the Sample A WRAT Group profiles in the next section.

Each of the internal validation samples (N=1000, N=800, and N=600) were clustered into four subtypes using Ward's method. The profiles of these cluster solutions for each of these samples are shown in Figures 24 to 26. Overall, the plots of these solutions appeared to be quite similar to the four-cluster solution of the Sample A academic measures (Figure 22) with respect to elevation and profile shape. However, there were some differences noted between the Sample A Group 4 and the fourth subtypes derived from the validation samples. For example, in Figure 24 the subtype 4 profile for the N=1000 sample shows more elevation in the Spelling subtest score and less elevation in the Arithmetic subtest score when compared to the fourth Sample A subtype. As is evident in Figure 26, the subtype 4 which emerged from the cluster analysis of the N=600 sample shows a decrease in the profile elevation of the WRAT Reading and Spelling scores by at least one-half of a standard deviation in comparison to the Sample A Group 4 (Figure 22).

Due to the above considerations, the individual profiles on the academic measures for each WRAT subtype from Sample A and all three validation samples were plotted together to determine if Ward's four-cluster solution was replicated

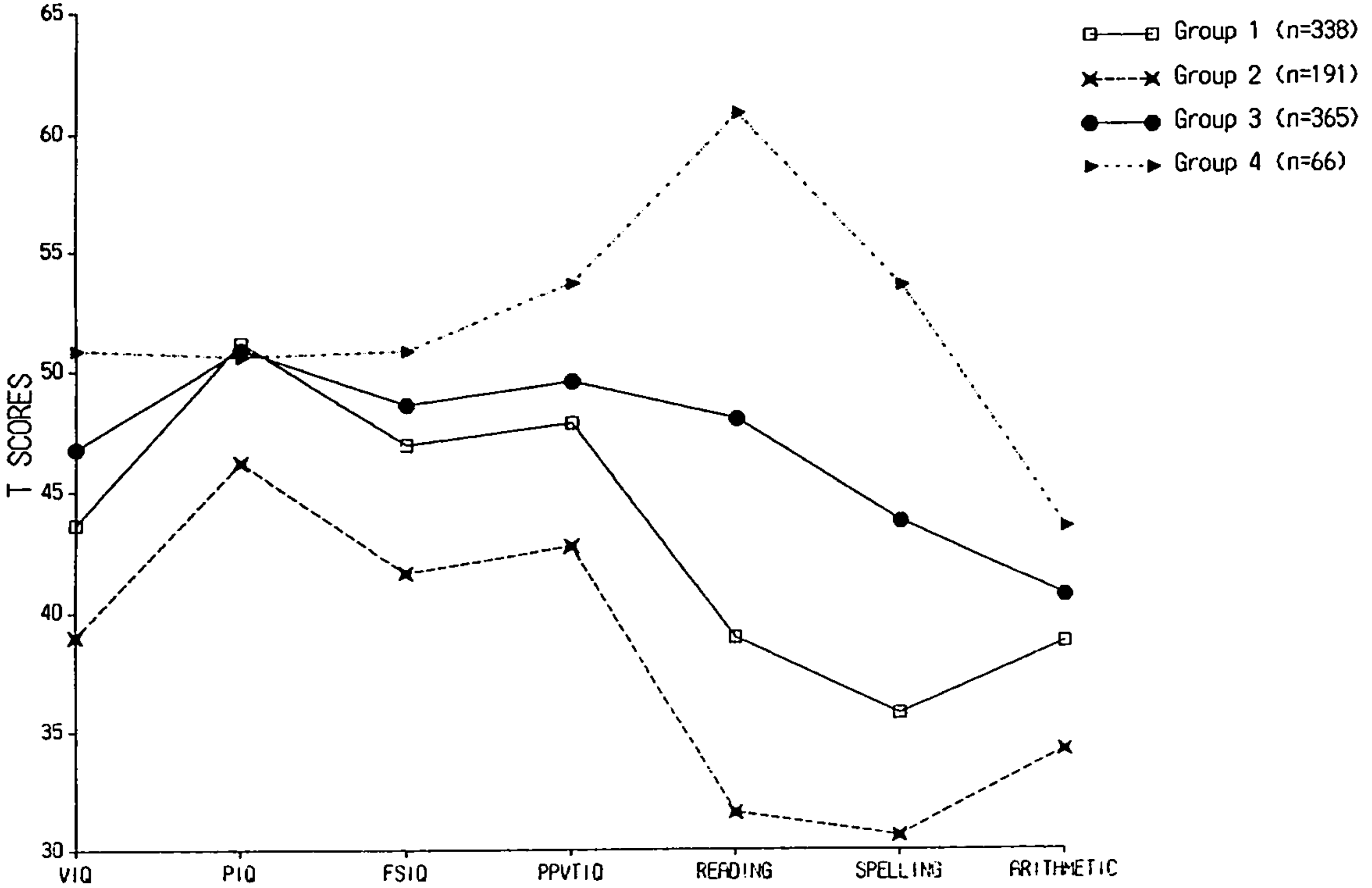


Figure 24. Mean profiles of Ward's four cluster solution of Internal Validation Sample N=1000 (Academic Measures).

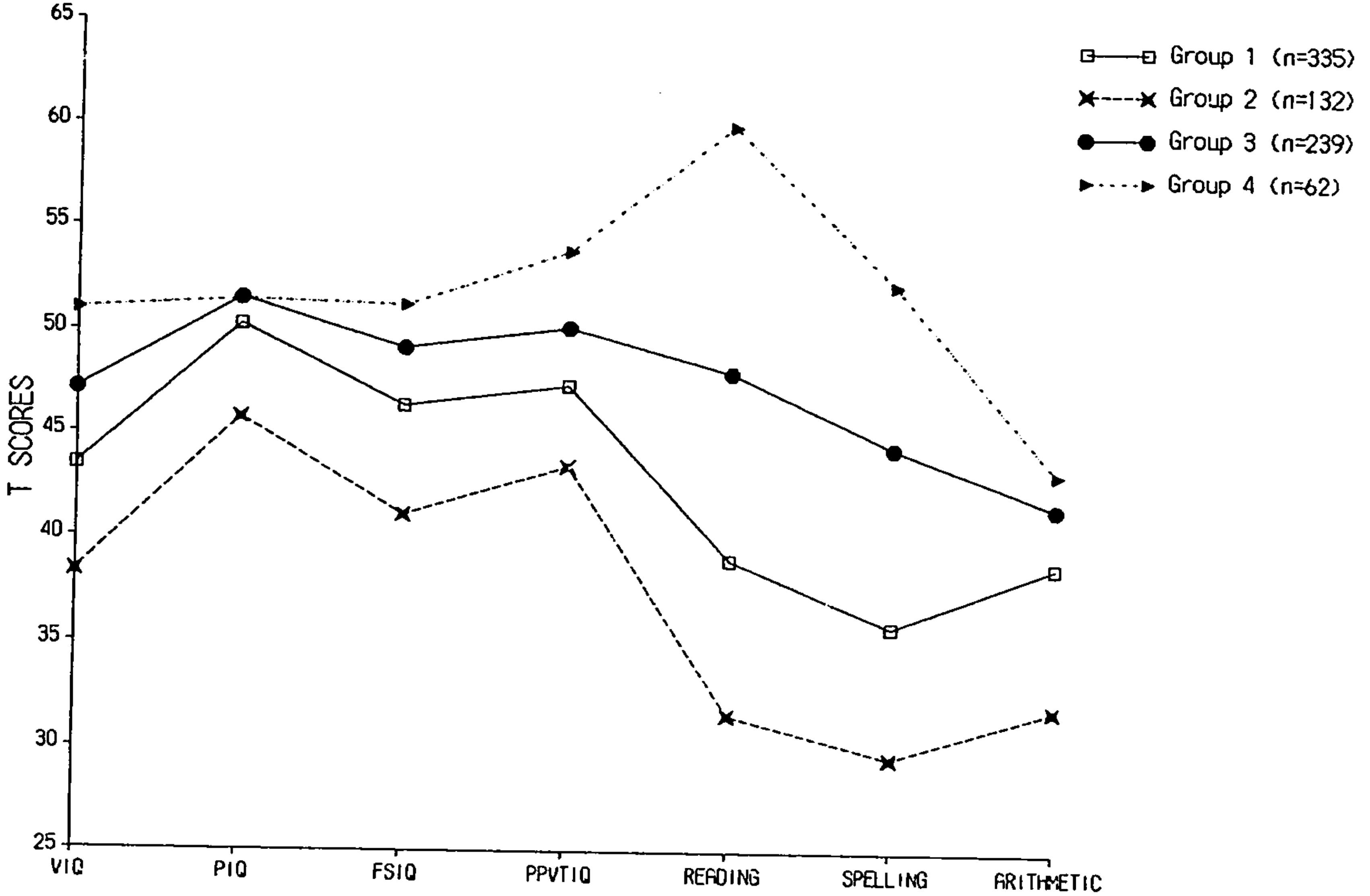


Figure 25. Mean profiles of Ward's four-cluster solution of Internal Validation Sample N=800 (Academic Measures).

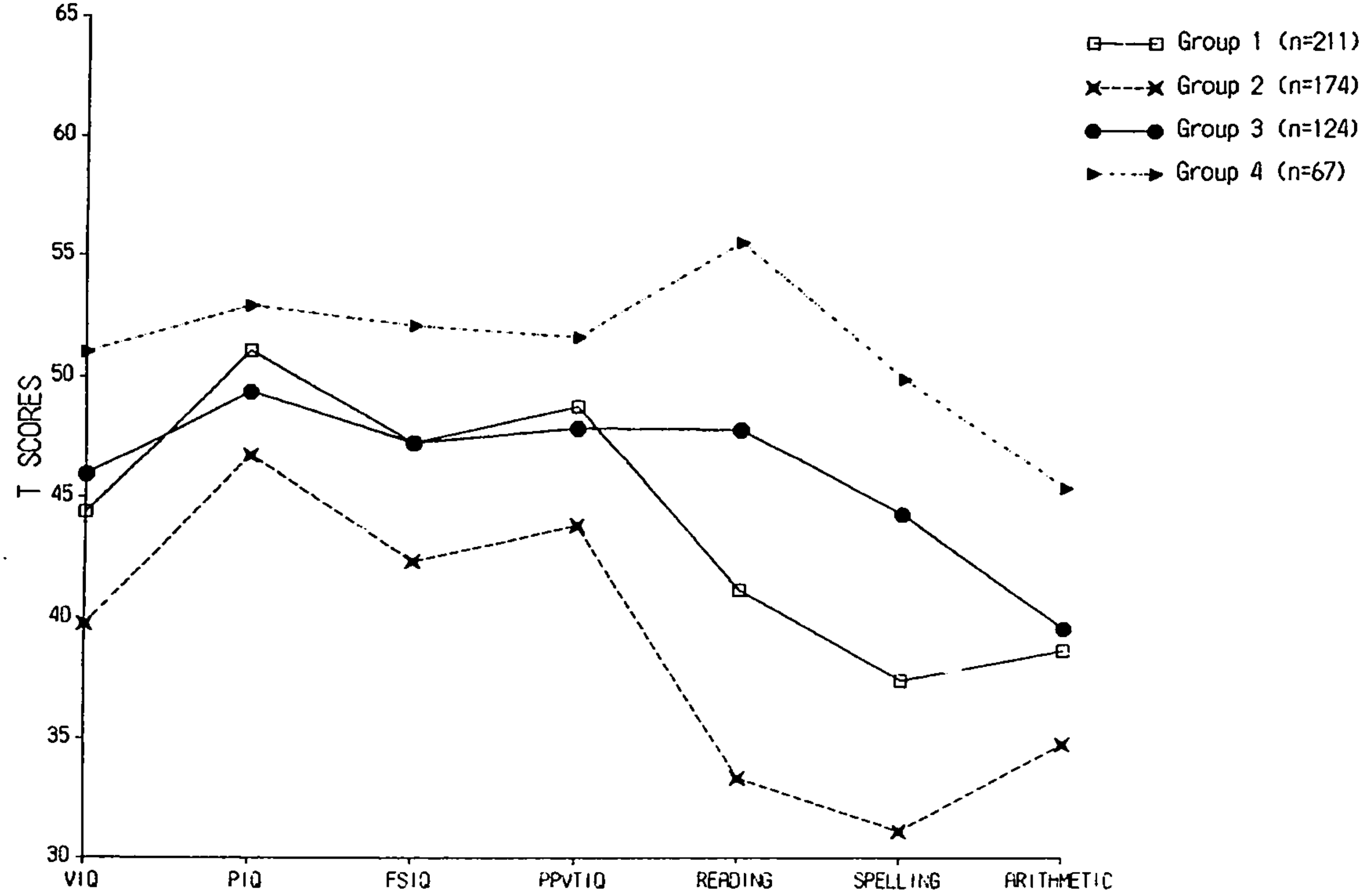


Figure 26. Mean profiles of Ward's four-cluster solution of Internal Validation Sample N=600 (Academic Measures).

across samples of different sizes. The profiles of the Sample A Group 1 and the validation sample group 1 subtypes for the academic measures were plotted together in Figure 27. The other WRAT subtypes from Sample A and the three validation samples are displayed in Figures 28 to 30. It is apparent in these graphs that WRAT Groups 1 to 3 were accurately recovered across the different sample sizes. However, it is obvious in Figure 30 that, depending on the sample size, there were differences in the emergence of the fourth WRAT subtype. It should be noted that the subtype plots in Figure 30 appear to differ primarily with respect to profile elevation rather than profile shape.

At this point, it was considered important to demonstrate that each WRAT subtype which emerged from the Sample A and validation sample cluster analyses exhibited similar patterns of cognitive strengths and weaknesses with respect to the 12 measures of neuropsychological abilities. It was thought that this comparison would yield strong evidence for the validity of the four WRAT subtypes and, in particular, for WRAT Group 4. The profiles of the Sample A Group 1 and the validation sample group 1 subtypes with respect to their average performances on the neuropsychological variables are shown in Figure 31. The profiles on the measures of neuropsychological ability structure for the other WRAT subtypes and relevant validation

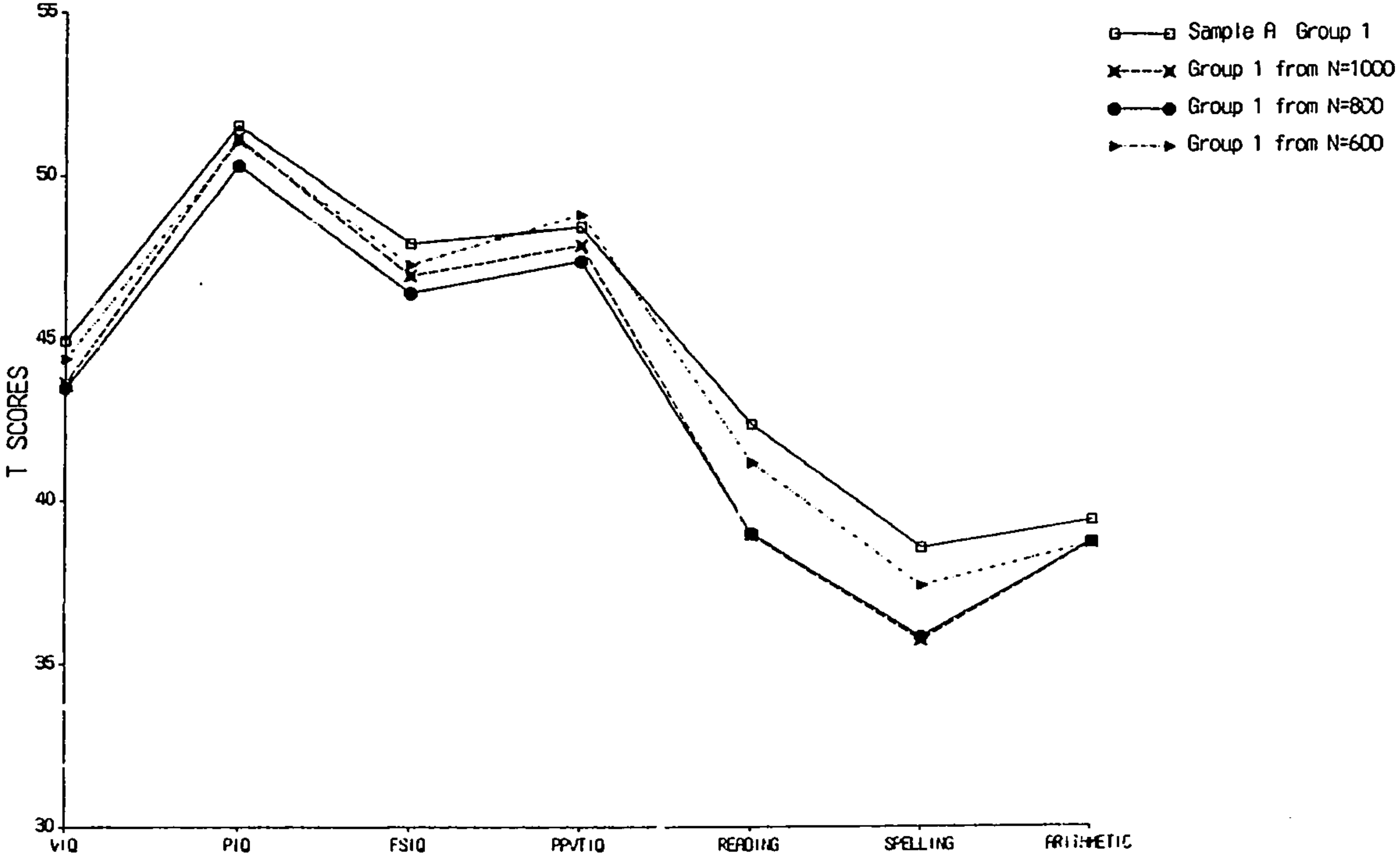


Figure 27. Composite plot of all Group 1 mean profiles from the cluster analyses of Sample A (n=1200), N=1000, N=800, and N=600 on the academic measures.

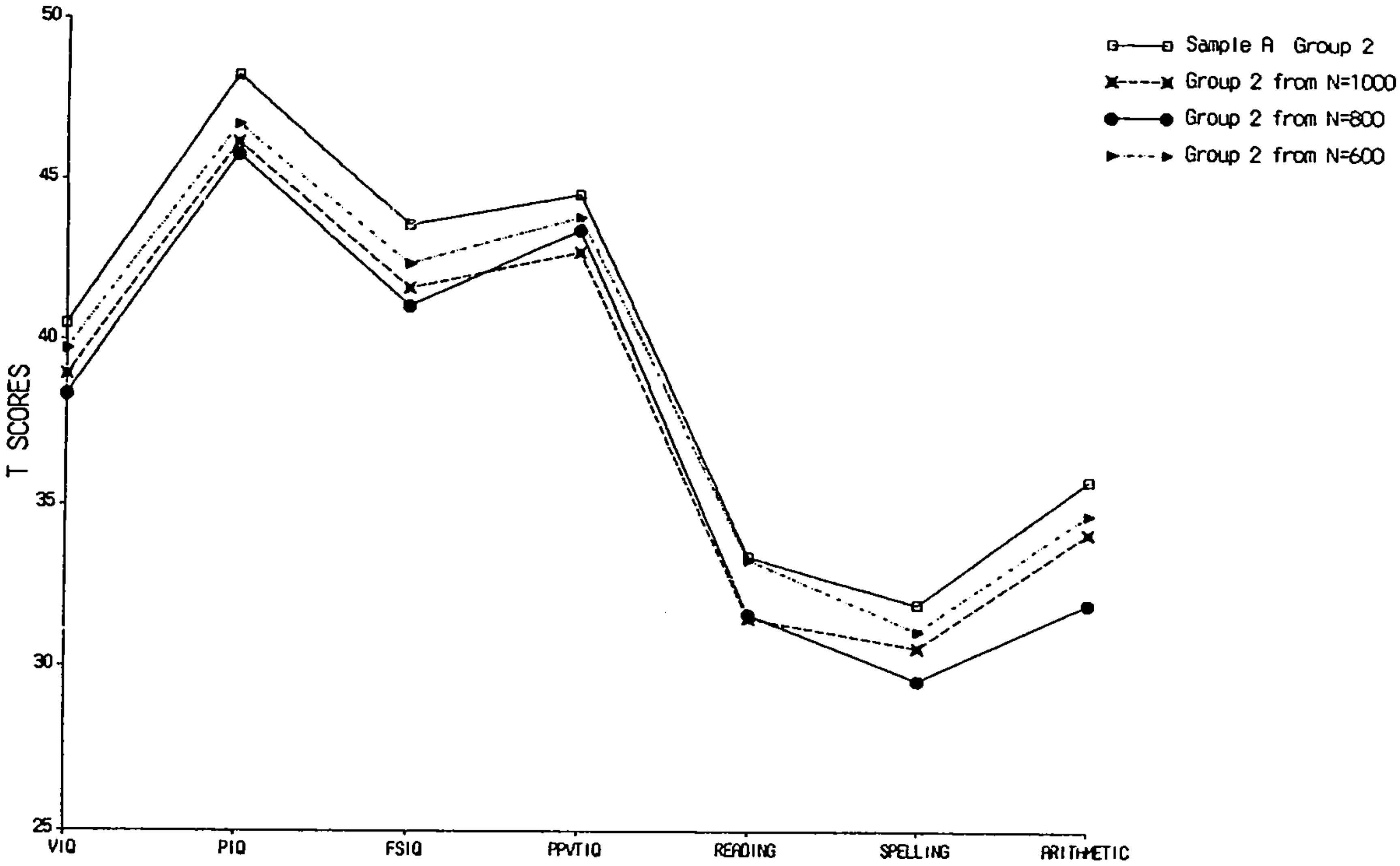


Figure 28. Composite plot of all Group 2 mean profiles from the cluster analyses of Sample A (n=1200), N=1000, N=800, and N=600 on the academic measures.

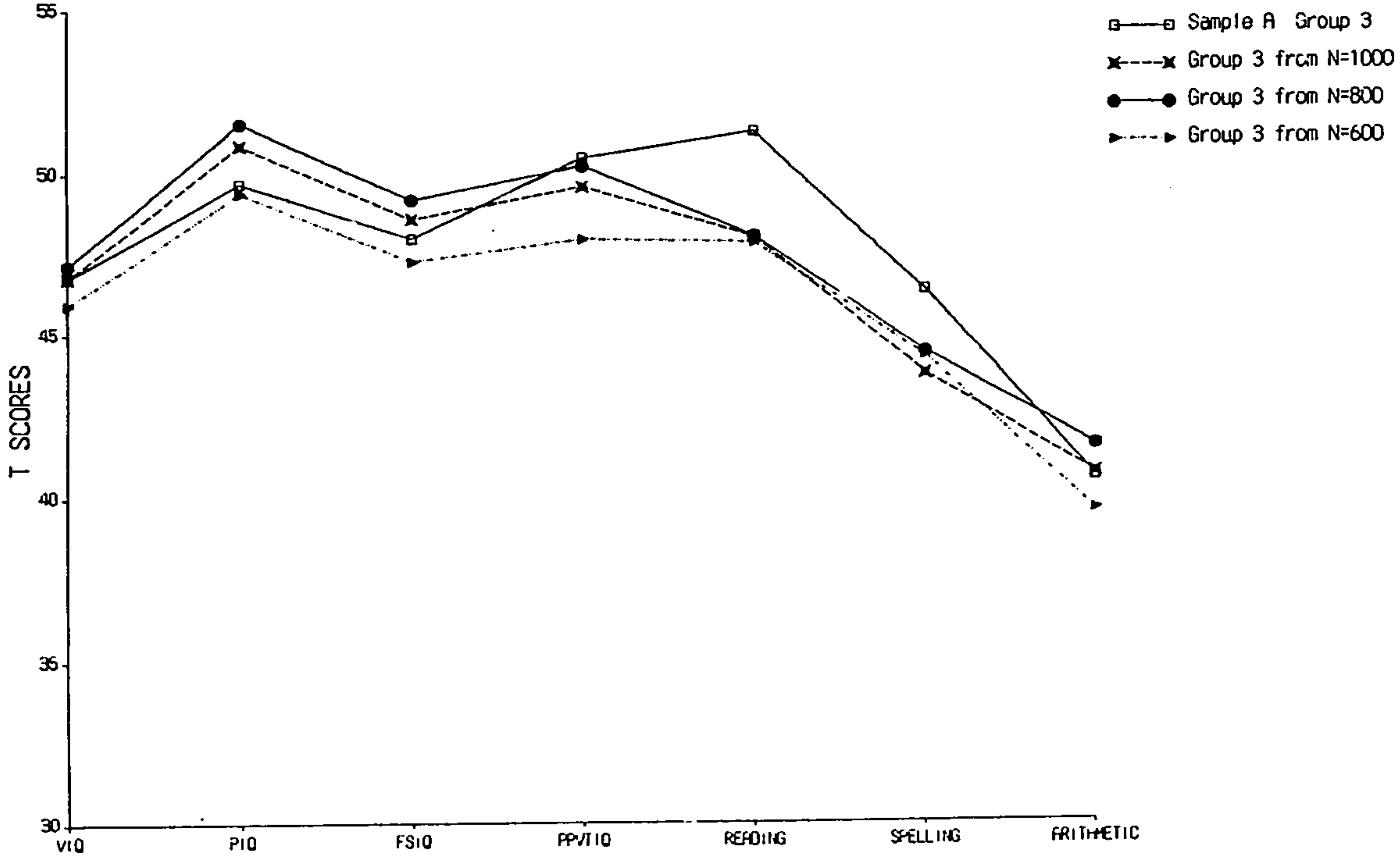


Figure 29. Composite plot of all Group 3 mean profiles from the cluster analyses of Sample A (n=1200), N=1000, N=800, and N=600 on the academic measures.

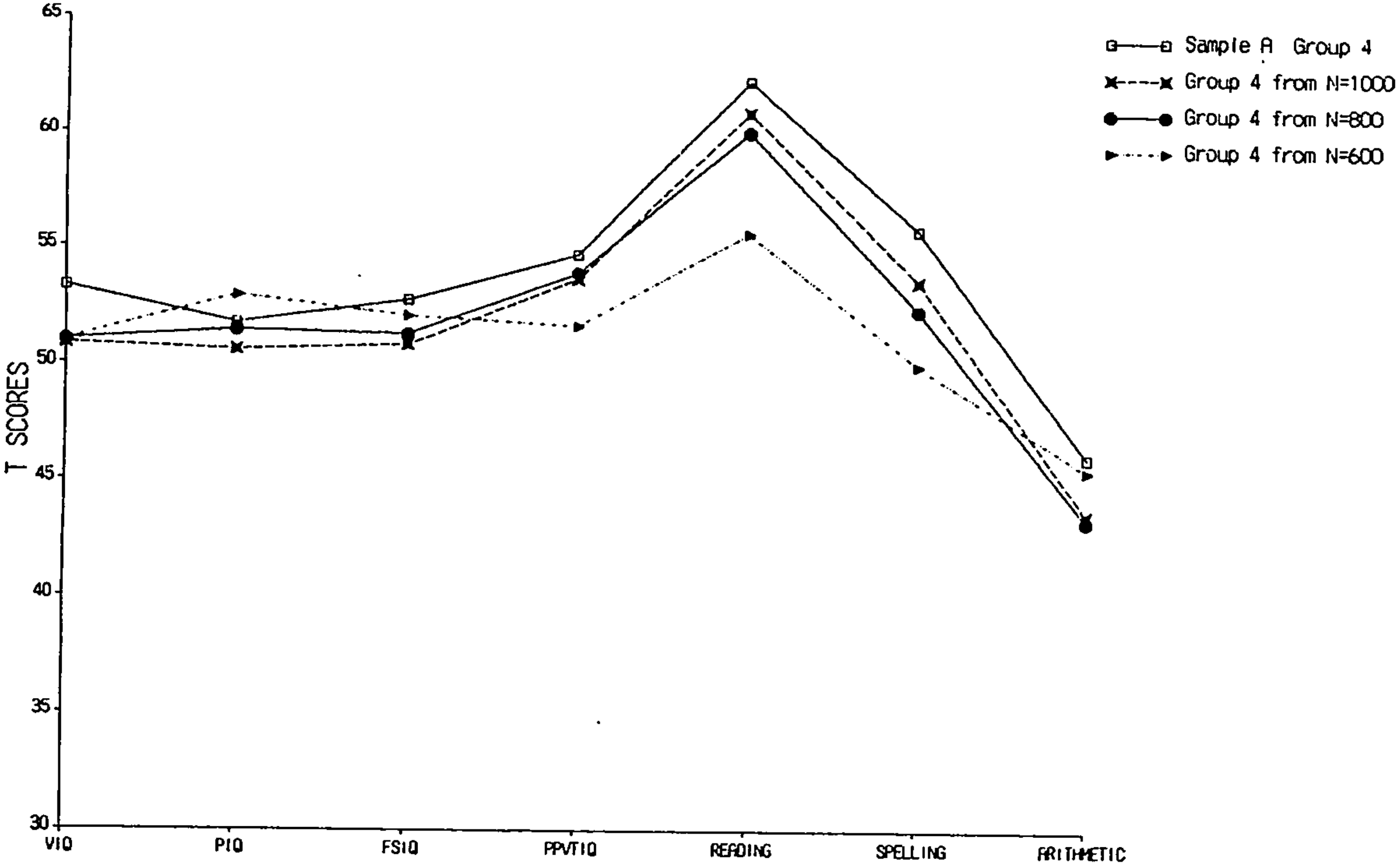


Figure 30. Composite plot of all Group 4 mean profiles from the cluster analyses of Sample A (n=1200), N=1000, N=800, and N=600 on the academic measures.

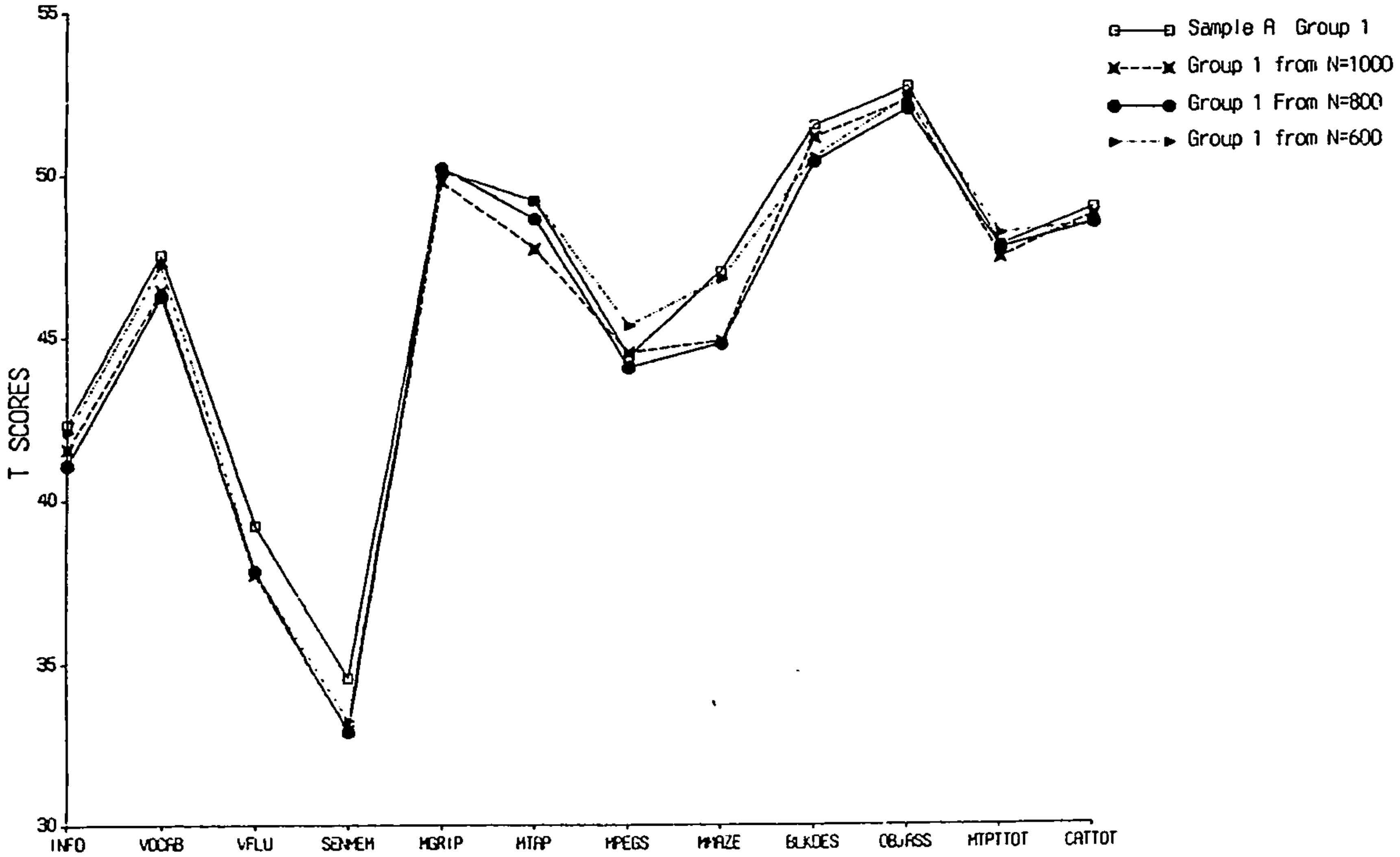


Figure 31. Composite plot of all WRAT Group 1 mean profiles from Sample A, N=1000, N=800, and N=600 on the neuropsychological measures.

sample subtypes are graphically graphically in Figures 32 to 34. Visual inspection of these graphs revealed few deviations between the Sample A WRAT group profiles and the corresponding validation sample subtype profiles. The composite profiles appear very similar in terms of both elevation and shape. In addition, the composite profiles for WRAT Groups 1 and 2 are close together indicating minimal dispersion from the original cluster solution. Although the composite profiles in Figures 33 and 34 appear to deviate more from the original cluster solutions, this was not considered significant.

These comparisons have demonstrated that the original four-cluster solution with the academic measures (WRAT) for Sample A (n=1200) could be reliably recovered from analyses with subsets of the data. Furthermore, these solutions were highly similar to the original, both in terms of profile elevation and profile shape on the academic measures. In addition, the WRAT clusters which emerged from the validation samples exhibited profiles on the neuropsychological measures which were also very similar to the four Sample A WRAT subtypes with respect to elevation and shape. The results presented thus far were considered indicative of the validity of the four Sample A (n=1200) subtypes. In the next section, each of these four WRAT clusters is examined in detail.

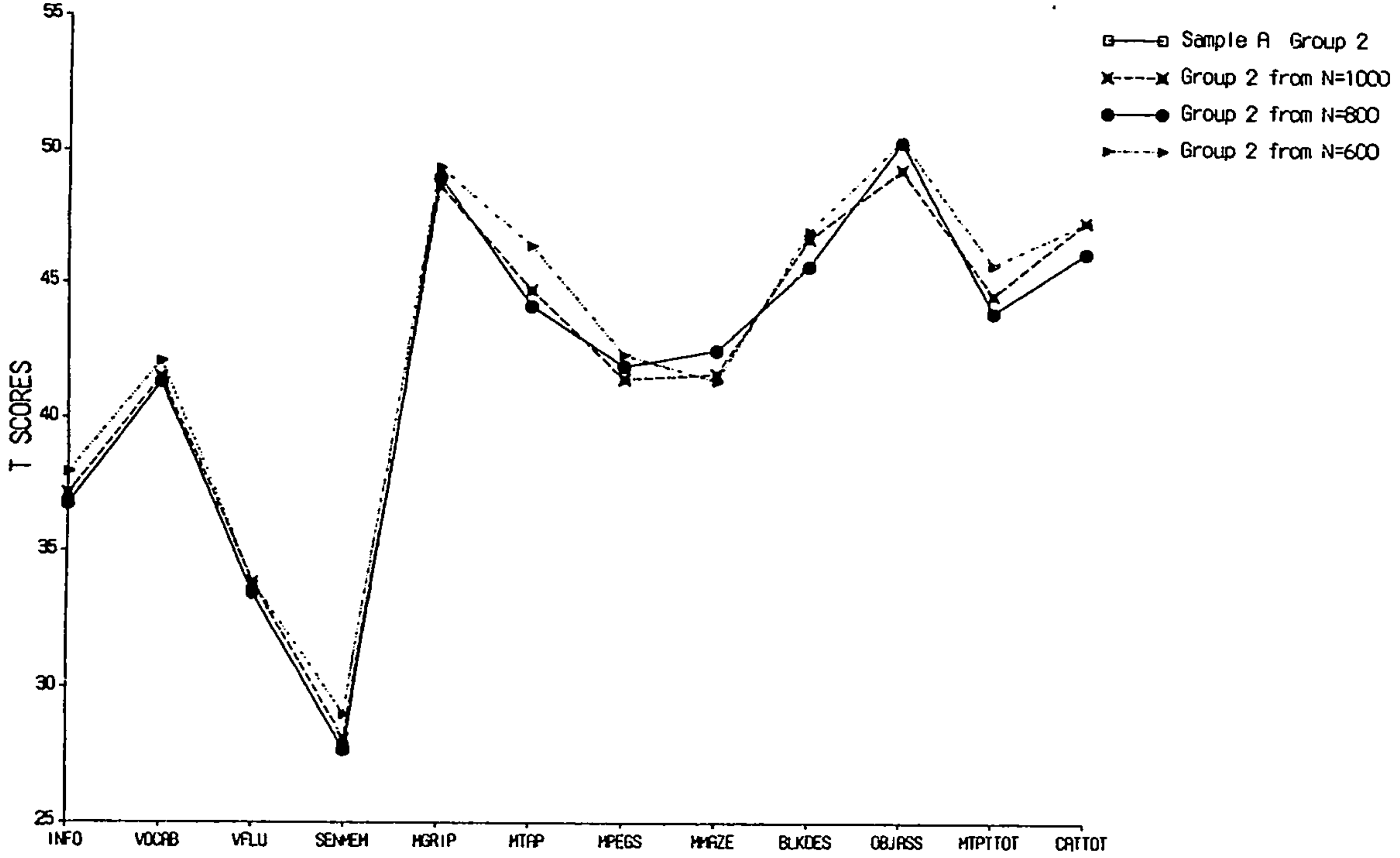


Figure 32. Composite plot of all WRAT Group 2 mean profiles from Sample A, N=1000, N=800, and N=600 on the neuropsychological measures.

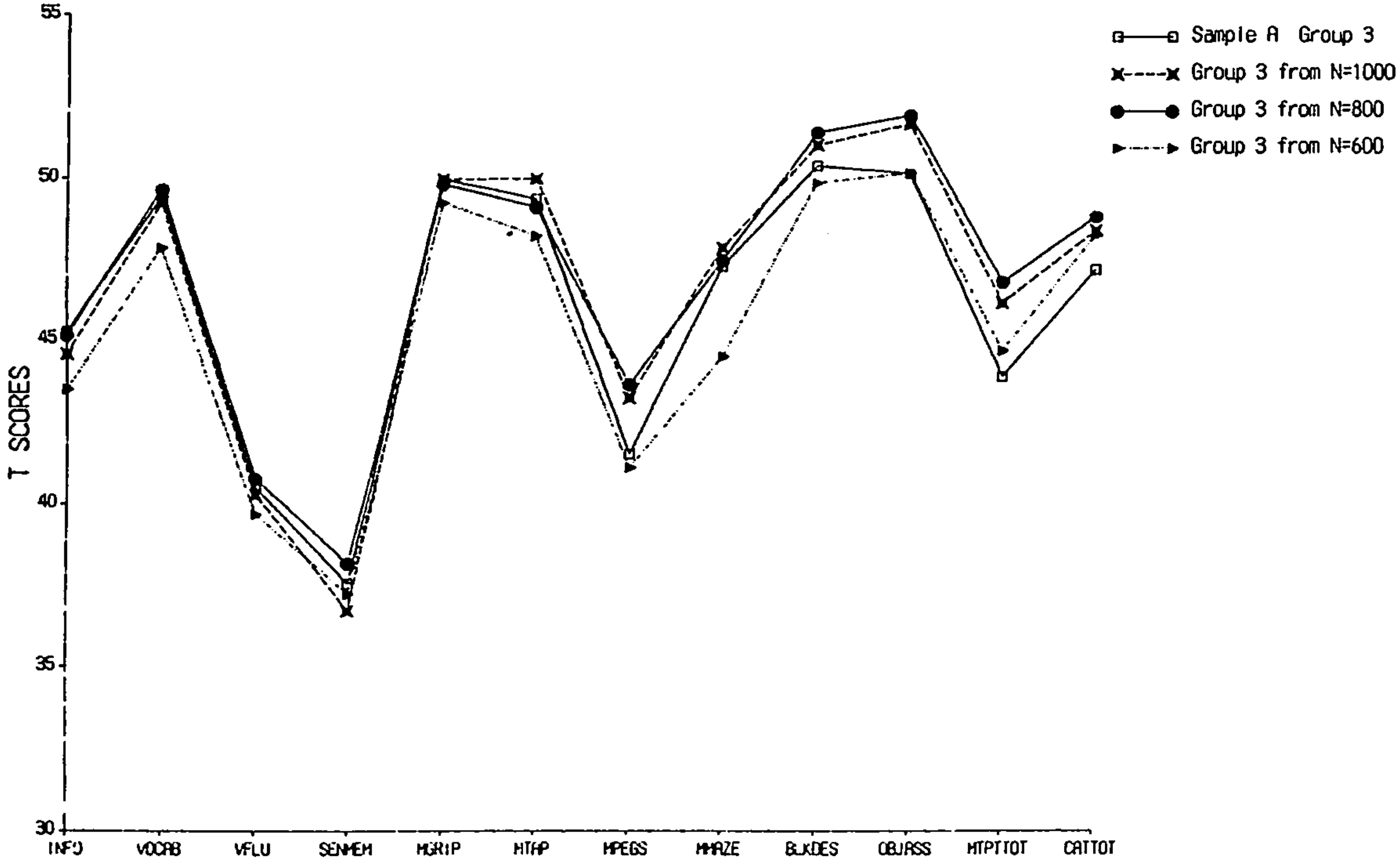


Figure 33. Composite plot of all WRAT Group 3 mean profiles from Sample A, N=1000, N=800, and N=600 on the neuropsychological measures.

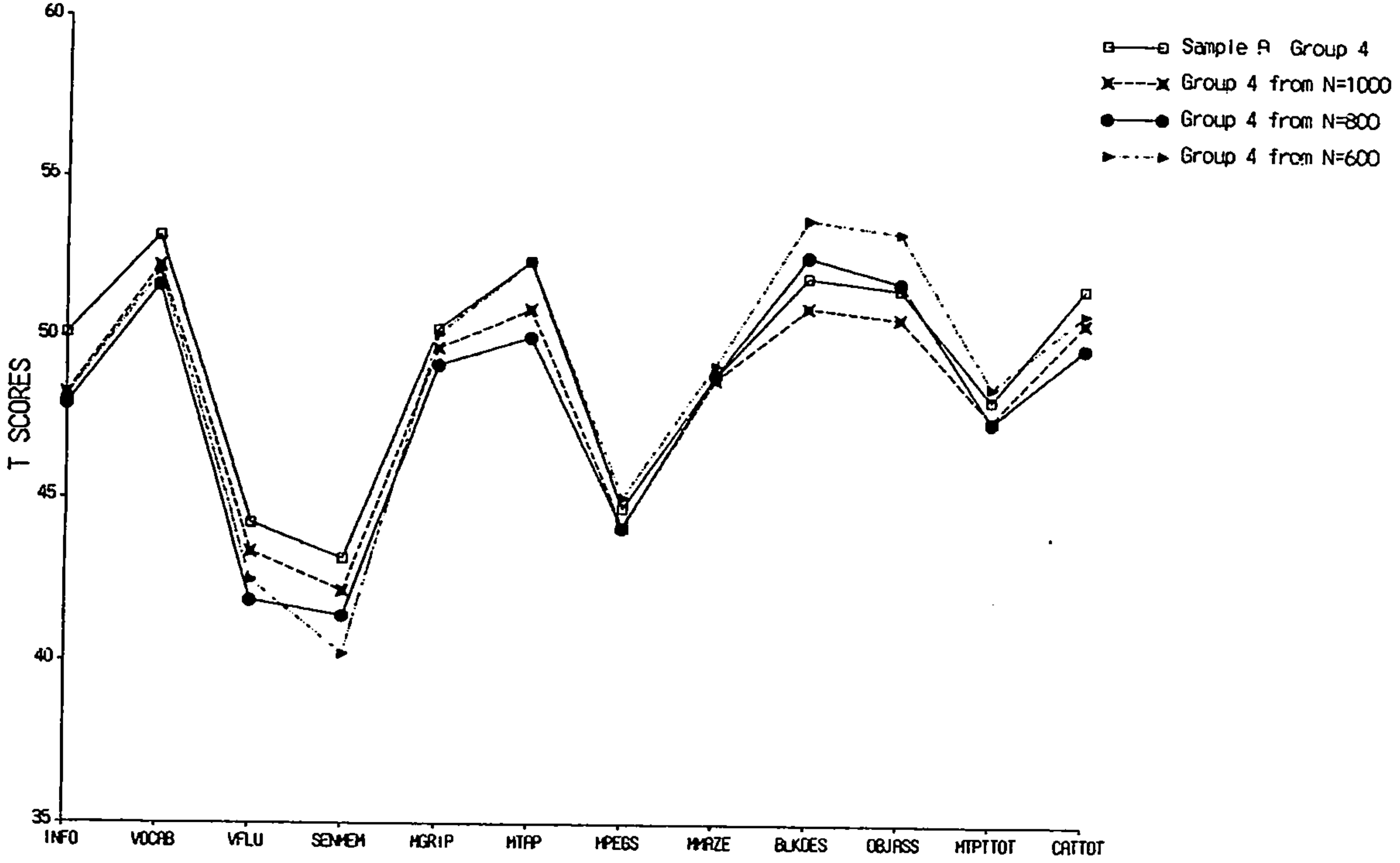


Figure 34. Composite plot of all WRAT Group 4 mean profiles from Sample A, N=1000, N=800 and N=600 on the neuropsychological measures.

In this section the Sample A WRAT subtypes are presented first with respect to the obtained scores on the academic measures. These subtypes are then described in terms of performances attained on the measures of neuropsychological ablities. The outliers from the Sample A cluster analysis are presented next with respect to the academic and neuropsychological measures. Finally, the WRAT subtypes and outliers are described in terms of the presence of attributes usually excluded from traditional learning disability studies (e.g., low IQ, emotionally disturbed).

The means, standard deviations, and maximum and mimimum values obtained on the WRAT Reading, Spelling, and Arithmetic subtests by each subtype are presented in standard score, T-score, and centile score form in Tables 18 to 21. Also included in these tables are the standard scores for the WISC and PPVT.

It is apparent that subtype 4 exhibited a higher mean WISC Full Scale IQ than any other group. The mean WISC Performance IQs for subtypes 4 and 1 are roughly equivalent and are slightly higher than those obtained by the other two groups. Subtype 2 exhibited the lowest mean WISC Verbal, Performance, and Full Scale IQs. Subtype 2 also exhibited the largest VIQ-PIQ difference (approximately 12 points) in favour of the latter. Subtype 1 evidenced a similar VIQ-PIQ difference of approximately 10 points. Subtype 3 showed a

Table 18

Phase I:
Academic Measures: Means, Standard Deviations, Minimum and Maximum Values for the Sample A WRAT Group 1 (n=460)

	Mean (n=460)	Standard Deviation	Minimum Value	Maximum Value
Chronological Age in years	11.28	1.63	9.01	14.99
WISC				
Verbal IQ	92.43	9.85	61.00	121.00
Performance IQ	102.36	14.42	61.00	146.00
Full Scale IQ	96.88	11.17	64.00	120.00
PPVT IQ	97.67	13.13	61.00	137.00
WRAT (T-Score Conversion of Standard Scores)				
Reading	42.40	3.41	34.67	52.00
Spelling	38.58	3.78	26.67	50.67
Arithmetic	39.46	5.02	25.33	50.67
WRAT (Standard Scores)				
Reading	88.60	5.12	77.00	103.00
Spelling	82.87	5.67	65.00	101.00
Arithmetic	84.19	7.53	63.00	101.00
WRAT (Subtest Centiles)				
Reading %	23.53	10.45	6.00	58.00
Spelling %	14.39	8.72	1.00	78.00
Arithmetic %	17.35	10.92	1.00	53.00

Table 19

Phase I:
Academic Measures: Means, Standard Deviations, Minimum and Maximum Values for the Sample A WRAT Group 2 (n=382)

	Mean (n=382)	Standard Deviation	Minimum Value	Maximum Value
Chronological Age in years	11.62	1.59	9.01	14.99
WISC				
Verbal IQ	85.77	9.87	60.00	118.00
Performance IQ	97.37	14.04	65.00	138.00
Full Scale IQ	90.41	11.26	62.00	120.00
PPVT IQ	91.88	13.88	57.00	140.00
WRAT (T-Score Conversion of Standard Scores)				
Reading	33.41	3.96	21.33	42.67
Spelling	31.93	3.24	21.33	40.67
Arithmetic	35.80	4.68	23.33	46.67
WRAT (Standard Scores)				
Reading	75.12	5.94	57.00	89.00
Spelling	72.89	4.85	57.00	86.00
Arithmetic	78.70	7.02	60.00	95.00
WRAT (Subtest Centiles)				
Reading %	6.27	5.36	1.00	75.00
Spelling %	4.48	4.71	1.00	77.00
Arithmetic %	10.00	7.96	1.00	75.00

Table 20

Phase I:
Academic Measures: Means, Standard Deviations, Minimum and Maximum Values for the Sample A WRAT Group 3 (n=254)

	Mean (n=254)	Standard Deviation	Minimum Value	Maximum Value
Chronological Age in years	11.26	1.63	9.00	14.98
WISC				
Verbal IQ	95.15	9.69	71.00	121.00
Performance IQ	99.54	14.52	54.00	132.00
Full Scale IQ	97.00	11.29	71.00	120.00
PPVT IQ	100.76	13.70	59.00	138.00
WRAT (T-Score Conversion of Standard Scores)				
Reading	51.32	3.90	42.67	62.67
Spelling	46.38	3.79	36.67	56.00
Arithmetic	40.63	5.41	28.00	52.67
WRAT (Standard Scores)				
Reading	101.98	5.86	89.00	119.00
Spelling	94.57	5.69	80.00	109.00
Arithmetic	85.95	8.12	67.00	104.00
WRAT (Subtest Centiles)				
Reading %	54.82	14.37	23.00	90.00
Spelling %	36.89	13.47	9.00	73.00
Arithmetic %	20.48	14.13	1.00	61.00

Table 21

Phase I:
Academic Measures: Means, Standard Deviations, Minimum and Maximum Values for the Sample A WRAT Group 4 (n=56)

	Mean (n=56)	Standard Deviation	Minimum Value	Maximum Value
Chronological Age in years	11.00	1.51	9.01	14.84
WISC				
Verbal IQ	104.93	9.62	85.00	125.00
Performance IQ	102.68	13.15	55.00	122.00
Full Scale IQ	104.14	10.41	68.00	119.00
PPVT IQ	107.11	14.87	70.00	140.00
WRAT (T-Score Conversion of Standard Scores)				
Reading	62.30	3.53	54.00	70.00
Spelling	55.83	3.44	49.33	64.00
Arithmetic	46.01	4.48	36.00	53.33
WRAT (Standard Scores)				
Reading	118.45	5.30	106.00	130.00
Spelling	108.75	5.16	99.00	121.00
Arithmetic	94.02	6.72	79.00	105.00
WRAT (Subtest Centiles)				
Reading %	87.78	6.86	66.00	98.00
Spelling %	71.03	10.73	47.00	92.00
Arithmetic %	35.86	15.33	8.00	63.00

similar pattern of VIQ-PIQ difference but to a much lesser extent (only 4 points). Subtype 4 obtained the highest mean PPVT IQ followed in descending order by subtype 3, subtype 1 and subtype 2.

With respect to the mean T-scores on the WRAT it is clear that subtype 2 performed well below average (almost 2 standard deviations from the mean) on reading and spelling, while performing almost as poorly (nearly 1.5 standard deviations below the mean) on arithmetic. Subtype 4 evidenced above-average reading, high-average spelling, and average arithmetic; subtype 3 exhibited average reading and spelling in the context of poor arithmetic; subtype 1 exhibited poor reading, and slightly below-average performances in spelling and arithmetic.

The means, standard deviations, and maximum and minimum values obtained on the neuropsychological measures by the children classified into the four WRAT subtypes are given in Tables 22 to 25. At first glance it is obvious that there is a very large range associated with each of the neuropsychological variables for all of the four WRAT subtypes. For example, the Maze Test scores range from a low of 10 to a high of approximately 65 for each of the subtypes. This is most likely an indication of the heterogeneity occuring within the four WRAT subtypes. In general, the subtypes appeared to differ most with respect

Table 22

Phase I:
Neuropsychological Measures: Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for the Sample A WRAT Group 1 (n=460)

	Mean (n=460)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	42.36	6.52	26.67	63.33
WISC Vocabulary	47.55	7.39	23.33	66.67
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	39.22	9.47	15.78	67.86
Sentence Memory	34.56	11.68	10.00	64.00
SIMPLE MOTOR SKILLS				
Grip Strength[1]	50.15	7.60	29.18	80.52
Finger Tapping[1]	49.24	11.02	10.00	81.82
COMPLEX MOTOR				
Grooved Pegboard[2]	44.44	13.63	10.00	75.70
Maze Test[2]	47.06	14.41	10.00	66.66
VISUAL-SPATIAL SKILLS				
WISC Block Design	51.60	10.15	23.33	80.00
WISC Object Assembly	52.80	11.14	20.00	83.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	47.87	10.06	10.00	64.98
Category Test (Total error score)	49.06	9.09	12.80	71.14

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time score for the right- and left-hand trials combined

Table 23

Phase I:
Neuropsychological Measures: Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for the Sample A WRAT Group 2 (n=254)

	Mean (n=254)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	38.66	6.24	23.33	60.00
WISC Vocabulary	43.10	7.58	20.00	63.33
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	34.74	9.66	12.21	62.21
Sentence Memory	29.79	12.01	10.00	76.09
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.09	6.83	25.56	78.10
Finger Tapping[1]	45.41	11.19	10.00	75.08
COMPLEX MOTOR				
Grooved Pegboard[2]	42.90	13.90	10.00	86.43
Maze Test[2]	42.05	15.26	10.00	65.40
VISUAL-SPATIAL SKILLS				
WISC Block Design	48.29	9.38	23.33	73.33
WISC Object Assembly	51.05	10.94	16.67	80.00
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	46.14	10.55	10.00	69.50
Category Test (Total error score)	47.82	9.30	10.00	72.76

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 24

Phase I:
Neuropsychological Measures: Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for the Sample A WRAT Group 3 (n=254)

	Mean (n=254)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	45.25	7.46	23.33	66.67
WISC Vocabulary	49.41	8.00	23.33	70.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	40.48	9.92	17.86	71.43
Sentence Memory	37.51	10.94	10.00	64.00
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.98	8.31	25.50	85.29
Finger Tapping[1]	49.38	12.56	10.00	83.53
COMPLEX MOTOR				
Grooved Pegboard[2]	41.57	14.69	10.00	72.92
Maze Test[2]	47.32	15.56	10.00	65.95
VISUAL-SPATIAL SKILLS				
WISC Block Design	50.46	10.09	26.67	76.67
WISC Object Assembly	50.22	10.46	16.67	80.00
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	43.95	11.38	10.00	63.48
Category Test (Total error score)	47.23	10.06	10.00	66.82

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 25

Phase I:
Neuropsychological Measures: Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for the Sample A WRAT Group 4 (n=56)

	Mean (n=56)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	50.12	7.70	33.33	70.00
WISC Vocabulary	53.15	8.32	33.33	70.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	42.25	10.52	16.78	70.68
Sentence Memory	43.17	9.97	19.56	64.00
SIMPLE MOTOR SKILLS				
Grip Strength[1]	50.32	8.65	29.80	81.30
Finger Tapping[1]	52.42	11.48	14.66	75.04
COMPLEX MOTOR				
Grooved Pegboard[2]	44.73	15.04	10.00	70.94
Maze Test[2]	48.84	14.11	10.50	65.54
VISUAL-SPATIAL SKILLS				
WISC Block Design	51.96	10.93	20.00	80.00
WISC Object Assembly	51.61	9.45	16.67	70.00
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	48.15	11.19	11.27	60.39
Category Test (Total error score)	51.68	9.67	24.27	67.43

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

to simple and complex language skills. The four subtypes differed the least on Grip Strength. Subtype 2 performed rather poorly on simple as well as complex language abilities; subtype 1 exhibited below-average mean scores on complex language skills; and subtype 3 evidenced a below-average mean score only on the Sentence Memory Test (Complex Language Skill Area). Only subtype 4 exhibited mean scores within the low-average to average range on all of the neuropsychological measures.

In order to characterize the four WRAT subtypes in terms of degree of impairment on the neuropsychological measures, the percentage of children in each subtype with T-scores below 40 (at least one standard deviation below the mean) is presented in Table 26. The percentages given in Table 26 represent the average number of children showing impairment within each skill area and across all six skill areas for each subtype. It is clear in Table 26 that subtype 4 contains the smallest group percentage of children exhibiting impairment on the neuropsychological measures. Subtype 2 contains the greatest proportion of children (34%) evidencing impairment on these measures. Subtypes 1 and 3 appear very similar with respect to the overall percentage of children showing impairment; however, subtype 1 contains a higher proportion of children with impairment on simple (18%) and complex (60%) language skills than does

Table 26

Phase I:
Percentage of Children Impaired in Each Neuropsychological Skill Area for the Sample A WRAT Subtypes and Outliers

	WRAT Subtypes				
	1 (n=460)	2 (n=382)	3 (n=254)	4 (n=56)	Outliers (n=48)
Simple Language Skills	18	38	12	5	12
Complex Language Skills	60	76	52	33	37
Simple Motor Skills	12	18	16	8	18
Complex Motor Skills	28	37	32	23	22
Visual Spatial Skills	8	14	11	9	18
"Higher-Order" Skills	17	22	27	15	22
Mean	24	34	25	16	21

subtype 3. On the other hand, subtype 3 contains a larger proportion of children with impairment on simple (16%) and complex (32%) motor skills, and on visual-spatial (11%) and "higher-order" (27%) skills than does subtype 1. The academic and neuropsychological performances of the children classified as outliers (i.e., unique individuals) by Ward's method will be presented next.

There were a total of 48 children discarded as outliers prior to the cluster analysis of the WRAT reading, spelling, and arithmetic subtest scores. These children were categorized as outliers by employing the TRIM option for the hierarchical agglomerative cluster techniques in the SAS statistical software package. As mentioned previously, the TRIM option was set to discard 4 percent of the subjects from the 1200 in Sample A. A value for K of 11 was used in conjunction with TRIM=4 for Sample A. Using these parameters the SAS statistical software discards points (i.e., subjects) in the three-dimensional space formed by the WRAT variables which are significantly isolated from the surrounding 'neighbour' points. It was thought most likely that the TRIM option culled the 'most impaired' and 'most normal' children from the cluster analysis, as well as children with unusual profiles.

The means, standard deviations, maximum, and minimum values of the Sample A WRAT outliers for the academic and neuropsychological measures are given in Table 27 and Table 28, respectively. It is apparent in Table 27 that there is a large range in the values for all academic measures including the WISC and PPVT IQs. There is also a large range in the values of the neuropsychological variables as shown in Table 28. It is suggested that this reflects a high degree of heterogeneity within the group of children designated as outliers.

As shown in Table 26, an overall average of 21 percent of the children considered to be outliers were impaired on the measures of neuropsychological abilities. Only subtype 4 exhibited a smaller mean percentage of overall impairment within its members. Inspection of Table 26 revealed that the outliers evidenced the greatest proportion of children with impairment in complex language skills (37%), complex motor skills (22%), and "higher-order" skills (22%). In the following part of the results for Phase I the types of children (e.g., environmentally deprived) occuring in the WRAT subtypes and outliers are presented.

The number of children in the Sample A WRAT subtypes and outliers corresponding to typical exclusionary criteria which are traditionally employed in learning disability studies are provided in Table 29. The exclusionary criteria examined here include several levels of low IQ (e.g., PPVT IQ < 90,

Table 27

Phase I:
Academic Measures: Means, Standard Deviations, Minimum and Maximum Values for the Sample A WRAT Outliers (n=48)

	Mean (n=48)	Standard Deviation	Minimum Value	Maximum Value
Chronological Age in years	11.30	1.70	9.10	14.95
WISC				
Verbal IQ	100.87	16.31	62.00	125.00
Performance IQ	100.54	18.70	62.00	136.00
Full Scale IQ	100.77	17.01	60.00	120.00
PPVT IQ	107.60	16.16	68.00	135.00
WRAT (T-Score Conversion of Standard Scores)				
Reading	57.11	17.64	20.67	87.33
Spelling	48.76	16.91	16.67	80.67
Arithmetic	42.67	10.93	21.33	63.33
WRAT (Standard Scores)				
Reading	110.67	26.46	56.00	156.00
Spelling	98.14	25.37	50.00	146.00
Arithmetic	89.00	16.39	57.00	120.00
WRAT (Subtest Centiles)				
Reading %	67.58	37.17	1.00	99.00
Spelling %	49.19	37.49	1.00	99.00
Arithmetic %	32.56	26.41	1.00	91.00

Table 28

Phase I:
Neuropsychological Measures: Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for the Sample A WRAT Outliers (n=48)

	Mean (n=48)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	49.51	10.52	23.33	73.33
WISC Vocabulary	52.08	11.23	30.00	76.67
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	45.11	12.79	17.11	72.46
Sentence Memory	42.35	11.34	10.00	64.00
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.17	7.72	32.98	78.33
Finger Tapping[1]	49.88	14.71	10.46	79.27
COMPLEX MOTOR				
Grooved Pegboard[2]	45.08	13.87	10.00	68.25
Maze Test[2]	49.88	12.86	10.00	63.15
VISUAL-SPATIAL SKILLS				
WISC Block Design	52.22	11.96	26.67	80.00
WISC Object Assembly	50.00	11.63	30.00	76.67
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	45.92	11.35	17.50	62.14
Category Test (Total error score)	49.52	11.29	24.76	66.64

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 29

Phase I:
Number (Percentage) of Children in the Sample A WRAT Groups and Outliers Corresponding to Typical Exclusionary Criteria

	Group 1 (n=460)	Group 2 (n=382)	Group 3 (n=254)	Group 4 (n=56)	Outliers (n=48)
PPVT IQ<90	119(26)[1]	160(42)	52(20)	7(13)	5(10)
WISC FSIQ<90	115(25)	175(46)	61(24)	3(5)	13(27)
WISC FSIQ<85	53(12)	119(31)	40(16)	3(5)	9(19)
WISC FSIQ<80	31(7)	76(20)	18(7)	2(4)	6(13)
Emotionally Disturbed	105(23)	65(14)	98(39)	28(50)	12(25)
Brain Lesioned	22(5)	15(4)	20(8)	7(13)	2(4)
Environmental Deprivation	1(0.2)	6(2)	3(1)	0(0)	0(0)
Hearing Anomalies	49(11)	47(12)	24(9)	3(5)	3(6)
Visual Anomalies	25(5)	33(9)	16(6)	5(9)	3(6)
Impairment on Sweep Hearing Test	88(19)	72(19)	57(22)	5(9)	11(23)

Note 1: The numbers in parentheses represent the percentages of children within that group corresponding to the exclusionary criteria. For example, 119 of the 460 children (i.e., 26%) in WRAT Group 1 have a PPVT IQ < 90. Similarly, 28 of the 56 children (i.e., 50%) in WRAT Group 4 were considered emotionally disturbed.

WISC FSIQ < 85) as well as categories indicative of the following: impairment on the Sweep Hearing Test, visual and hearing anomalies, environmental deprivation, presence of brain pathology, and emotional disturbance. The number of children occuring in these categories for the entire Sample A (n=1200) were presented previously in Table 2.

As shown in Table 29, WRAT Group 2 contained the greatest proportion of low IQ children. The subjects classified into WRAT Group 4 and Group 3 evidenced the largest proportions of emotional disturbance (50% and 39% of the group totals, respectively). In contrast, WRAT Group 2 (which yielded the lowest achievement scores), contained the smallest proportion (i.e., 14%) of emotionally disturbed children. The largest group proportion of children with some form of brain pathology occured with WRAT Group 3 (13%). Six of the 10 children considered environmentally deprived were clustered into WRAT Group 2. Children with hearing anomalies occured with the greatest frequency in Group 1 (11%) and Group 2 (12%). Children with visual anomalies or impairment on the Sweep Hearing Test occured in similar proportions across all four WRAT groups and outliers.

In order to further investigate the 'types' (e.g., learning disabled) of children occuring in the outliers and in each of the WRAT Groups, several commonly used definitions of learning disability (IQ-Achievement Discrepancies, WRAT Typologies) were applied to these subjects. Similar IQ-Achievement discrepancy definitions as employed here have been used in several well-known LD studies (e.g., Joschko & Rourke, 1985; Petrauskas & Rourke, 1979). In the present study, all children with at least one WRAT centile score $\leq$ 25 and corresponding to a certain WISC FSIQ or PPVT IQ cutoff point (e.g., IQ $\geq$ 90, see Table 30) were categorized as 'learning disabled'.

Children who could be characterized as learning disabled on the basis of a configurational approach derived from the WRAT typologies employed by Ozols and Rourke (1988) are also given in Table 30 for each subtype and the ouliers. The procedure for constructing this typology is indicated in Table 30.

As well, the number of children who could be (arbitrarily) characterized as "normal achievers" on the basis of exhibiting at least low-average levels of academic achievement on all three of the WRAT subtests and evidencing a WISC FSIQ $\geq$ 85 were also determined for the outlier children and for those in the four subtypes. The number (and group percentage) of children in the outlier category and within each WRAT cluster who corresponded to these various definitions are shown in Table 30.

As shown in Table 30, none of the children in WRAT

Table 30

Phase I:
Number (Percentage) of Children in the Sample A WRAT Subtypes and Outliers Evidencing at least Low-Average Levels of Academic Achievement or Corresponding to Definitions of Learning Disabilities

	Group 1 (n=460)	Group 2 (n=382)	Group 3 (n=254)	Group 4 (n=56)	Outliers (n=48)
Low-Average or Better Achievement by WRAT Standard Scores					
WRAT R, S, A all ≥ 85	106(23)	0(0)	123(48)	49(82)	27(56)
Learning Disability Definitions.					
A) IQ-Achievement Discrepancy: At least one WRAT Centile Score ≤ 25, and WISC or PPVT IQ cutoff as follows;					
1. FSIQ ≥ 80	413(90)	306(80)	169(67)	14(25)	22(46)
2. FSIQ ≥ 85	391(85)	263(69)	128(58)	14(25)	19(40)
3. FSIQ ≥ 90	329(72)	207(54)	128(50)	14(25)	16(33)
4. PPVT IQ ≥ 90	329(72)	222(58)	143(56)	13(23)	23(48)
B) Configurational Approach (WRAT Typologies)[1]					
1. Rourke G1	63(14)	201(53)	0(0)	0(0)	2(4)
2. Rourke G2	19(4)	44(12)	0(0)	0(0)	0(0)
3. Rourke G3	0(0)	0(0)	26(10)	26(46)	7(15)

Note 1: These 'configurational' definitions of learning disability were adapted from Ozols and Rourke (1988) as follows: for all children WISC FSIQ ≥ 85, and;

Rourke G1: WRAT R,S, and A Centiles all ≤ 16.

Rourke G2: WRAT R,S ≤ 16; 16 ≤ A ≤ 34; and the Arithmetic centile score was at least 10 points higher than the Reading centile score for all G2 children.

Rourke G3: WRAT R,S ≥ 45; A ≤ 34; and the Arithmetic centile score was at least 25 points lesser than the centile scores for both Reading and Spelling.

Group 2 (n=382) could be characterized as 'normal' academic achievers on the basis of having all WRAT standard scores at least equal to or greater than one standard deviation below the mean (i.e., $\geq$ 85). Group 2 also contained the largest number (i.e., 201, or 53% of that group) of the WRAT type referred to as 'Rourke G1' based on the configurational approach. WRAT Group 4 contains the largest proportion of children (82%) considered at least low-average achievers, and the largest percentage of children (i.e., 46%) who could be classified as arithmetic disabled according to the 'Rourke G3' type definition. None of the children in Groups 1 or 2 could be classified as arithmetic disabled with this typology. It is also apparent in Table 30 that none of the children in WRAT Groups 3 or 4 could be considered as 'Rourke G1 or G2' on the basis of the criteria adapted from the Ozols and Rourke (1988) study.

WRAT Group 1 contained the largest number of children designated as learning disabled with respect to IQ-Achievement discrepancy and and the various IQ cutoff points. Group 4 had the fewest number of children (i.e., 25% or less) considered learning disabled according to the IQ discrepancy criteria and several IQ cutoff scores. The outliers appeared to consist of a variety of children, some of whom could be considered 'normal' achievers, some corresponded to an IQ discrepancy definition; two (4%) could be classified as Rourke G1 and 7 (15%) could be categorized as arithmetic disabled (Rourke G3).

It was unexpected that <u>none</u> of the WRAT groups emerging from the cluster analysis of Sample A could <u>not</u> be categorized as a "pure normal group". Although Group 4 approaches this designation (82% of the children at least low-average achievers), it also contains children who could be considered learning disabled on the basis of an IQ-achievement discrepancy and/or arithmetic disabled according to a configurational approach. As this was the case, no group of children could be considered entirely 'normal' and deleted from Sample A prior to the cluster analysis of this sample on the neuropsychological measures. For this reason, all children in Sample A (n=1200) were clustered on the 12 neuropsychological variables in Phase II of the present study. In the next part of the results the cluster analyses of Sample A with respect to the 12 neuropsychological variables are presented.

Phase II: Measures of Neuropsychological Abilities (Sample A n=1200)

The findings of the cluster analyses of Sample A with respect to the 12 neuropsychological variables are presented here in two sections. Part A consists of the initial cluster analysis of Sample A on the 12 neuropsychological variables with respect to profile shape. The procedure recommended by Lorr (1983) to remove elevation and cluster on the basis of profile shape was employed to cluster the Sample A observations. In Part B of this phase of the analyses, the profile shapes which emerged using Lorr's (1983) method were again clustered individually on the basis of elevation and shape. The results of these two stages of cluster analysis are presented below.

Part A: Clustering for Profile Shape

As described in the METHOD section of the present study, the strategy developed by Skinner (1978) and the procedure suggested by Lorr (1983) to generate clusters first on the basis of profile shape was used on Sample A as the initial step. The findings of this approach are presented as follows: (1) the cluster fusion coefficients 'pseudo F and T' for the four hierarchical agglomerative cluster analytic methods are depicted graphically and a particular solution is suggested; (2) then the cross-method agreement between Ward's technique (which was employed as the target method) and the other three cluster procedures is displayed; (3) the misclassification analyses for the three internal validation samples are presented; (4) the mean T-score profiles of the clusters on the neuropsychological variables are calculated and plotted for the cluster solution determined by at least two methods; and, finally, (5) the split-sample replication attempts are graphically diplayed. In Part A, the 'types' of children occuring in the clusters and outliers were not considered of prime importance and so are not reported.

The raw scores for all 12 neuropsychological variables were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The T-score means, standard deviations, and maximum and minimum values for the Sample A (n=1200) neuropsychological variables are presented in Table 31.

The plots of the pseudo F and T cluster coefficients for Ward's method are displayed in Figure 35. There appears to be a 'rise' in the pseudo F plot at the four- or five-cluster level associated with low values of the pseudo T coefficient. However, there was very poor agreement between the various cluster methods at this point. There is a small drop in pseudo T at the seven-cluster level and again at the fourteen-cluster level; however, there was limited cross-method agreement and these possible solutions were not investigated further. Plots of the flexible-beta, complete linkage, and average linkage methods are displayed in Figures 36 to 38.

Inspection of the graphs of the pseudo F and T coefficients in Figures 36 to 38 indicated that the various cluster methods offered a variety of possible cluster solutions for Sample A with respect to the neuropsychological

Table 31

Phase II Part A;
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A (N=1200)

	Mean (n=1200)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	42.44	7.65	23.33	73.33
WISC Vocabulary	46.97	8.35	20.00	76.67
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	38.53	10.25	12.21	72.46
Sentence Memory	34.38	12.16	10.00	76.09
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.75	7.58	25.50	85.29
Finger Tapping[1]	48.23	11.76	10.00	83.53
COMPLEX MOTOR				
Grooved Pegboard[2]	43.38	14.05	10.00	86.40
Maze Test[2]	45.72	15.06	10.00	66.60
VISUAL-SPATIAL SKILLS				
WISC Block Design	50.35	10.11	20.00	80.00
WISC Object Assembly	51.53	10.92	16.67	83.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	46.23	10.70	10.00	69.50
Category Test (Total error score)	48.42	9.53	10.00	72.76

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

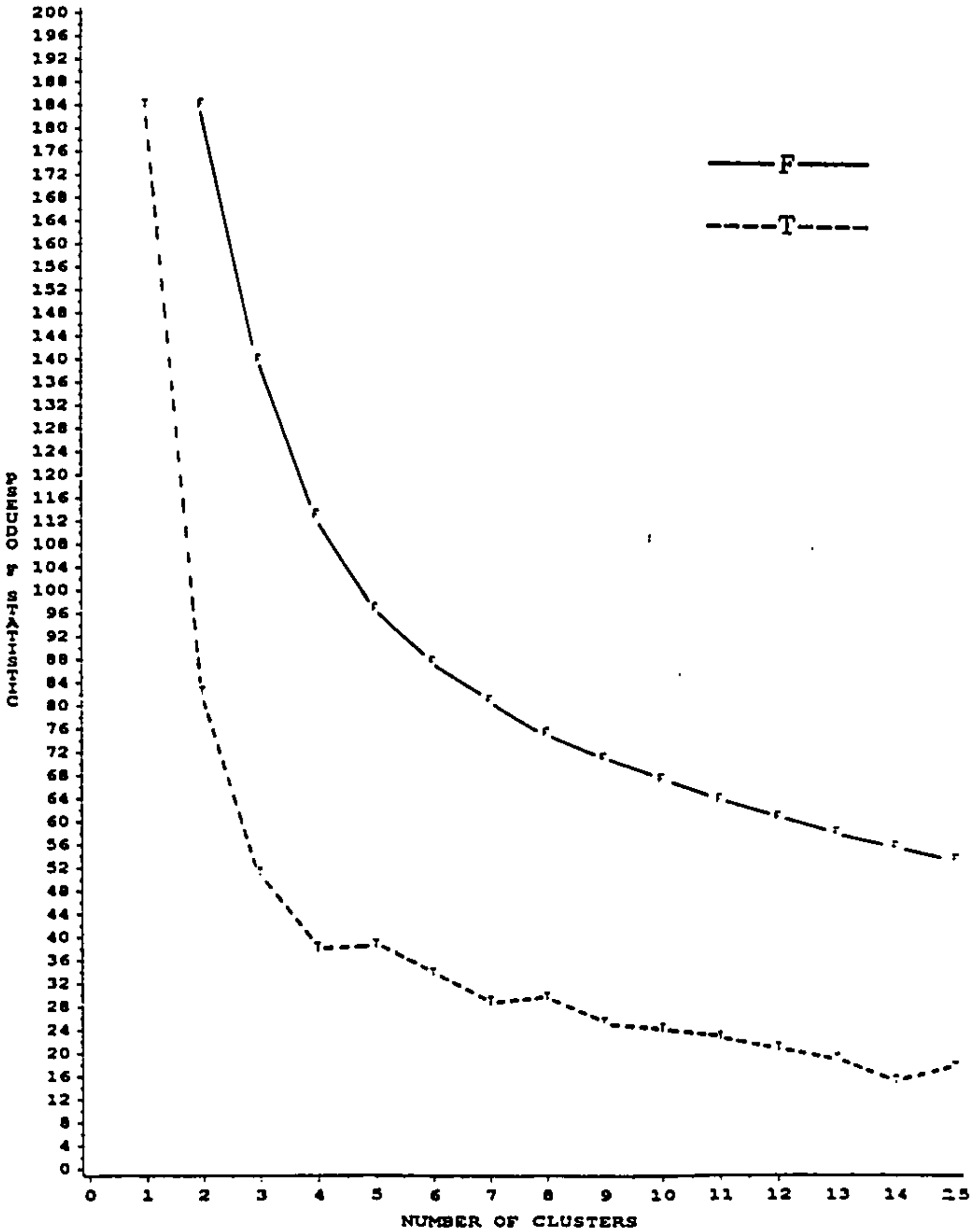


Figure 35. Phase II Part A: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Sample A (n=1200) with TRIM=4, K=11.

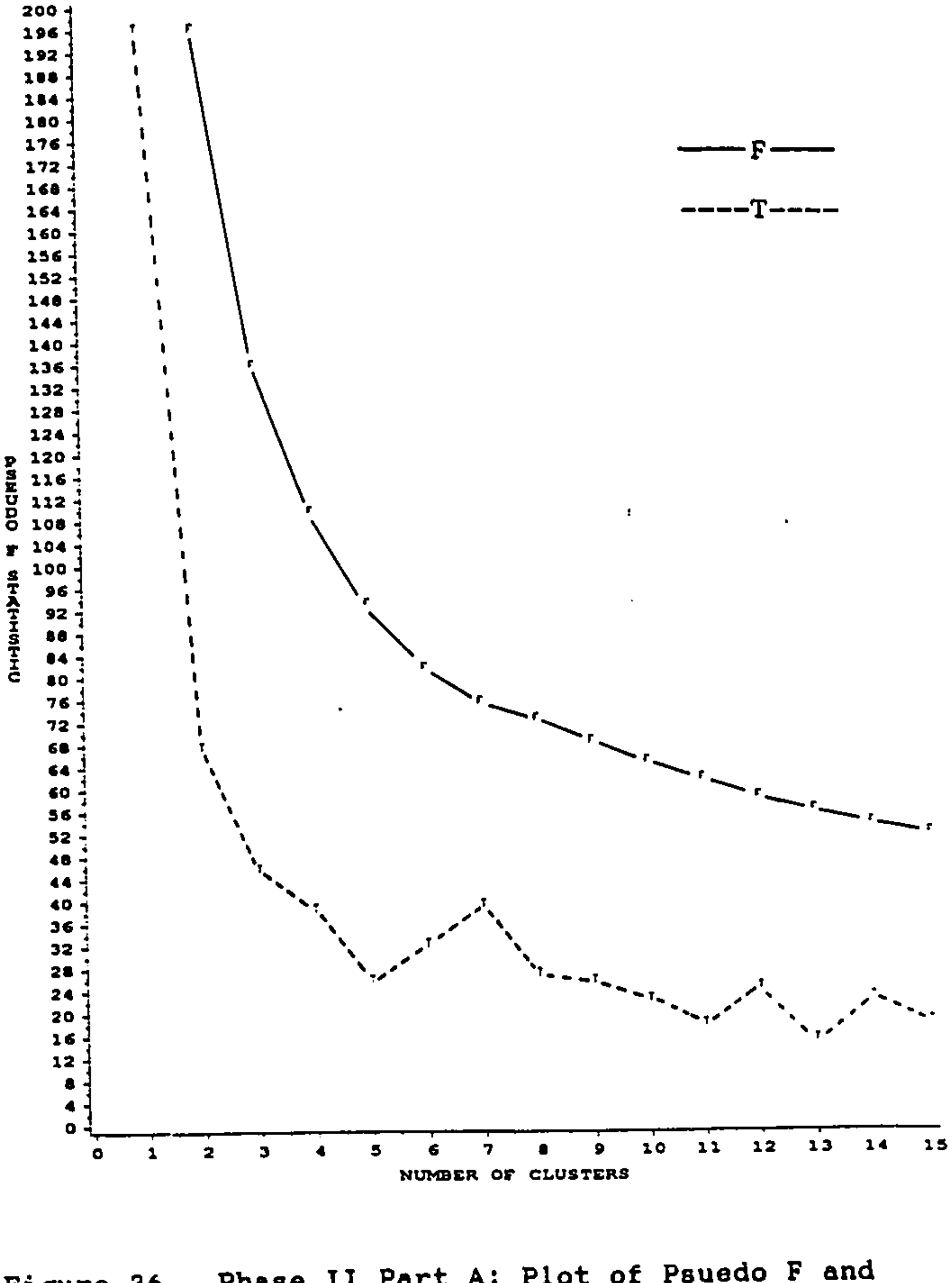


Figure 36. Phase II Part A: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Sample A (n=1200) with TRIM=4, K=11.

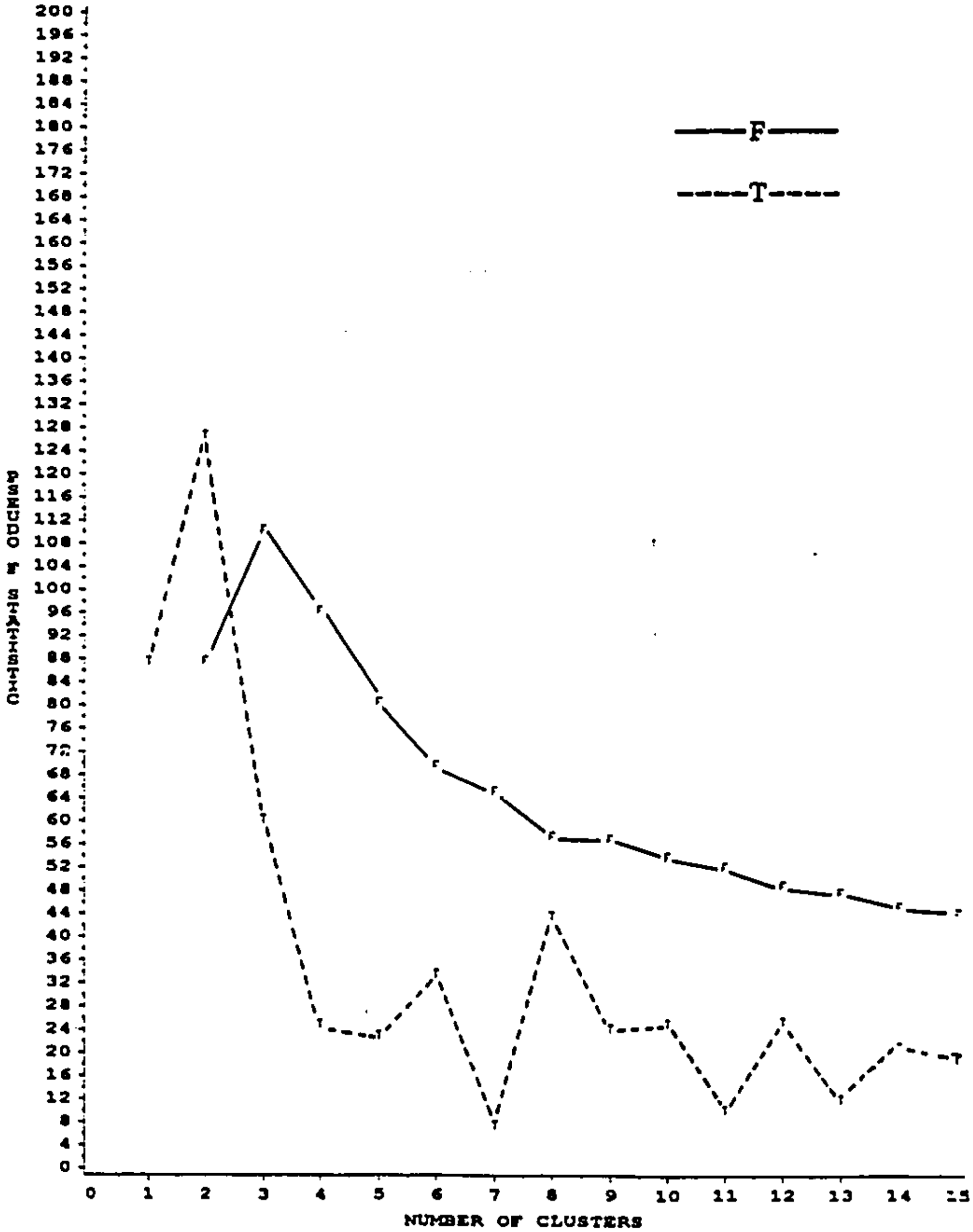


Figure 37. Phase II Part A: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Sample A (n=1200) with TRIM=4, K=11.

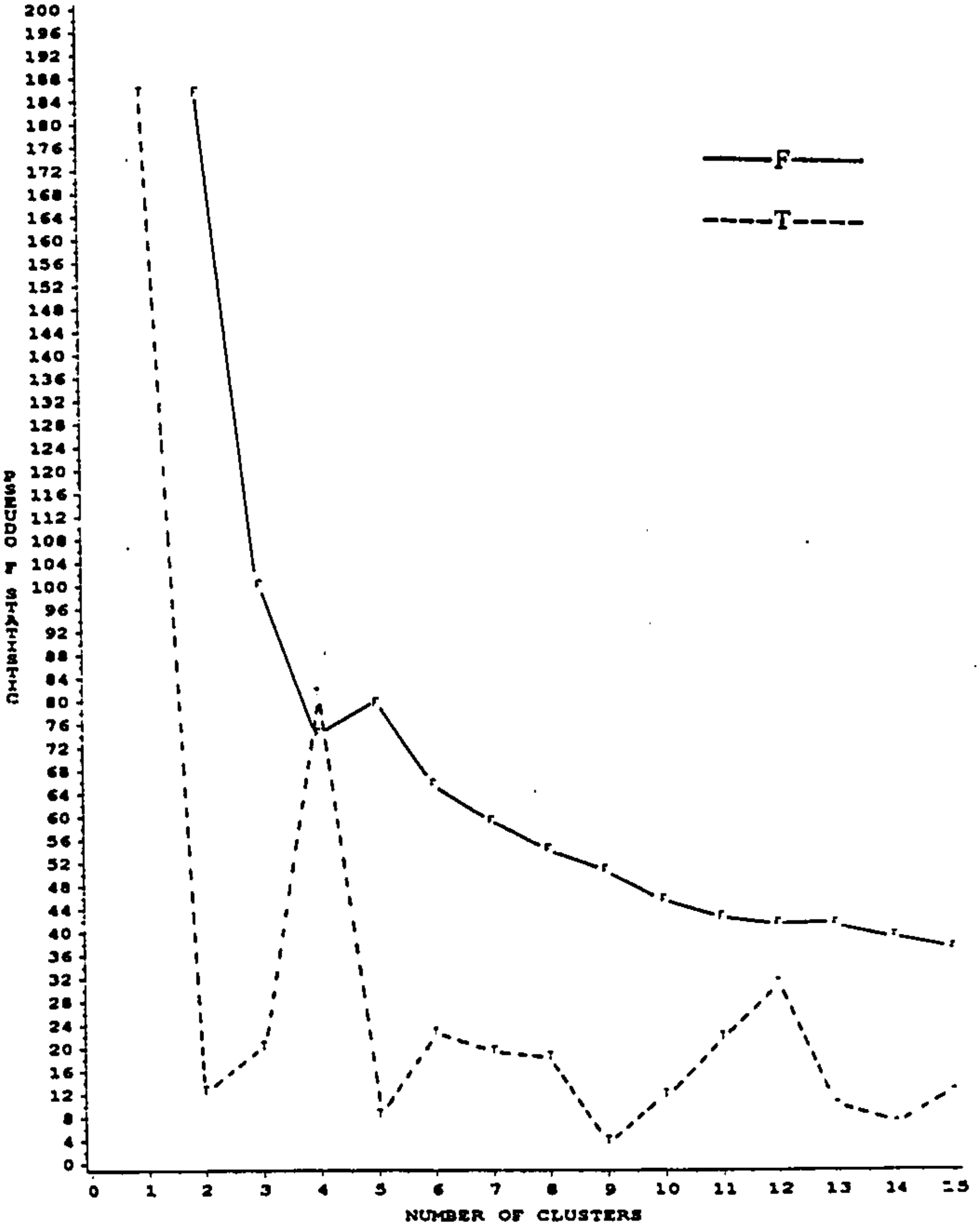


Figure 38. Phase II Part A: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Sample A (n=1200) with TRIM=4, K=11.

variables. For example, there is a rise in the value of pseudo F and a corresponding drop in pseudo T at 5 clusters in Figure 36 for the flexible-beta method. This pattern was also apparent at 5 clusters for the complete linkage and average linkage techniques (Figures 37 and 38). However, this possible solution was not investigated further as the cross-method agreement was very poor.

In Figure 37 it is apparent that a seven-cluster solution is possible, but again, there was limited agreement between the four cluster methods at this level. Other possibilities suggested by these plots such as a 13 cluster partition and a 11 cluster partition (Figures 36 to 37), and a nine-cluster solution (Figure 38) were also discarded due to limited cross-method agreement.

The only solution displayed in these fusion coefficient plots which produced exceptable levels of agreement is a three-cluster solution. For Ward's method the pseudo F plot (Figure 35) does show a sharp increase at 3 clusters, and the pseudo T plot does exhibit a substantial drop (from the two- to three-cluster level) at this point. A sharp rise in the pseudo F plots accompanied by a large drop in the pseudo T plots is quite apparent in Figures 36 to 37 for the flexible-beta and complete linkage cluster analytic techniques. Although the pseudo T coefficient plot for the average linkage method does not show a drop (from 2 to 3 clusters), the pseudo F plot (Figure 38) does exhibit a sharp rise at the three-cluster level. Since a three-cluster solution was apparent in all of the fusion coefficient plots, it was considered the best choice for further investigation in the present study.

The misclassification analysis for the four cluster methods are presented in Table 32. Ward's method (TRIM=4, K=11) was the target solution. A total of 48 children were removed as outliers and the remaining 1152 were classified into three groups. Since these analyses were done with elevation removed to emphasize profile shape, the three clusters which emerged will be referred to as Profile 1, Profile 2, and Profile 3.

As shown in Table 32, there was good agreement between Ward's three-cluster solution and the three-cluster solution which emerged from the flexible-beta method. Only 24% (overall) of the children classified into three profiles by Ward's method were misclassified by the flexible-beta technique, while 31% and 34% were misclassified by the complete and average linkage methods, respectively. These last two misclassification rates were considered unacceptably high according to the criteria outlined in the METHOD section of the present study. However, with respect to the individual profiles derived from the cluster analysis of the neuropsychological measures, complete linkage misclassified

Table 32

Phase II Part A;
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Sample A N=1200 Neuropsychological Variables)

	Ward's Cluster Groups			
Cluster analysis method	1 (n=554)	2 (n=280)	3 (n=318)	Total (n=1152)
Flexible-Beta Method	178 (32)	72 (26)	28 (9)	278 (24)
Complete Linkage	254 (46)	72 (26)	30 (9)	356 (31)
Average Linkage	91 (16)	269 (96)	35 (11)	395 (34)

only 26% of the children assigned to Ward's Profile 2 (n=280) and only 9% of the children in Ward's Profile 3 (n=318) were misclassified by this method. The average linkage technique misclassified only 16% of the children assigned to Ward's Profile 1 and only 11% of the children in Ward's Profile 3. In general, all three of the profiles emerging from Ward's method were reproduced across at least two of the other cluster techniques. The only exception to this was Ward's Profile 1 which was most accurately recovered by the average linkage method. The misclassification analyses for the three split-sample replication attempts will be presented next.

The three internal validation samples (N=1000, N=800, and N=600), identical to those employed in Phase I of the present study, were cluster analysed with the same methods as used previously. In order to remove the outliers, an identical TRIM=4 value was employed to discard 4% of the most extreme subjects in each of the samples. Different values for the K parameter were used. Following the convention suggested by Wong (1982) with sample size N=1000, K=10 was used; for sample N=800, K=9; and for sample N=600, K=8.

The misclassification analyses for Ward's three profile solution (TRIM=4, K=10, 9, or 8) with the internal validation samples are given in Tables 33 to 35. With respect to overall percentages of misclassified subjects it is clear in Table 33

Table 33

Phase II Part A;
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods

(Internal Validation Sample N=1000)
(Neuropsychological Variables)

	Ward's Cluster Groups			
Cluster analysis method	1 (n=277)	2 (n=400)	3 (n=283)	Total (n=960)
Flexible-Beta Method	32 (12)	276 (69)	45 (16)	353 (37)
Complete Linkage	39 (14)	309 (77)	39 (14)	387 (40)
Average Linkage	6 (2)	374 (93)	282 (99)	662 (69)

Table 34

Phase II Part A;
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods

(Internal Validation Sample N=800)
(Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=325)	 2 (n=213)	 3 (n=230)	Total (n=768)
Flexible-Beta Method	63 (19)	124 (58)	54 (23)	241 (31)
Complete Linkage	111 (34)	44 (21)	60 (26)	215 (28)
Average Linkage	16 (5)	133 (62)	42 (18)	191 (25)

Table 35

Phase II Part A;
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods

(Internal Validation Sample N=600)
(Neuropsychological Variables)

	Ward's Cluster Groups			
Cluster analysis method	1 (n=285)	2 (n=156)	3 (n=135)	Total (n=576)
Flexible-Beta Method	53 (19)	15 (10)	18 (13)	86 (15)
Complete Linkage	64 (22)	10 (6)	36 (27)	110 (19)
Average Linkage	20 (7)	19 (12)	135 (100)	174 (30)

that none of the other three cluster methods recovered the three Ward's profiles within the 30% or less misclassification rate used in the present study for sample N=1000. However, in terms of the individual profiles, it is apparent in Table 33 that Profile 1 (flexible-beta, complete linkage and average linkage) and Profile 3 (flexible-beta and complete linkage) were accurately reproduced. Due to the overall high misclassification rates for sample N=1000, it was not considered further in the present study as evidence for good recovery of the three Ward's profiles.

The misclassification analysis for internal validation sample N=800 is given in Table 34. Although the overall misclassification rate for the flexible-beta method was unacceptably high (31%), the complete and average linkage techniques yielded good overall agreement rates of 28% and 25%, respectively. In terms of the individual Ward cluster groups, Profile 1 appeared to be recovered well by the flexible-beta and average linkage methods (19% and 5% misclassified, respectively). Profile 3 was recovered by all three of the other cluster analytic algorithms. Profile 2 was recovered well only by the complete linkage method (21% misclassified).

The misclassification analysis for internal validation sample N=600 is shown in Table 35. It is clear that all three cluster methods recovered the three Ward's profile shapes at a misclassification rate of 30% or less. Indeed, with respect to the individual Ward profile shapes, only the average linkage technique failed to recover all of individual the profiles accurately.

In summary, these comparisons revealed good evidence for a three profile solution. With respect to the Sample·A analyses of the neuropsychological measures, only the flexible-beta technique reproduced the 3 clusters at an overall misclassification rate less than 30 percent. Although this was the case, there was some recovery of the individual Ward profiles by the complete and average linkage methods. With respect to the internal validation samples, it was apparent that the cluster analysis of sample N=1000 did not recover the three Ward profiles at an acceptable rate in terms of overall misclassification. However, the Ward profiles were recovered quite adequately when the other two split-samples (N=800 and N=600) were cluster analyzed. In the next section, the three Ward profiles for Sample A and samples N=800 and N=600 are graphically displayed.

The three subtype profiles derived from the cluster analysis of the neuropsychological variables are displayed in Figure 39. The mean T-scores of the 12 measures of neuropsychological ability in Figure 39 were taken from the Ward method of cluster analysis which was the target method in the present study. Differences are apparent between

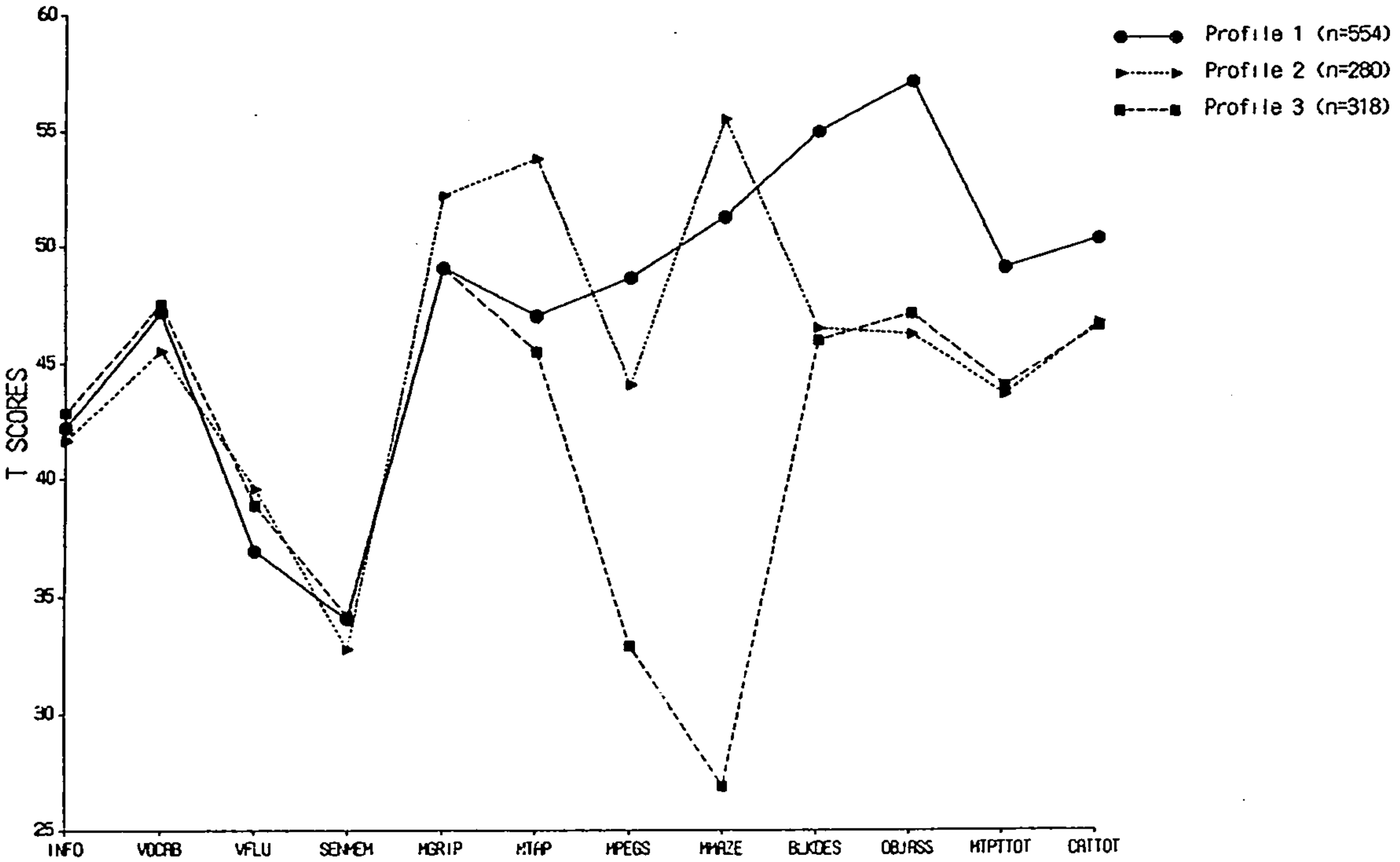


Figure 39. Plot of the three profile shapes which emerged from the cluster analysis of Sample A (n=1200) with respect to the neuropsychological variables.

Profile 1 (n=554) and the other two profiles for the neuropsychological variables thought to represent complex motor, visual-spatial, and "higher order" abilities. Profiles 2 (n=280) and 3 (n=318) appear to be dissimilar with respect to simple and complex motor measures.

The three cluster profiles for the internal validation samples (N=800, N=600) are shown in Figures 40 and 41. The profile for group 1 which emerged from the cluster analysis of sample N=600 exhibits slightly higher elevation for the two measures of simple motor skill than does Profile 1 in Figure 39. Also, for sample N=600, the profile for group 2 shows a decrease in elevation for the measures of complex motor abilities compared to Profile 2 in Figure 39. In general, the differences noted between the three profiles emerging from the cluster analysis of Sample A (n=1200) and the two split-sample replication attempts (N=800 and N=600) could be characterized as dissimilarities in profile elevation rather than profile shape. Since the cluster analyses in this part of the present study were done to emphasize profile shape, these minor differences in profile elevation between the Sample A clusters and the split-sample clusters were not considered significant.

The most relevant result of these comparisons is that the profiles for the Sample A clusters (Figure 39) and the profiles derived from the two internal validation samples

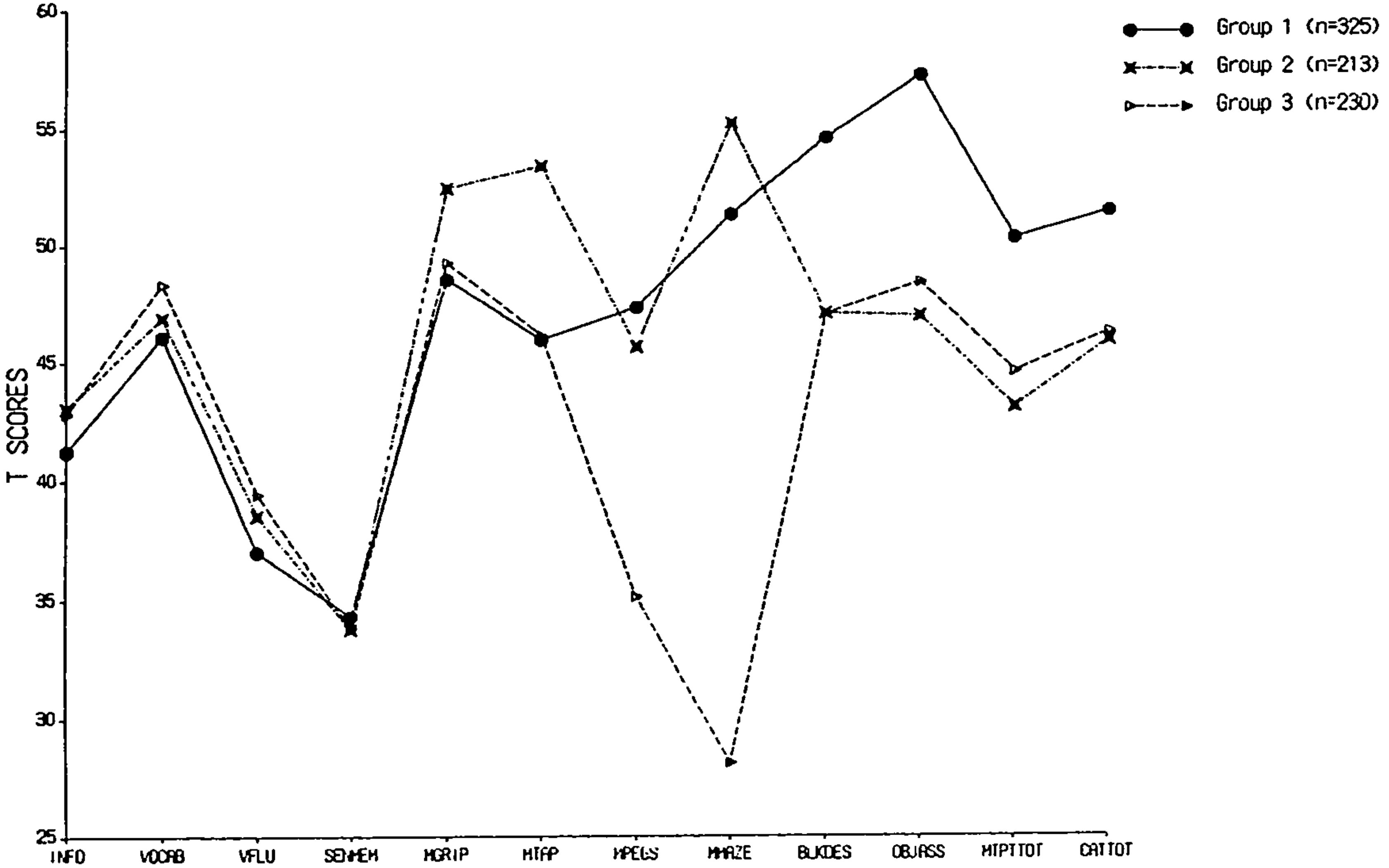


Figure 40. Plot of the three profile shapes which emerged from the cluster analysis of sample N=800 with respect to the neuropsychological variables.

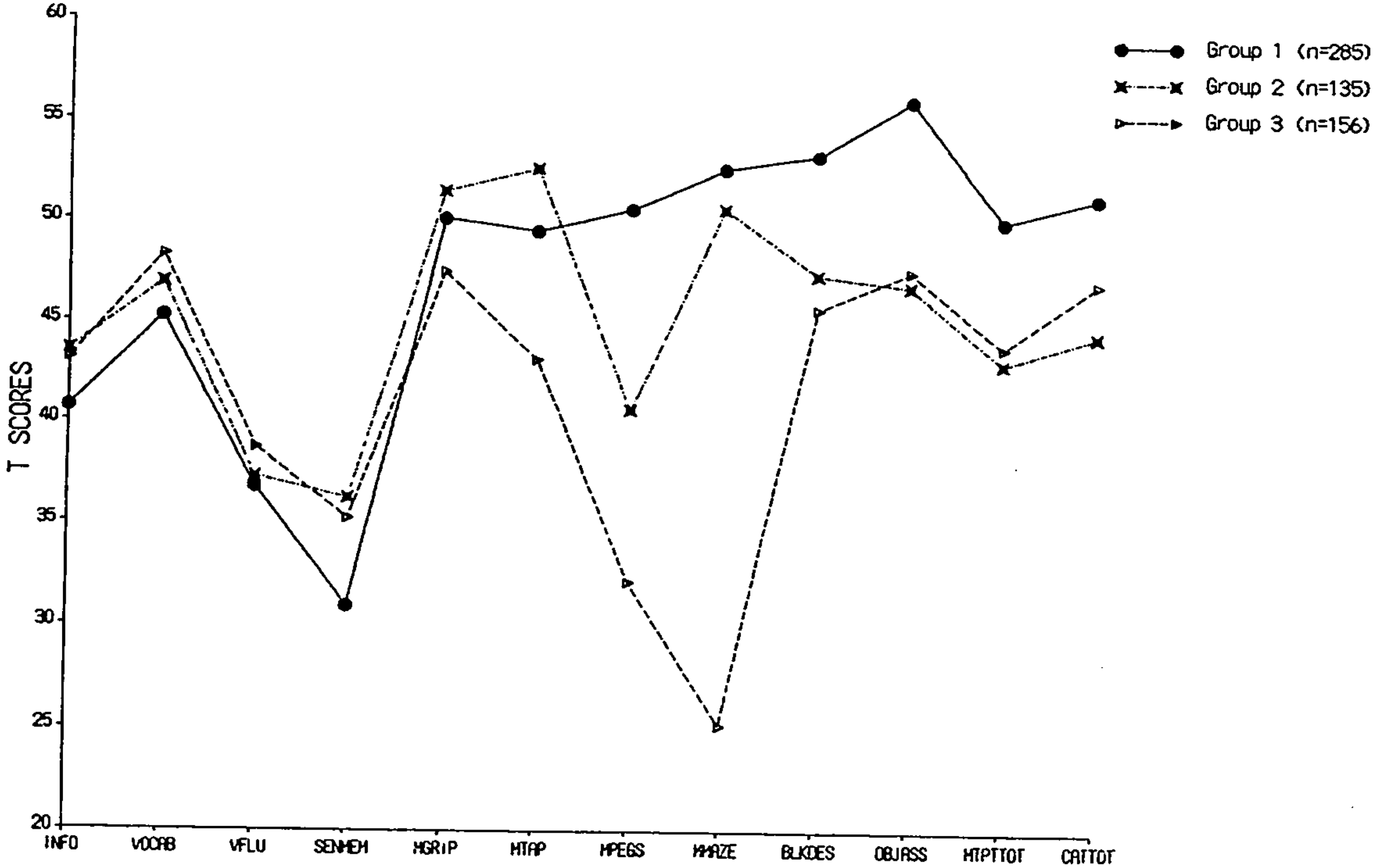


Figure 41. Plot of the three profile shapes which emerged from the cluster analysis of sample N=600 with respect to the neuropsychological variables.

(Figures 40 and 41) are obviously not different with respect to profile shape. These comparisons have demonstrated that the original three cluster solution on the neuropsychological measures for Sample A (n=1200) could be reliably recovered from analyses of subsets of the data (i.e., from N=800 and N=600). In the next section of the Phase II analyses (Part B), the results of clustering each of the three individual profiles derived from Sample A are presented.

Phase II Part B: Clustering for Profile Shape and Elevation

In this second step of the Phase II analyses, the three profile shapes derived from the cluster analysis of Sample A (n=1200) were further subtyped on the basis of profile shape and elevation in accordance with Skinner's (1978) strategy. More specifically, these three profile shapes which were thought to be reliably recovered from two subsets of the data were individually clustered once more with respect to the 12 neuropsychological variables. These clusters were labelled Profiles 1, 2, and 3 in the previous section (Phase II, Part A). The findings of clustering each profile shape with respect to shape and elevation are presented as follows: (1) the cluster fusion coefficients 'pseudo F and T' for the four hierarchical agglomerative cluster analytic methods are depicted graphically and a particular solution is suggested; (2) then the cross-method agreement between Ward's technique (which was the target method) and the other three cluster procedures is displayed; (3) the mean T-score profiles of the cluster groups on the neuropsychological variables are calculated and plotted for the cluster solution determined by at least two methods; (4) for each of the original three profiles derived from Sample A (n=1200), one split-sample (a random selection of 50% of the profile data) replication attempt is presented; and (5) following the presentation of the cluster analyses of Profiles 1, 2, and 3, the subtypes which emerged are described in terms of their performances on the neuropsychological measures, and then on the academic variables with respect to sex. Finally, the 'types' of children (e.g., emotionally disturbed) occuring in all of the resulting neuropsychological subtypes and outliers are reported.

Part B: Cluster Analysis of Profile 1 (n=554)

The raw scores for all 12 neuropsychological variables for Profile 1 were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The T-score means, standard deviations, and maximum and minimum values for the Profile 1 (n=554) neuropsychological variables are presented in Table 36.

The plots of the pseudo F and T cluster coefficients for Ward's method are displayed in Figure 42. There appears to be

Table 36

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for PROFILE I (N=554)

	Mean (n=554)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	42.23	7.63	23.33	66.67
WISC Vocabulary	47.17	8.59	20.00	76.67
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	36.91	9.85	12.21	67.86
Sentence Memory	34.08	12.69	10.00	64.00
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.12	6.45	29.18	76.53
Finger Tapping[1]	47.07	10.74	10.00	83.53
COMPLEX MOTOR				
Grooved Pegboard[2]	48.72	10.60	10.00	86.44
Maze Test[2]	51.35	9.35	15.41	66.60
VISUAL--SPATIAL SKILLS				
WISC Block Design	55.08	9.27	30.00	80.00
WISC Object Assembly	57.26	9.62	33.33	83.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	49.23	8.82	10.00	69.50
Category Test (Total error score)	50.49	8.64	10.00	72.76

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Figure 42. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Profile 1 (n=554) with TRIM=9, K=8.

a relative 'drop' in the pseudo T statistic at the 12 and seven-cluster levels; however, there was very poor agreement between the four cluster methods at these points. There is a slight 'rise' in the pseudo F coefficient corresponding to a relatively large drop in the pseudo T coefficient at 5 clusters. At this point, however, there was limited cross-method agreement and these possible solutions were not considered further. Plots of the flexible-beta, complete linkage and average linkage cluster methods are displayed in Figures 43 to 45.

Inspection of these graphs revealed several other possible cluster solutions for Profile 1 with respect to the 12 neuropsychological variables. For example, in Figure 43 (flexible-beta method) there is a small drop in the pseudo T coefficient at the thirteen-cluster level and a relatively large drop at the ten-cluster level. Neither of these possible solutions generated an acceptable level of cross-method agreement and thus were not considered further. In Figure 44 (complete linkage) and Figure 45 (average linkage) there appears to be drops in the pseudo T statistic corresponding to increases in the pseudo F statistic, indicating the possibility of a six-cluster solution. The cross-method agreement at the six-cluster level was very limited and it was not considered further as a possible solution. A possible four-cluster solution, indicated by a

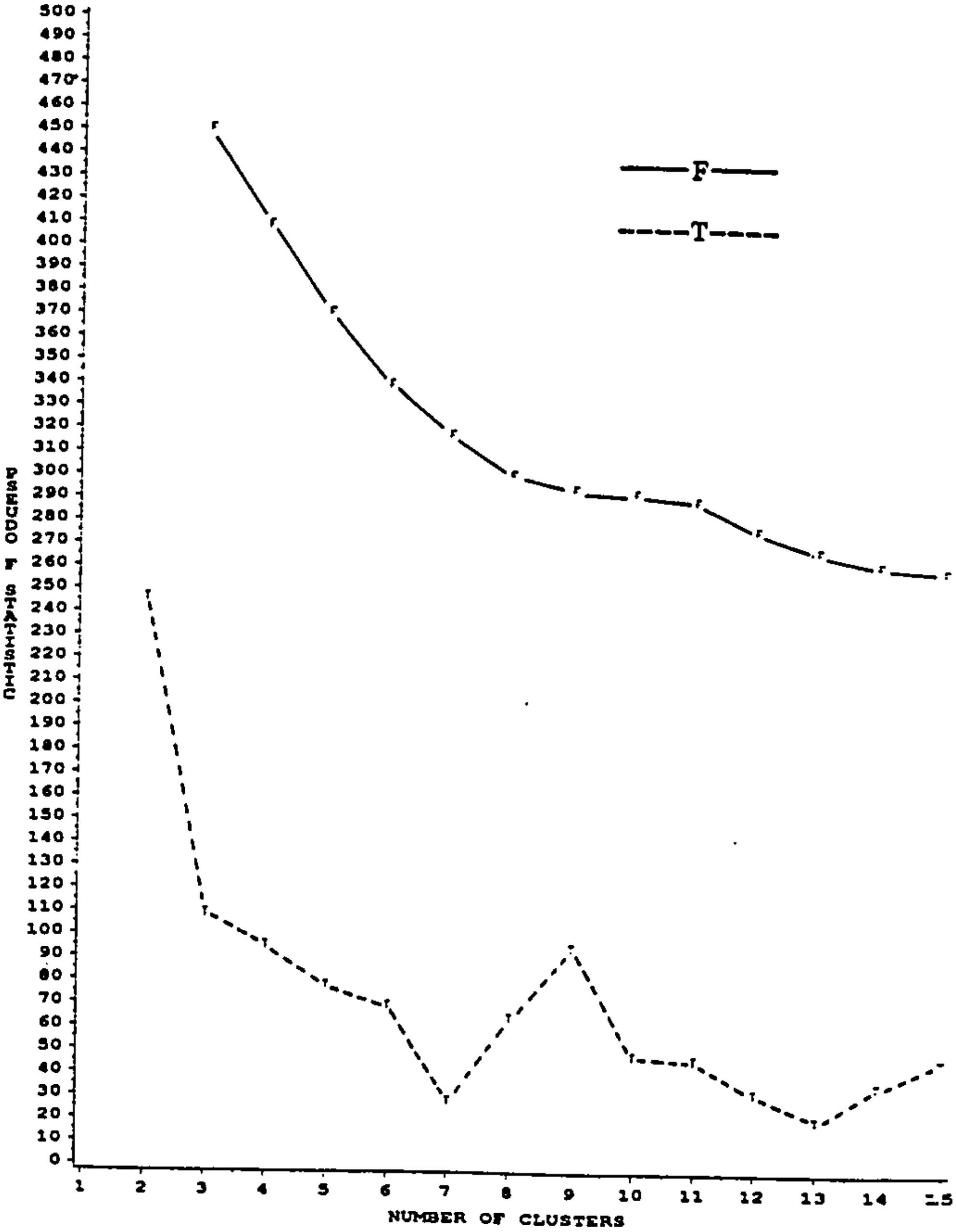


Figure 43. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Profile 1 (n=554) with TRIM=9, K=8.

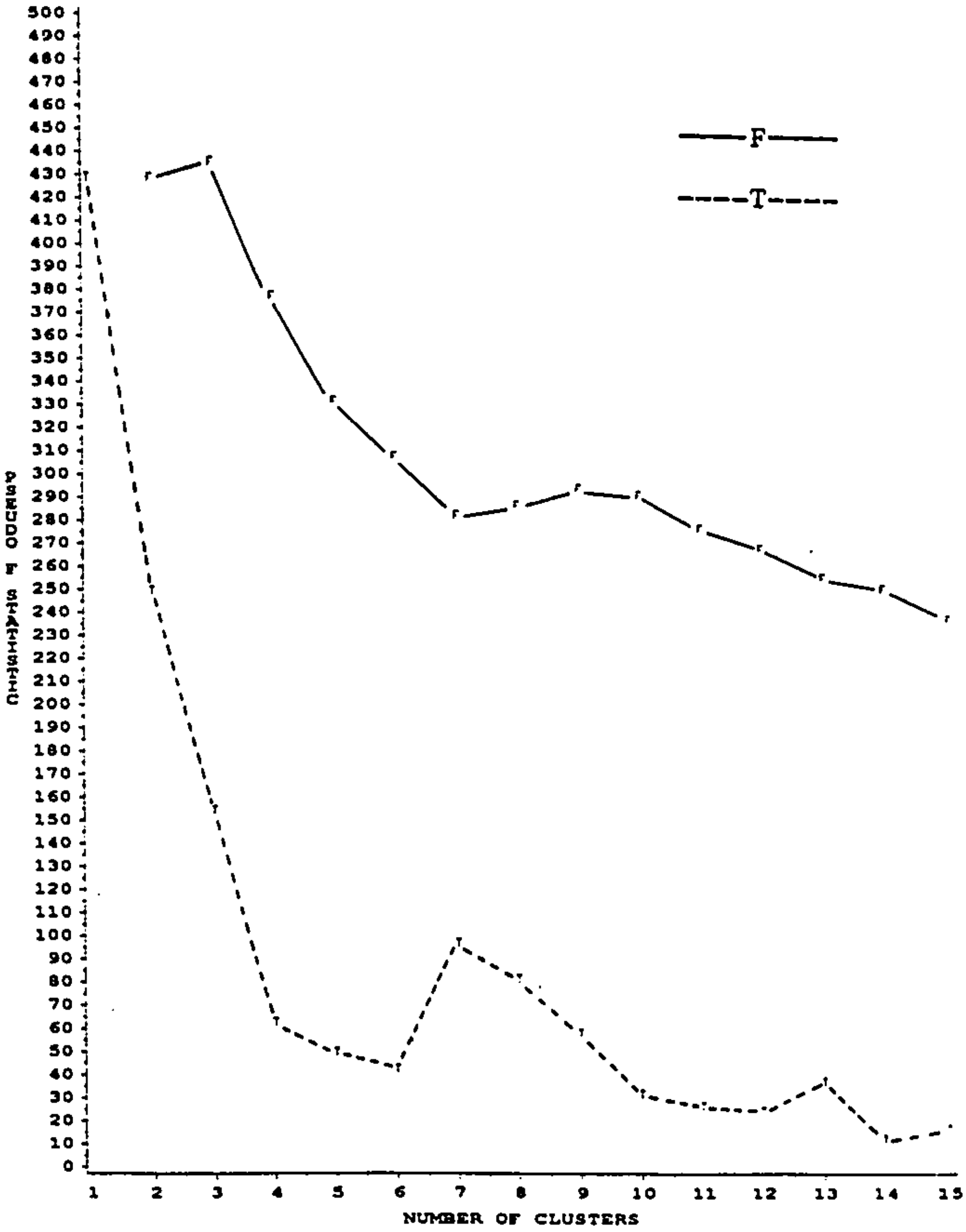


Figure 44. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Profile 1 (n=554) with TRIM=9, K=8.

Figure 45. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Profile 1 (n=554) with TRIM=9, K=8.

'rise' in the pseudo F coefficient in Figures 43 to 45, and by a relative 'drop' in the pseudo T coefficient in Figure 44, was also rejected due to limited cross-method agreement. The only solution displayed in these fusion coefficient plots which produced acceptable levels of cross-method agreement is a three-cluster solution.

This three-cluster solution is suggested by the relatively large drops in the value of the pseudo T coefficient at the three-cluster level for all four cluster methods as shown in Figures 42 to 45. A three-cluster solution is also indicated by the relative 'peaks' in the pseudo F coefficient plots for the complete and average linkage methods as evident in Figures 44 and 45. Since a three-cluster solution of Profile 1 was apparent in all of the fusion coefficient plots it was considered the best choice for further investigation in the present study.

The misclassification analysis between the four cluster methods for the three-cluster solution of Profile 1 is presented in Table 37. Ward's method (TRIM=9, K=8) was employed as the target solution. A total of 50 children were removed as outliers and the remaining 504 were classified into one of three groups. These analyses in this part of Phase II were carried out with respect to both profile elevation and profile shape. The three clusters which emerged will be referred to as Neuro Group 1 (n=230), Neuro Group 2 (n=185),

Table 37

Phase II Part B:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods for Sample A PROFILE I N=554

(Neuropsychological Variables)

	Ward's Cluster Groups			
Cluster analysis method	1 (n=230)	2 (n=185)	3 (n=89)	Total (n=504)
Flexible-Beta Method	91 (40)	31 (17)	15 (17)	137 (27)
Complete Linkage	58 (25)	32 (17)	33 (37)	123 (24)
Average Linkage	198 (86)	5 (3)	89 (100)	292 (58)

and Neuro Group 3 (n=89). As shown in Table 37, there was good cross-method agreement between Ward's method and the flexible-beta and complete linkage cluster techniques. Only 27% (overall) of the children classified into Neuro Groups 1, 2, and 3 by Ward's method were misclassified by the flexible-beta technique. Only 24% (overall) of the children were misclassified by the complete linkage cluster method, while an unacceptably high misclassification rate of 50 percent occurred between Ward's method and the average linkage technique. With respect to the individual clusters which emerged from this analysis, it is clear in Table 37 that all three subtypes were reproduced within the acceptable misclassification rate (30% or less) between Ward's method and the flexible-beta and complete linkage cluster algorithms. The misclassification analysis for the split-sample replication attempt of this three-cluster solution will be presented next.

An internal validation sample (N=277) was randomly selected to consist of 50% of the subjects in Profile 1. This split-sample was then clustered with the four cluster methods into three subtypes. In order to remove the outliers an identical TRIM=9 value was employed to discard 9% of the most extreme subjects prior to the cluster analysis. However, following the suggestion of Wong (1982), for this smaller sample size (N=277) the K parameter was assigned a value K=6.

The misclassification analysis for this split-sample replication attempt is shown in Table 38. With respect to overall percentages of misclassified subjects, it is clear that the three clusters identified by Ward's method were accurately recovered only by the flexible-beta technique. Although the overall misclassification rates for the complete and average linkage methods were unacceptably high (38% and 37%, respectively) some of the individual clusters appear to be recovered by these techniques. For example, as shown in Table 38, clusters 2 and 3 were adequately recovered by complete linkage with misclassification rates of 28% and 19%, respectively. It is also apparent that clusters 1 and 3 were well recovered by the average linkage technique with misclassification rates of 3% and 0%, respectively.

The profiles of Neuro Group 1 (n=230), Group 2 (n=185), and Group 3 (n=89) are displayed in Figure 46. These profiles appear to differ primarily in terms of elevation with Neuro Group 3 evidencing an outstanding deficit on one of the neuropsychological variables (i.e., Sentence Memory Task). The profiles of the split-sample replication attempt (N=277) are presented in Figure 47. The general similarities of these profiles with respect to the cluster profiles in Figure 46 is obvious. The split-sample profiles appear to differ primarily with respect to elevation and cluster 3 again

Table 38

Phase II Part B:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods for the Sample A PROFILE I Split-sample Replication

(Internal Validation Sample N=277)
(Neuropsychological Variables)

	Ward's Cluster Groups			
Cluster analysis method	1 (n=106)	2 (n=99)	3 (n=47)	Total (n=252)
Flexible-Beta Method	10 (9)	39 (39)	13 (28)	62 (25)
Complete Linkage	60 (57)	28 (28)	9 (19)	97 (38)
Average Linkage	3 (3)	89 (90)	0 (0)	92 (37)

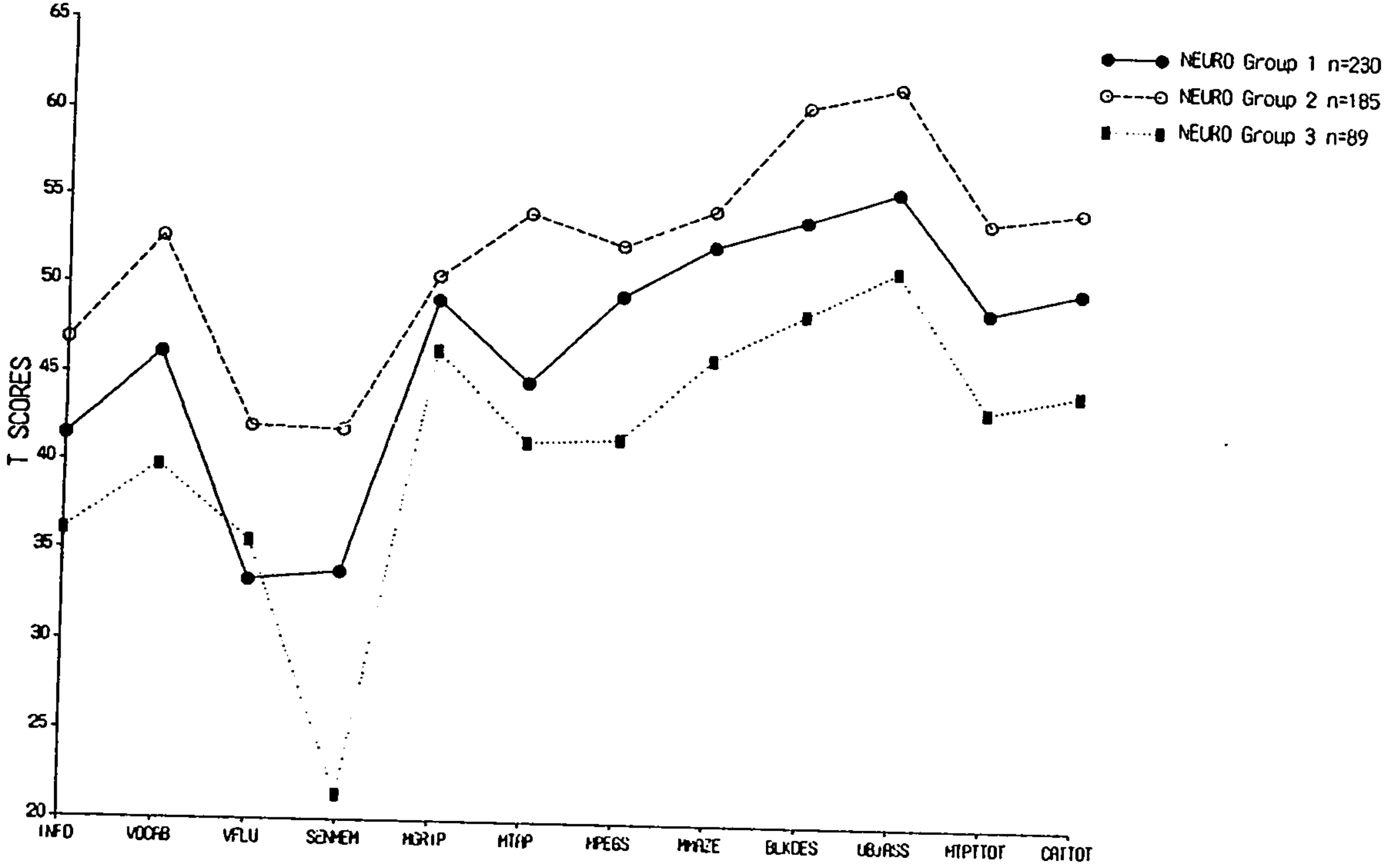


Figure 46. Plot of the three subtypes (NEURO Groups 1, 2, and 3) which emerged from Ward's cluster analysis of Profile 1 (n=554).

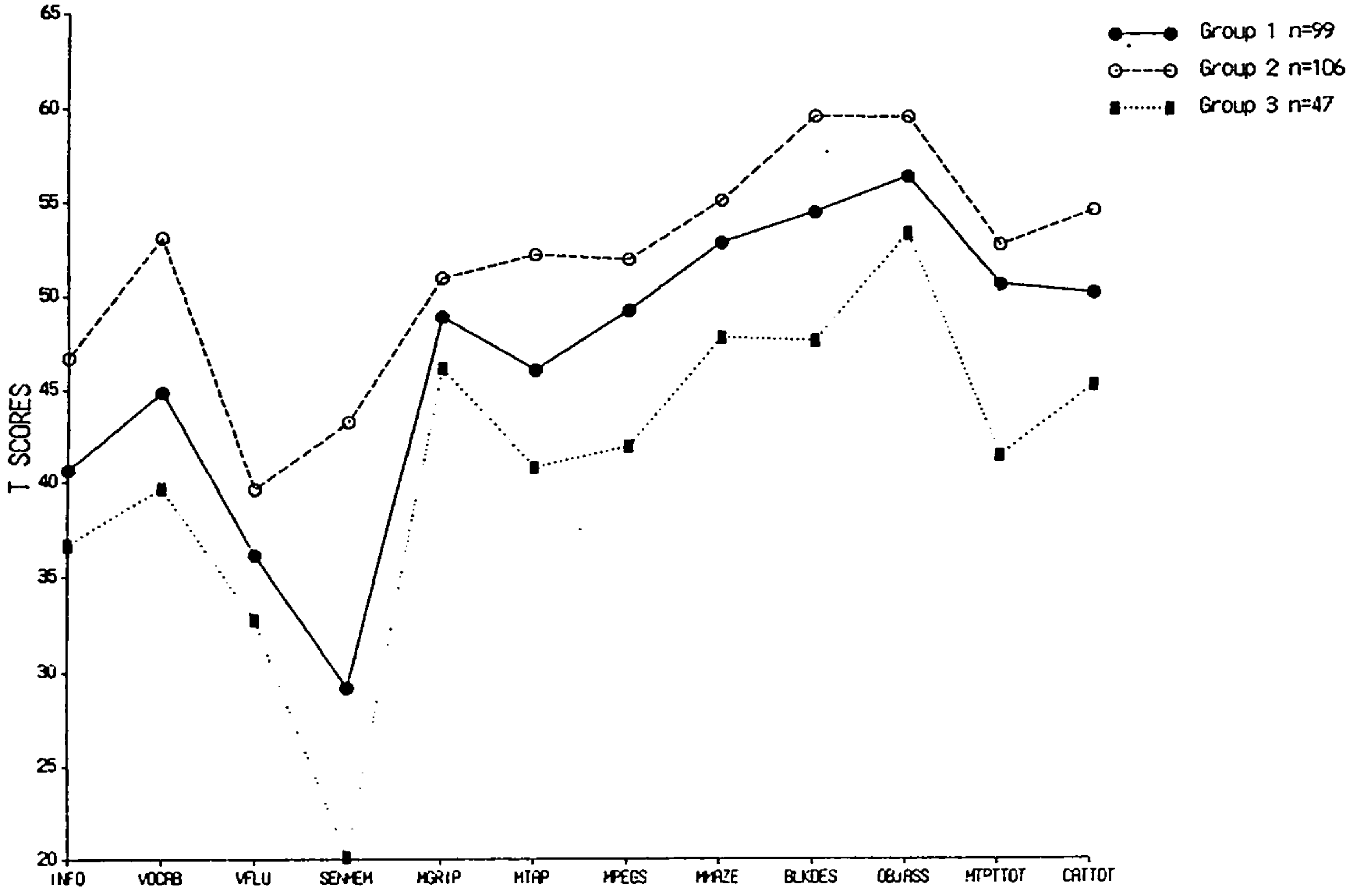


Figure 47. Plot of Ward's three cluster solution for internal validation sample N=277.

shows a severely impaired performance on the Sentence Memory Task. Cluster 2 in Figure 47 does show a drop on the Sentence Memory Task more severe than that found in the Neuro Group 2 profile on this variable, but this discrepancy was not considered significant for the purposes of the present study.

In summary, the cluster analysis of Profile 1 (n=554) generated a three-cluster solution consisting of Neuro Group 1 (n=230), Neuro Group 2 (n=185), and Neuro Group 3 (n=89). There were 50 outliers removed statistically (TRIM=9, K=8) prior to the cluster analysis. This three-cluster solution was considered replicated with a randomly chosen internal validation sample (n=277). In the next section, the cluster analysis of Ward's Profile 2 derived from Sample A is described.

Part B: Cluster Analysis of Profile 2 (n=280)

The raw scores for all 12 neuropsychological variables for Profile 2 were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The T-score means, standard deviations, and maximum and minimum values for the Profile 2 (n=280) neuropsychological variables are presented in Table 39.

The plots of the pseudo F and T cluster fusion coefficients for Ward's method are displayed in Figure 48. There appears to be a large 'drop' in the pseudo T

Table 39

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for PROFILE II (N=280)

	Mean (n=280)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	42.22	10.14	23.33	60.00
WISC Vocabulary	46.30	8.57	36.67	63.33
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	44.71	12.04	27.82	67.86
Sentence Memory	32.71	9.46	20.43	47.39
SIMPLE MOTOR SKILLS				
Grip Strength[1]	45.49	5.15	39.23	51.62
Finger Tapping[1]	48.92	10.56	33.03	61.03
COMPLEX MOTOR				
Grooved Pegboard[2]	34.45	13.65	10.00	54.00
Maze Test[2]	53.16	9.75	32.47	62.03
VISUAL-SPATIAL SKILLS				
WISC Block Design	42.22	8.33	26.67	53.33
WISC Object Assembly	44.07	8.78	30.00	56.67
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	38.23	13.37	18.98	56.51
Category Test (Total error score)	36.73	6.99	27.31	48.09

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

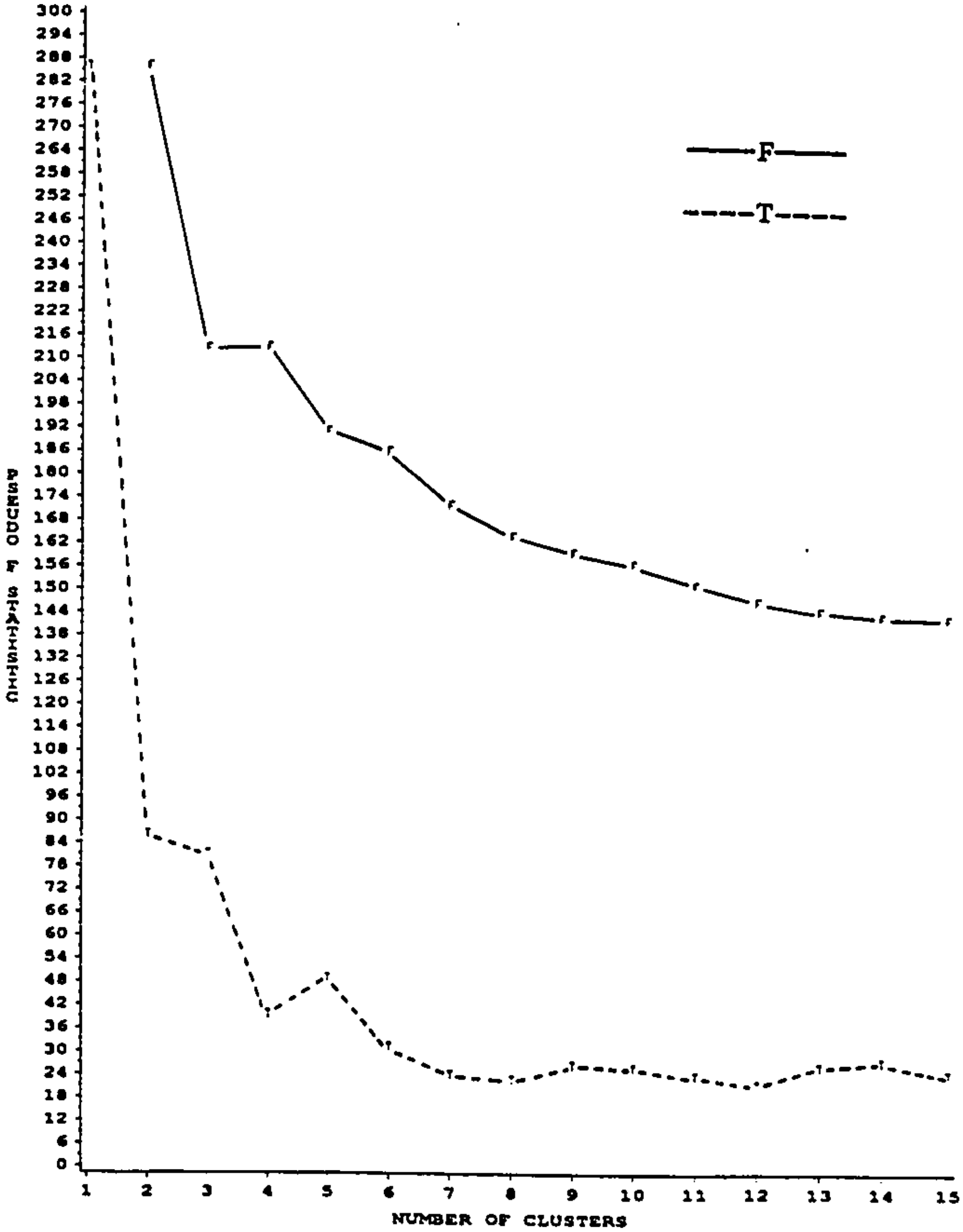


Figure 48. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Profile 2 (n=280) with TRIM=8, K=6.

coefficient corresponding to a large 'rise' in the pseudo F coefficient at the two-cluster level; however, there was limited agreement between the four cluster methods at this point. The possibility of a four-cluster or six-cluster solution was suggested by a rise in pseudo F and corresponding drop in pseudo T at these cluster levels as shown in Figure 48. However, poor cross-method agreement was the case at these cluster levels, and these possible solutions were not considered further.

Plots of the cluster fusion coefficients for the flexible-beta, complete and average linkage cluster methods are displayed in Figures 49 to 51. Inspection of these graphs suggested several other possible cluster solutions for Profile 2 with respect to the 12 neuropsychological variables. For example, there is a drop in the pseudo T coefficient at the 13, 11, 8, and 7 cluster levels for the complete linkage method as shown in Figure 50. Corresponding to these pseudo T 'drops' in Figure 50 were slight rises in the pseudo F coefficient; however, none of these possible solutions generated acceptable levels of agreement between the four cluster methods. In Figure 51 (average linkage) there are rises in the pseudo F coefficient at the 5 and 9 cluster levels which corresponded to drops in the pseudo T coefficient at these points. Neither of these possible solutions were considered further due to limited agreement

Figure 49. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Profile 2 (n=280) with TRIM=8, K=6.

Figure 50. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Profile 2 (n=280) with TRIM=8, K=6.

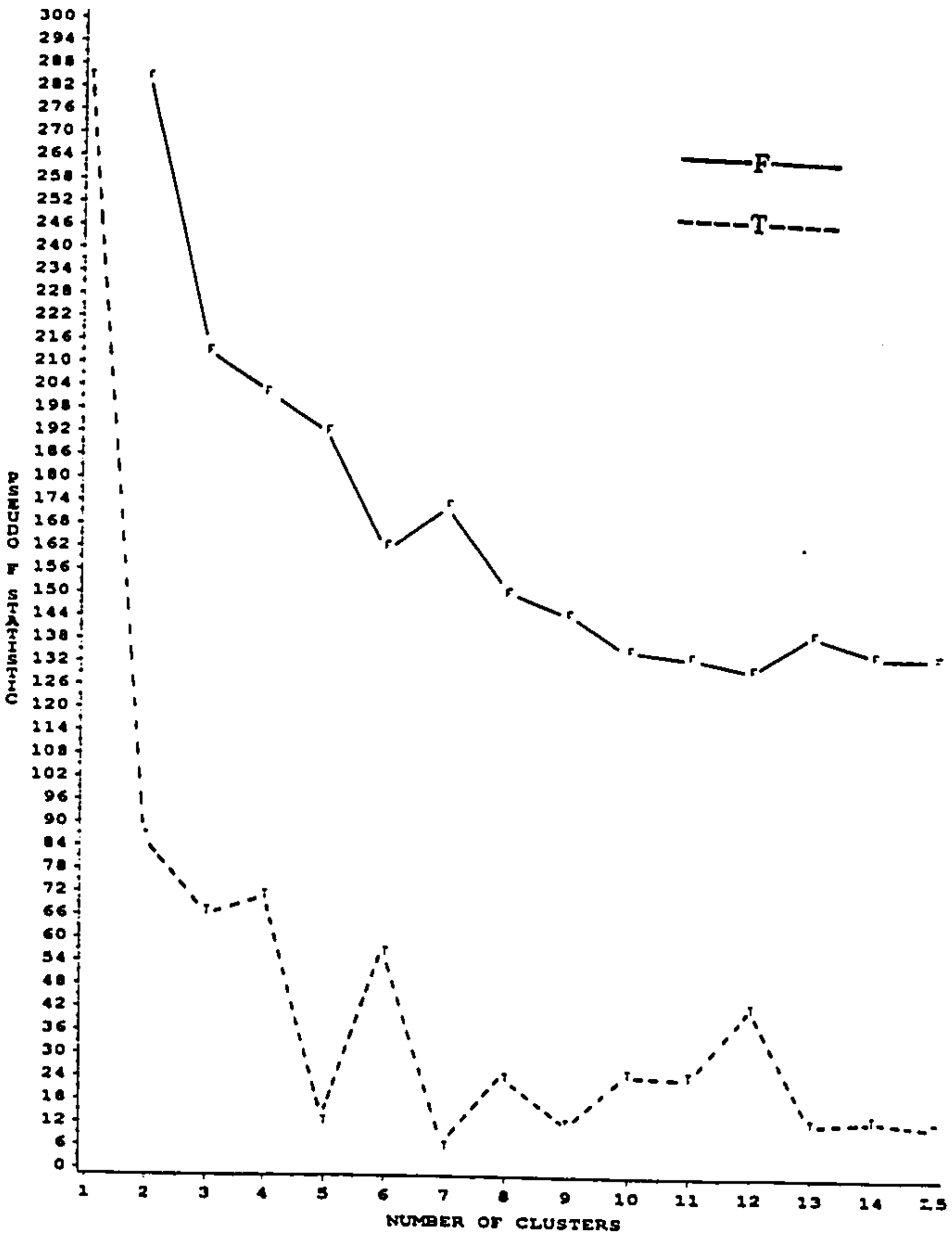


Figure 51. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Profile 2 (n=280) with TRIM=8, K=6.

(i.e., misclassification of subjects) between the four cluster methods.

Although a three-cluster solution is not readily visible in Figure 48 (Ward's method) this possibility is apparent in Figure 50 and 51 (complete and average linkage techniques) and in the rise in the pseudo F coefficient shown in Figure 49 (flexible-beta method). The cross-method agreement for this solution was within acceptable limits (see below) and since the three-cluster solution of Profile 2 was apparent in most of the fusion coefficient plots it was considered the best choice for further consideration in the present study.

The misclassification analysis between the four cluster methods for the three-cluster solution of Profile 2 is presented in Table 40. Ward's method (TRIM=8, K=6) was employed as the target solution. A total of 23 children were removed as outliers and the remaining 257 were classified into one of three subtypes. As mentioned previously, these Phase II cluster analyses were carried out with respect to both profile elevation and shape. The three clusters which emerged are referred to as Neuro Group 4 (n=111), Neuro Group 5 (n=51), and Neuro Group 6 (n=95). As shown in Table 40 there was good cross-method agreement between Ward's method and the flexible-beta technique. Only 18% (overall) of the children classified into Neuro Groups 4, 5, and 6 by

Table 40

Phase II Part B:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods for Sample A PROFILE II N=280

(Neuropsychological Variables)

	Ward's Cluster Groups			
Cluster analysis method	1 (n=111)	2 (n=51)	3 (n=95)	Total (n=257)
Flexible-Beta Method	35 (32)	7 (14)	4 (4)	46 (18)
Complete Linkage	45 (41)	2 (4)	35 (37)	82 (32)
Average Linkage	0 (0)	47 (92)	39 (41)	86 (33)

Ward's method were misclassified by the flexible-beta technique. Comparison of the assignment of children to subtypes between Ward's method, complete and average linkage techniques produced (overall) unacceptably high misclassification rates of 32 and 33 percent. With respect to the individual clusters which emerged from this analysis it appears that all three subtypes were recovered within an acceptable misclassification rate (30% or less) across the four clustering methods. Although the average linkage method was poor at recovering Neuro Groups 5 and 6, it successfully recovered all 111 children originally assigned to Ward's Neuro Group 4. The misclassification analysis for the split-sample replication attempt of this three-cluster solution will be presented next.

An internal validation sample (N=140) was randomly selected to consist of 50% of the subjects in Profile 2. This split-sample was then clustered with the four cluster methods into three subtypes. In order to remove the outliers an identical TRIM=8 value was employed to discard 8% of the most extreme subjects prior to the cluster analysis. Following the recommendation of Wong (1982), for this smaller sample size (N=140) the K parameter was assigned a value K=5.

The misclassification analysis for this split-sample replication attempt is shown in Table 41. With respect to

Table 41

Phase II Part B:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods for the Sample A PROFILE II Split-sample Replication

(Internal Validation Sample N=140)
(Neuropsychological Variables)

	Ward's Cluster Groups			
Cluster analysis method	1 (n=43)	2 (n=27)	3 (n=58)	Total (n=128)
Flexible-Beta Method	0 (0)	3 (11)	2 (3)	5 (4)
Complete Linkage	13 (30)	7 (26)	29 (50)	49 (38)
Average Linkage	22 (51)	21 (78)	0 (0)	43 (35)

the overall percentages it is apparent that the three clusters which emerged from Ward's method were accurately recovered only by the flexible-beta technique. With respect to recovery of individual clusters, complete linkage reproduced subtype 2 (26% misclassified) within acceptable limits, while average linkage recovered subtype 3 without misclassifying any of these subjects.

The profiles of Neuro Group 4 (n=111), Group 5 (n=51), and Group 6 (n=95) are displayed in Figure 52. Neuro Groups 4 and 6 show deficits on both measures of complex language (i.e., Verbal Fluency and Sentence Memory). Neuro Group 5 also evidences below-average performances on the Grooved Pegboard and the mean TPT total time score. Neuro Group 5 exhibits difficulties on the Sentence Memory task and above-average performances on Finger Tapping and the Maze Test. The profiles of the split-sample (N=140) replication attempt are presented in Figure 53. The subtype 3 which emerged from this analysis appears to be very similar to Neuro Group 6 (see Figure 52) with respect to both profile shape and elevation. The subtype 1 in Figure 53 appears very similar to Neuro Group 4, with a deficient performance on the mean total TPT score being the only major discrepancy. The subtype 2 in Figure 53 was thought to be most similar to Neuro Group 5 (see Figure 52). However, the Finger Tapping performance was not as elevated

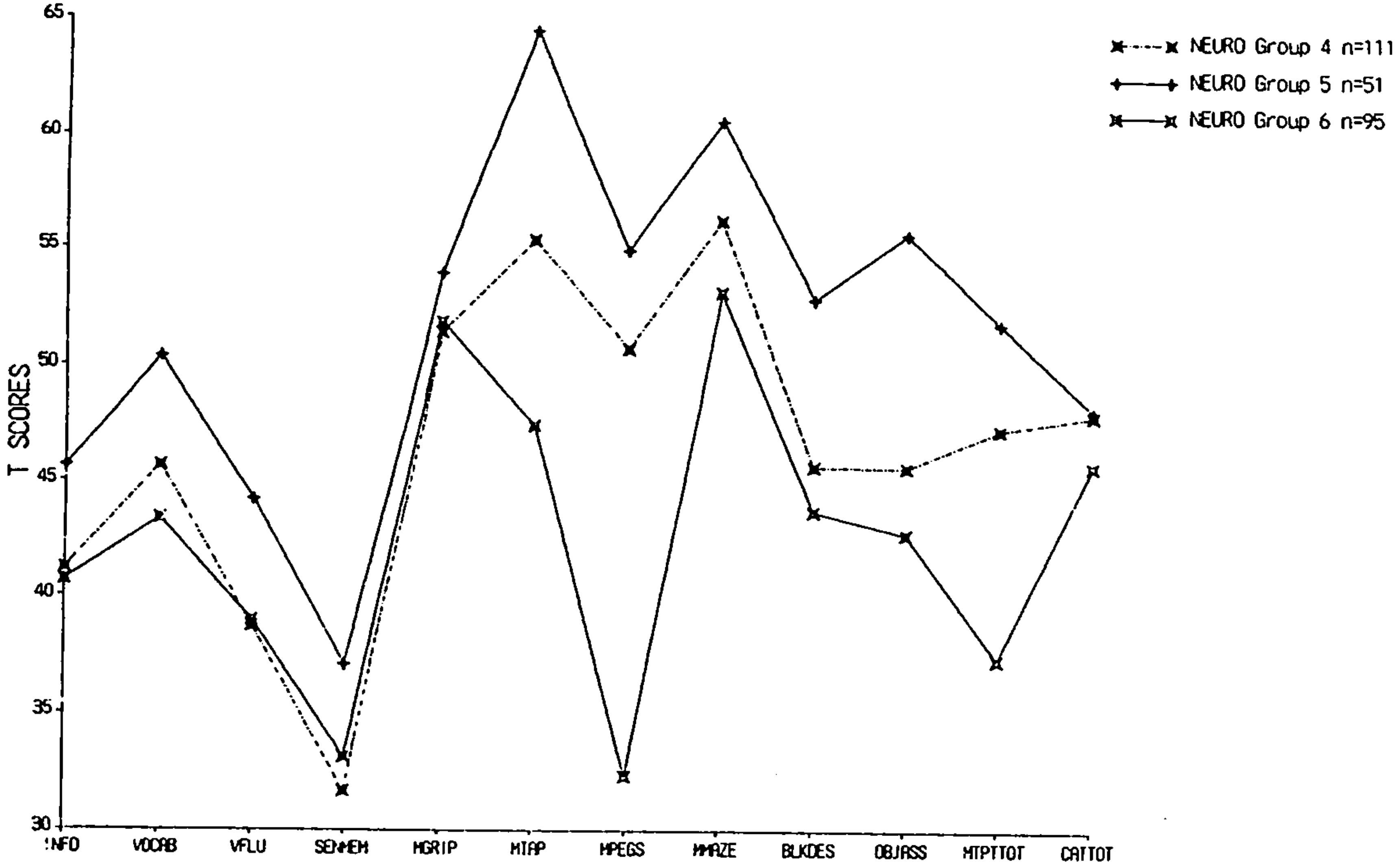


Figure 52. Plot of the three subtypes (NEURO Groups 4, 5, and 6) which emerged from Ward's cluster analysis of Profile 2 (n=280).

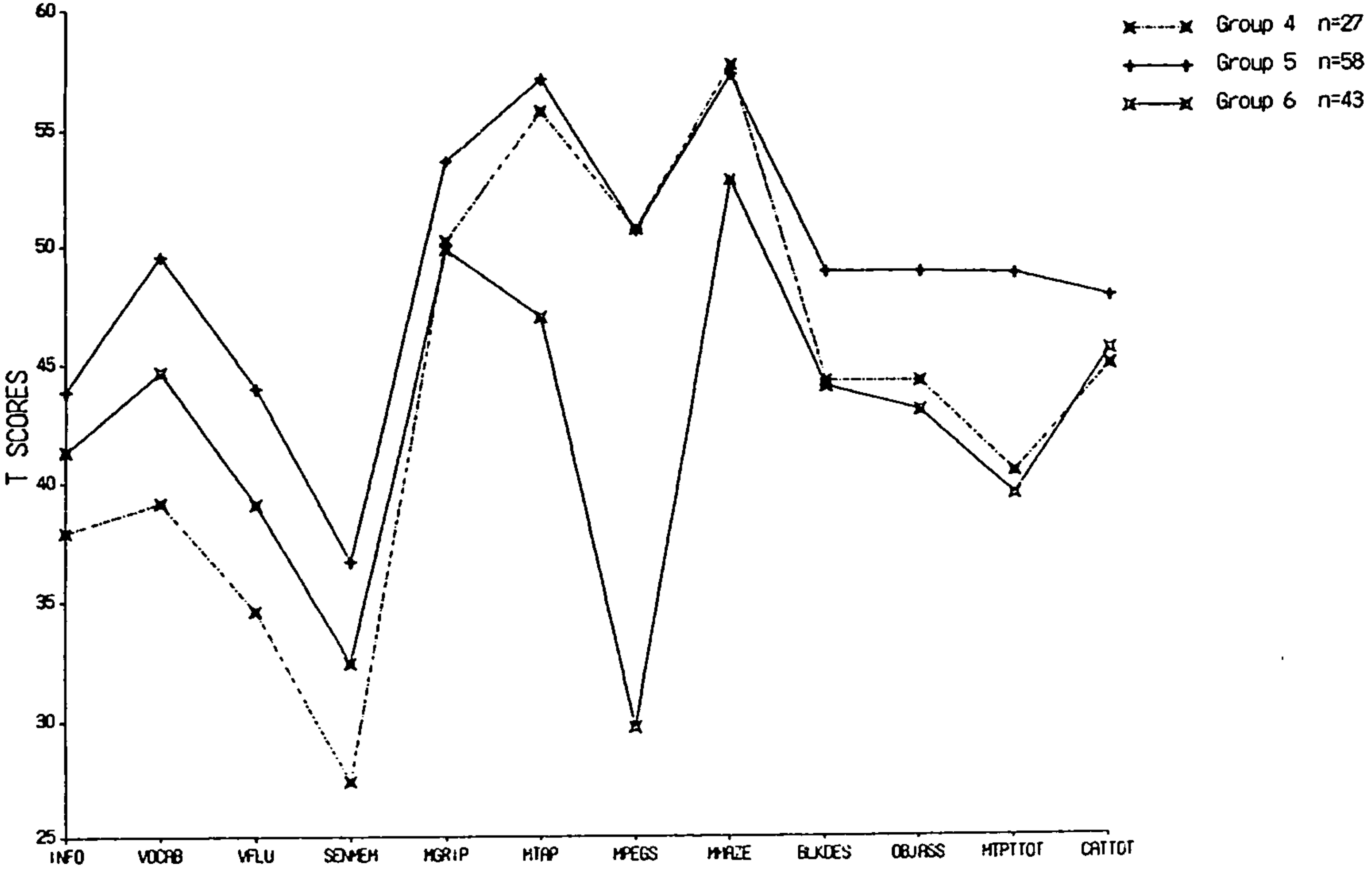


Figure 53. Plot of Ward's three cluster solution for internal validation sample N=140.

and the profile shape for the "visual-spatial" and "higher order" measures was 'smoother' than for the Neuro Group 5 profile. These differences were not considered of major significance and the cluster analysis of Profile 2 was thought to be successfully replicated with the split-sample (N=140).

Part B: Cluster Analysis of Profile 3 (n=318)

The raw scores for all 12 neuropsychological variables for Profile 3 were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The T-score means, standard deviations, and maximum and minimum values for the Profile 3 (n=318) neuropsychological variables are presented in Table 42.

The plots of the pseudo F and T coefficients for Ward's method are displayed in Figure 54. There are 'drops' in the pseudo T fusion coefficient plot at the 2, 4, 5, 7, 10 and 11 cluster levels. Elevations in the pseudo F coefficient occur at the 2 and 4 cluster levels. These possible cluster solutions were investigated and discarded due to poor agreement between the four cluster methods (i.e., a high percentage of misclassified subjects). Plots of the fusion coefficients for the flexible-beta, complete linkage and average linkage cluster methods are displayed in Figures 55 to 57.

Table 42

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for PROFILE III (N=318)

	Mean (n=318)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	42.88	7.92	26.67	70.00
WISC Vocabulary	47.56	8.17	26.67	70.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	38.87	10.27	14.00	70.68
Sentence Memory	34.20	11.99	10.00	63.91
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.13	8.04	25.50	81.46
Finger Tapping[1]	45.58	12.57	10.00	81.82
COMPLEX MOTOR				
Grooved Pegboard[2]	32.92	13.82	10.00	68.40
Maze Test[2]	26.93	11.98	10.00	56.78
VISUAL-SPATIAL SKILLS				
WISC Block Design	46.11	9.55	20.00	73.33
WISC Object Assembly	47.23	10.62	16.67	73.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	44.19	11.53	10.03	64.99
Category Test (Total error score)	46.74	9.88	10.00	67.44

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

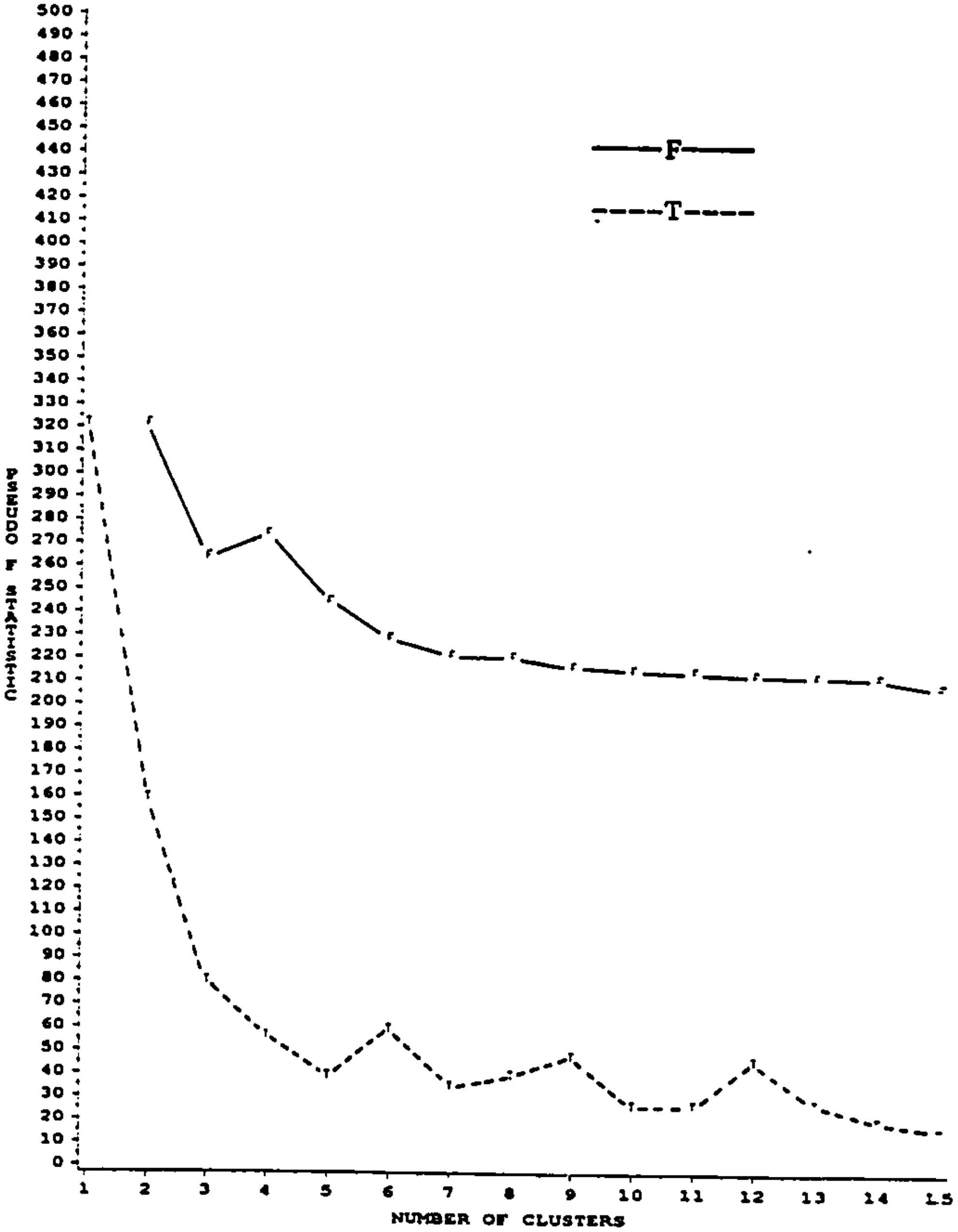


Figure 54. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Profile 3 (n=318) with TRIM=4, K=7.

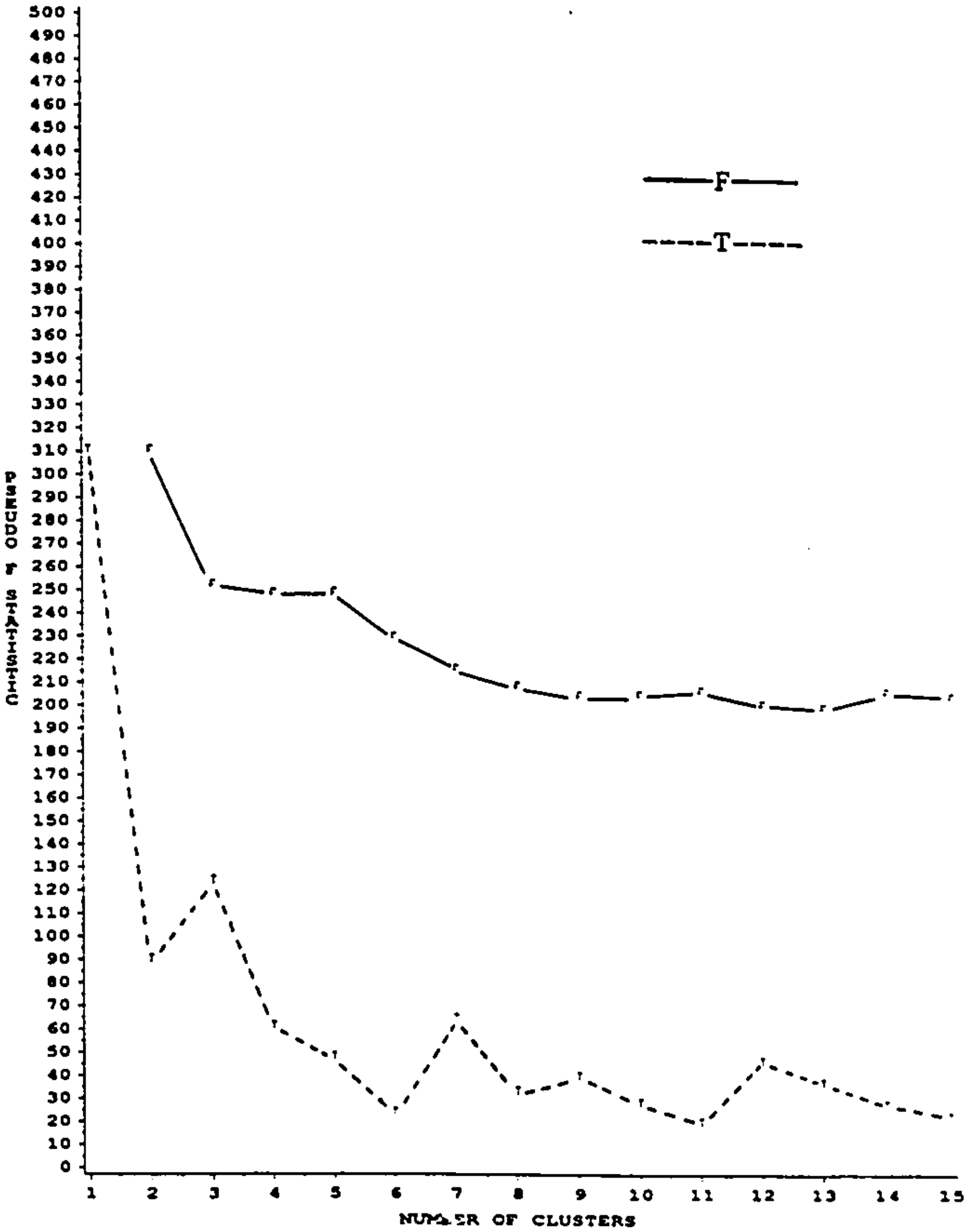


Figure 55. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Profile 3 (n=318) with TRIM=4, K=7.

Figure 56. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Profile 3 (n=318) with TRIM=4, K=7.

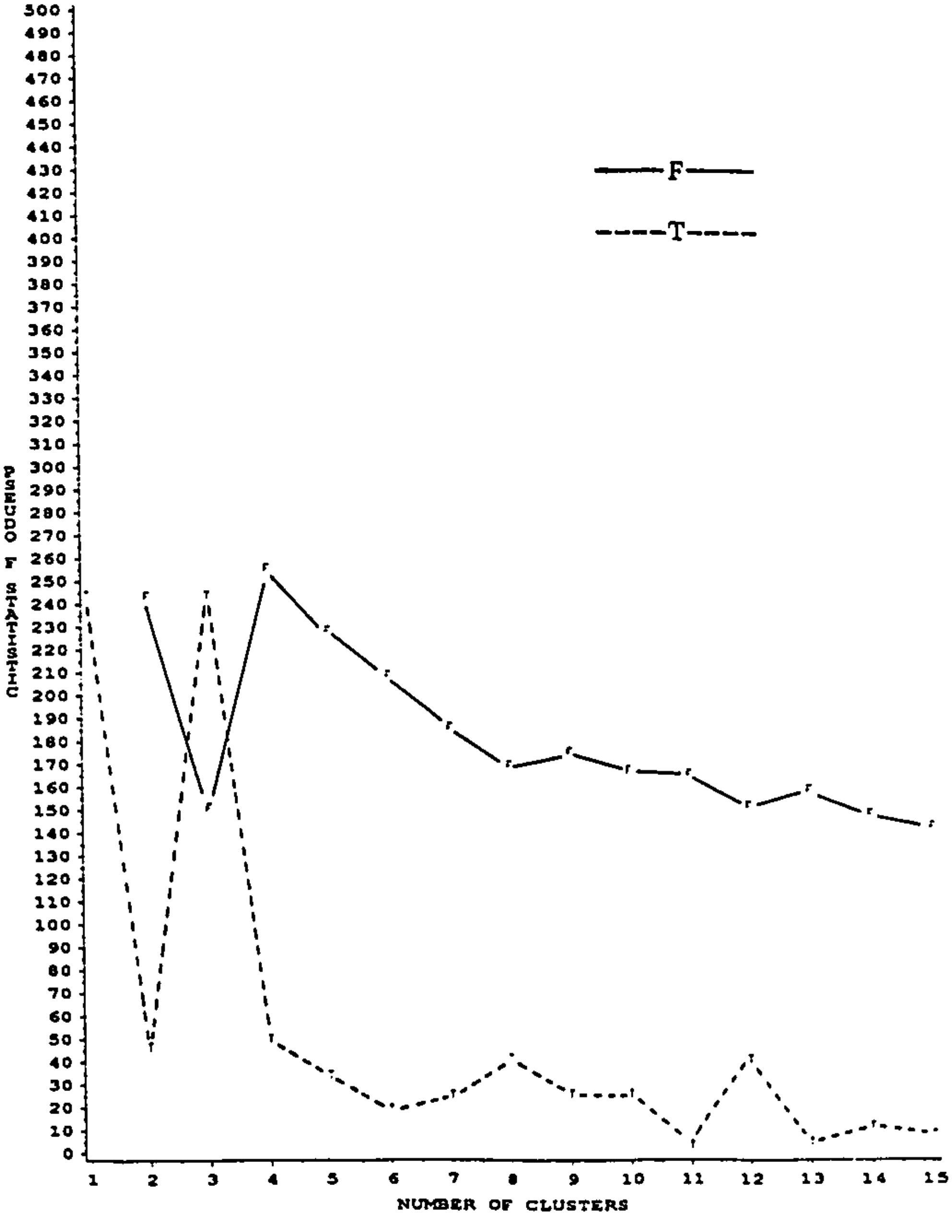


Figure 57. Phase II Part B: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Profile 3 (n=318) with TRIM=4, K=7.

Inspection of these graphs revealed that other cluster solutions for Profile 3 were possible. For example, a six-cluster solution is suggested by drops in pseudo T and by elevations in pseudo F (Figures 55 and 57). A drop in pseudo T at the eight-cluster level (Figure 55) was also considered as a possible solution. Apparent in Figure 56, a drop in the pseudo T coefficient corresponding to a rise in pseudo F at the seven-cluster level suggested yet another possible solution. As seen in Figure 57, a slight rise in the pseudo F coefficient corresponding to a drop in pseudo T at the nine-cluster level was also considered. However, none of the above mentioned possible solution points generated an acceptable level of cross-method agreement between the four cluster methods and were not examined further.

Although a three-cluster solution is not readily visible in Figures 55 and 57 (flexible-beta and average linkage methods), this possibility is apparent in Figure 56 (complete linkage technique) and in the drop in the pseudo T coefficient shown in Figure 54 (Ward's method). The cross-method agreement for this solution was within acceptable limits (see below) and since the three cluster solution of Profile 3 was apparent in two of the fusion coefficient plots it was considered the best choice for further consideration in the present study.

The misclassification analysis between the four cluster methods for the three-cluster solution of Profile 3 is presented in Table 43. Ward's method (TRIM=4, K=7) was employed as the target solution. A total of 13 children were removed as outliers and the remaining 305 were classified into one of three subtypes. These analyses in this part of Phase II were carried out with respect to both profile elevation and profile shape. The three clusters which emerged are referred to as Neuro Group 7 (n=107), Neuro Group 8 (n=170), and Neuro Group 9 (n=28).

As shown in Table 43 there was very good cross-method agreement between Ward's method and the flexible-beta and average linkage techniques. These two cluster methods misclassified only 7% (flexible-beta) and 9% (average linkage) of the children in Neuro Groups 7, 8, and 9 which were identified by Ward's cluster algorithm. An unacceptably high misclassification rate occured between Ward's method and complete linkage (i.e., 32%). With respect to the individual clusters that emerged from this analysis it is clear in Table 43 that all three subtypes were reproduced well within the acceptable misclassification rate (30% or less) between Ward's method, the flexible-beta, and average linkage techniques. The misclassification analysis for the split-sample replication attempt of this three-cluster solution is presented next.

An internal validation sample (N=160) was randomly

Table 43

Phase II Part B:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods for Sample A PROFILE III N=318

(Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=107)	 2 (n=170)	 3 (n=28)	Total (n=305)
Flexible-Beta Method	5 (5)	15 (9)	0 (0)	20 (7)
Complete Linkage	25 (41)	19 (4)	7 (37)	51 (32)
Average Linkage	6 (6)	18 (11)	0 (0)	24 (9)

selected to consist of approximately 50% of the subjects in Profile 3. This split-sample was then clustered with the four cluster algorithms into three subtypes. In order to remove the outliers an identical TRIM=4 value was employed to discard 4% of the most extreme subjects prior to the cluster analysis. Following the recommendation of Wong (1982), for this smaller sample size (N=160) the K parameter was assigned a value K=5.

The misclassification analysis for this split-sample replication attempt is shown in Table 44. With respect to overall percentages of misclassified subjects it is apparent that the three subtypes identified by Ward's method were recovered by the flexible-beta (16% misclassified) and complete linkage (24% misclassified) techniques. However, as regards the recovery of the individual clusters, complete linkage accurately reproduced only subtype 2 (6% misclassiifed). Average linkage successfully recovered subtype 1 (0% misclassified), while the flexible-beta technique recovered all three of the subtypes.

The profiles of Neuro Group 7 (n=107), Group 8 (n=170), and Group 9 (n=28) are displayed in Figure 58. These profiles appear to differ primarily in terms of profile elevation, with Neuro Group 9 (n=28) exhibiting outstanding deficits on the complex motor measures, and below-average performances on a majority of the neuropsychological

Table 44

Phase II Part B:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods for the Sample A PROFILE III Split-sample Replication

(Internal Validation Sample N=160)
(Neuropsychological Variables)

	Ward's Cluster Groups			
Cluster analysis method	1 (n=48)	2 (n=82)	3 (n=23)	Total (n=153)
Flexible-Beta Method	1 (2)	23 (28)	0 (0)	24 (16)
Complete Linkage	17 (35)	5 (6)	14 (61)	36 (24)
Average Linkage	0 (0)	80 (98)	11 (48)	91 (59)

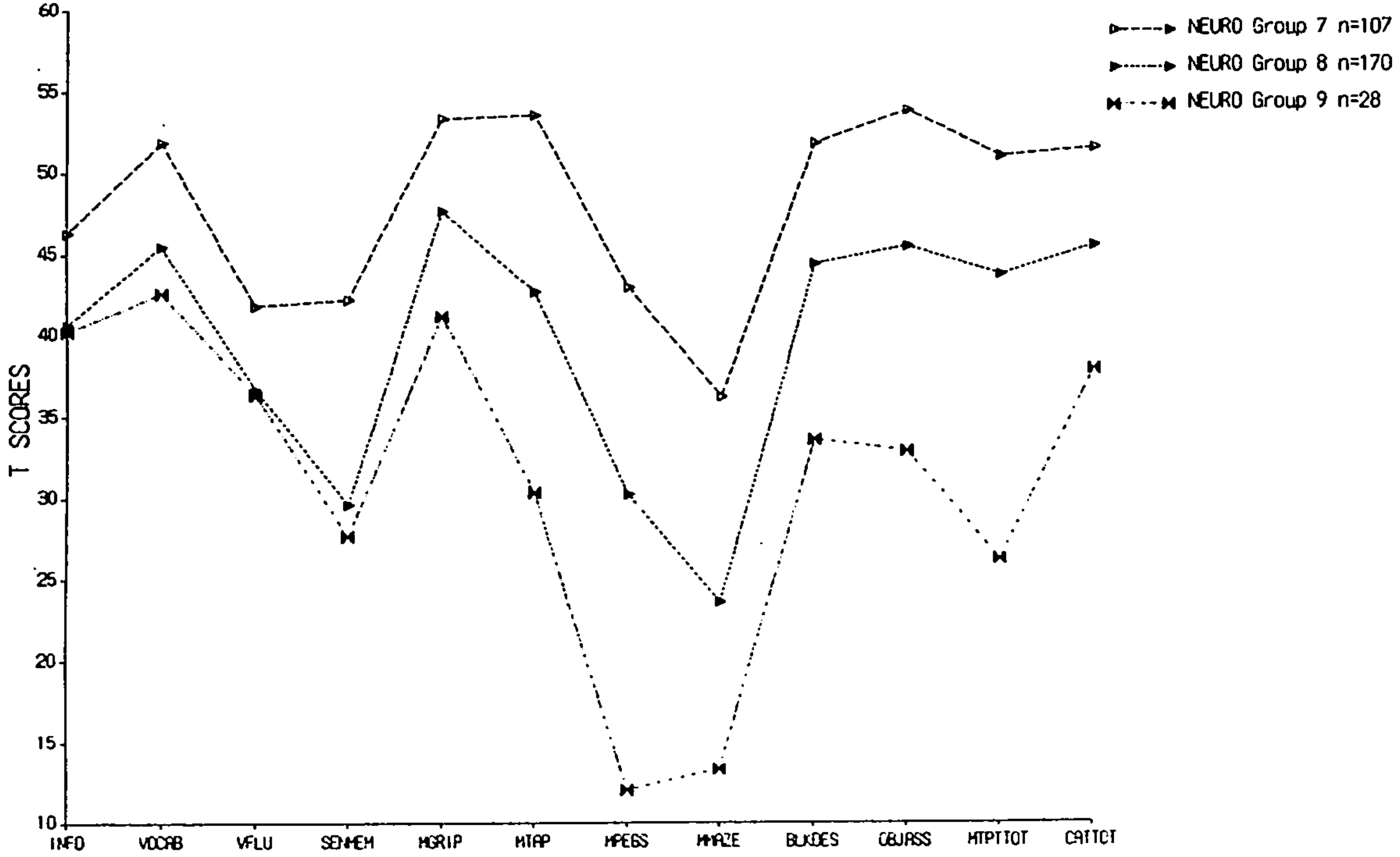


Figure 58. Plot of the three subtypes (NEURO Groups 7, 8, and 9) which emerged from Ward's cluster analysis of Profile 3 (n=318).

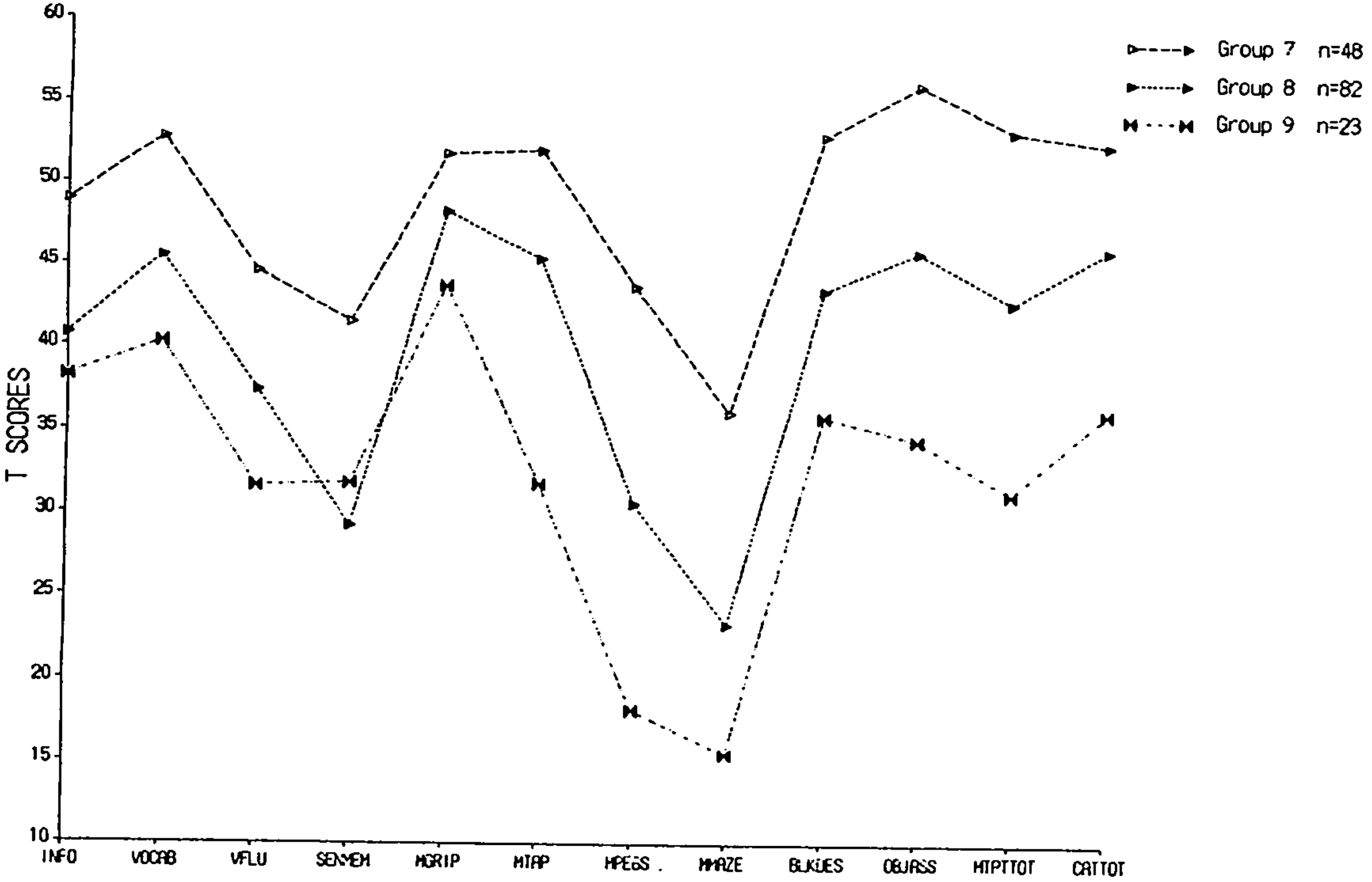


Figure 59. Plot of Ward's three cluster solution for internal validation sample N=160.

variables. Neuro Group 7 evidenced a below-average performance on the Maze Test, while Neuro Group 8 exhibited deficient performances on measures of complex language and complex motor skills. The profiles of the split-sample replication attempt (N=160) are shown in Figure 59. The similarity of the profiles in Figures 58 and 59 are obvious. Only sight differences in the elevation of the split-sample subtype 3 for the complex verbal measures (Figure 59) were apparent when compared to Neuro Group 9 (Figure 58).

The results of the Phase II analyses can be summarized as follows: (1) in Part A, the Sample A (n=1200) subjects were classified into three profile shapes (Profiles 1, 2, and 3) by eliminating the effect of profile elevation, and using the 12 neuropsychological measures as clustering variables; (2) this three profile solution in Part A was replicated with two subsets of the data (N=800 and N=600); (3) in Part B, Profiles 1, 2, and 3 were again clustered on the 12 neuropsychological variables with respect to both profile shape and elevation; (4) three clusters emerged from each of Profiles 1, 2, and 3; (5) each of these solutions was replicated (i.e., with a split-sample consisting of 50% of the original profile. These analyses resulted in nine subtypes referred to as Neuro Group 1 (n=230), Group 2 (n=185), Group 3 (n=89), Group 4 (n=111), Group 5 (n=51), Group 6 (n=95), Group 7 (n=107), Group 8 (n=170), and Group 9 (n=28). All nine of these Neuro Groups are displayed together in Figure 60.

In the next sections, these nine subtypes are examined as follows: (1) their performances on the 12 neuropsychological variables are presented in tabular form; (2) then their performances on the academic variables (e.g., WRAT) are presented with respect to sex; (3) the percentage of children considered impaired within each of the six neuropsychological skill areas are shown for the nine Neuro Groups; and finally, (4) the 'types' of children (e.g., learning disabled) occuring in all of the nine Neuro Groups and outliers are reported.

The means, standard deviations, and maximum and minimum values of the neuropsychological variables for each of the nine Neuro Groups are presented in Tables 45 to 53. It is apparent in these tables that there is a large range associated with some of the neuropsychological variables for several of the Neuro subtypes. For example, the Sentence Memory Task scores range from a low of 10.00 to a high of 60.43 in Table 46 for Neuro Group 2 (n=185). Wide ranges are also apparent for the Neuro Groups on other variables. It was thought that these large range values may indicate a lack of homogeneity in some of the subtypes. However, as these subtypes were all replicated with split-samples this apparent heterogeneity (although undesirable) was not considered

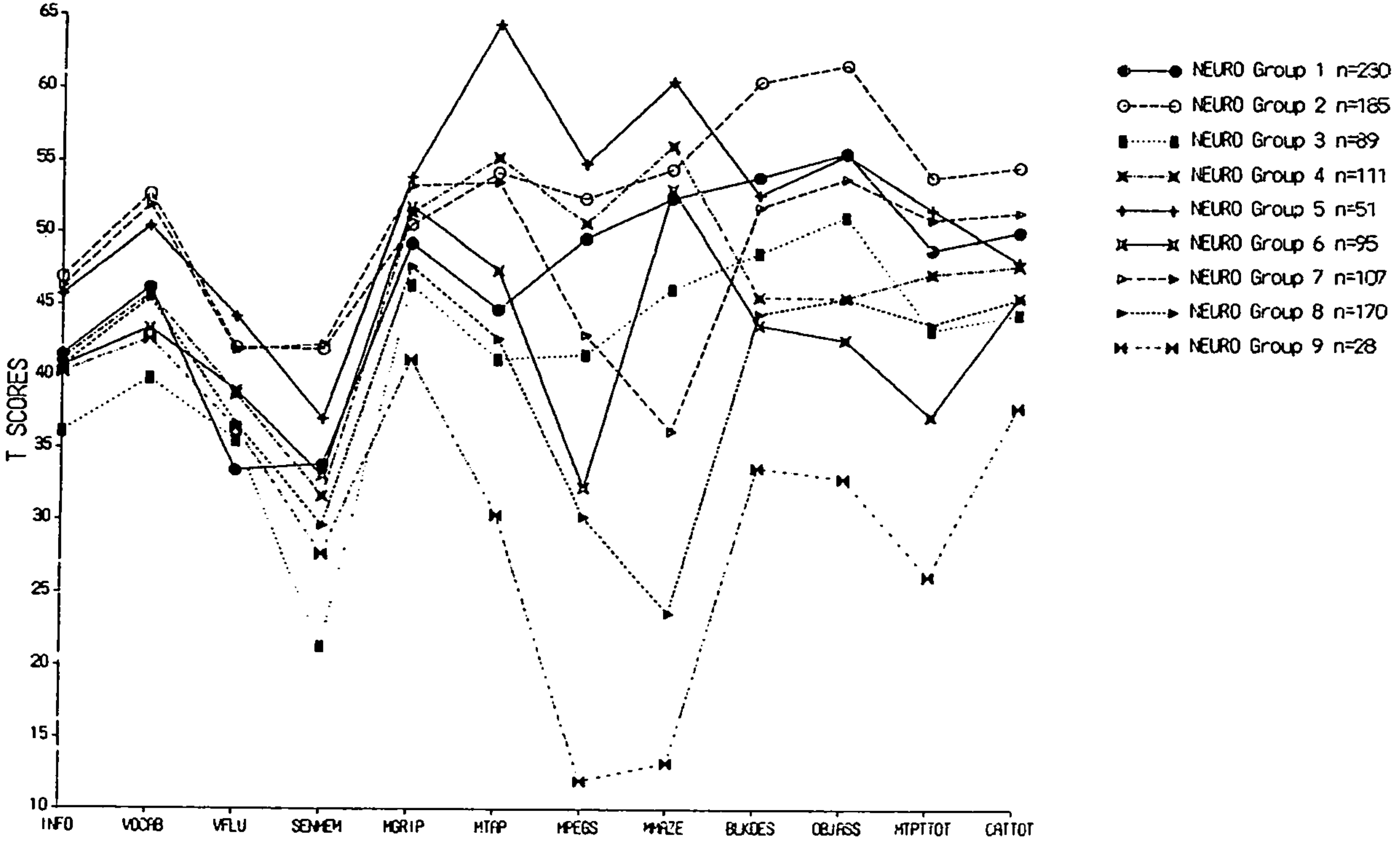


Figure 60. Mean profiles of all nine NEURO Groups which emerged from the Phase II cluster analyses.

Table 45

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A NEURO Group 1 (n=230)

	Mean (n=230)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	41.48	5.70	26.67	56.67
WISC Vocabulary	46.22	6.65	33.33	66.67
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	33.41	8.49	12.21	56.07
Sentence Memory	33.88	10.24	10.00	55.65
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.32	6.53	28.18	69.11
Finger Tapping[1]	44.77	8.23	20.66	66.52
COMPLEX MOTOR				
Grooved Pegboard[2]	49.70	7.82	28.05	68.33
Maze Test[2]	52.58	8.69	24.37	65.97
VISUAL-SPATIAL SKILLS				
WISC Block Design	54.10	7.63	30.00	70.00
WISC Object Assembly	55.84	7.85	36.67	80.00
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	49.08	7.47	25.09	64.13
Category Test (Total error score)	50.39	7.21	32.15	72.76

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 46

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A NEURO Group 2 (n=185)

	Mean (n=185)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	46.90	7.22	30.00	60.00
WISC Vocabulary	52.67	6.78	36.67	70.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	42.04	8.22	25.00	65.32
Sentence Memory	41.92	9.34	10.00	60.43
SIMPLE MOTOR SKILLS				
Grip Strength[1]	50.61	5.33	33.35	69.63
Finger Tapping[1]	54.30	7.20	30.28	74.83
COMPLEX MOTOR				
Grooved Pegboard[2]	52.55	8.59	22.01	75.70
Maze Test[2]	54.60	7.20	36.23	66.60
VISUAL-SPATIAL SKILLS				
WISC Block Design	60.65	7.51	43.33	80.00
WISC Object Assembly	61.82	9.16	40.00	83.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	54.13	5.26	34.19	63.90
Category Test (Total error score)	54.88	6.97	36.17	68.65

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 47

Phase II Part B: Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A NEURO Group 3 (n=89)

	Mean (n=89)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	36.10	5.58	23.33	53.33
WISC Vocabulary	39.81	7.02	23.33	56.67
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	35.56	9.69	14.29	53.57
Sentence Memory	21.40	9.33	10.00	56.09
SIMPLE MOTOR SKILLS				
Grip Strength[1]	46.44	5.38	35.11	66.03
Finger Tapping[1]	41.31	8.36	19.78	62.67
COMPLEX MOTOR				
Grooved Pegboard[2]	41.60	9.17	23.77	68.39
Maze Test[2]	46.24	7.99	26.91	65.30
VISUAL-SPATIAL SKILLS				
WISC Block Design	48.80	6.48	36.67	63.33
WISC Object Assembly	51.31	8.36	33.33	73.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	43.48	8.45	24.78	60.10
Category Test (Total error score)	44.57	7.61	28.06	66.92

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 48

<u>Phase II Part B:</u>
<u>Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A NEURO Group 4 (n=111)</u>

	Mean (n=111)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	41.23	4.84	26.67	56.67
WISC Vocabulary	45.71	6.58	33.33	63.33
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	38.74	9.53	14.29	68.89
Sentence Memory	31.67	9.04	10.00	51.30
SIMPLE MOTOR SKILLS				
Grip Strength[1]	51.45	5.55	39.72	71.48
Finger Tapping[1]	55.37	7.11	38.04	70.80
COMPLEX MOTOR				
Grooved Pegboard[2]	50.76	7.90	24.34	67.62
Maze Test[2]	56.25	6.01	39.13	66.35
VISUAL-SPATIAL SKILLS				
WISC Block Design	45.71	6.27	30.00	60.00
WISC Object Assembly	45.68	6.04	33.33	63.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	47.36	7.90	27.54	61.92
Category Test (Total error score)	47.95	9.05	24.27	65.38

<u>Note 1:</u> mean performances for the right- and left-hand trials combined

<u>Note 2:</u> mean time scores for the right- and left-hand trials combined

Table 49

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A
NEURO Group 5 (n=51)

	Mean (n=51)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	45.69	7.03	30.00	60.00
WISC Vocabulary	50.39	6.88	36.67	63.33
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	44.21	9.54	22.93	59.96
Sentence Memory	37.09	8.62	20.43	56.09
SIMPLE MOTOR SKILLS				
Grip Strength[1]	53.96	6.06	43.13	72.80
Finger Tapping[1]	64.53	6.98	52.36	82.92
COMPLEX MOTOR				
Grooved Pegboard[2]	54.98	7.94	40.00	70.94
Maze Test[2]	60.65	3.99	46.80	65.60
VISUAL-SPATIAL SKILLS				
WISC Block Design	52.88	5.33	40.00	66.67
WISC Object Assembly	55.69	6.58	43.33	70.00
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	51.85	5.96	32.18	63.48
Category Test (Total error score)	48.22	6.75	31.20	65.15

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 50

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A NEURO Group 6 (n=95)

	Mean (n=95)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	40.70	6.28	23.33	60.00
WISC Vocabulary	43.37	6.83	23.33	60.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	38.98	7.79	15.00	55.07
Sentence Memory	33.11	9.56	10.00	51.74
SIMPLE MOTOR SKILLS				
Grip Strength[1]	51.88	9.68	33.10	82.45
Finger Tapping[1]	47.47	8.99	28.38	67.18
COMPLEX MOTOR				
Grooved Pegboard[2]	33.33	11.36	10.00	51.36
Maze Test[2]	53.16	7.14	35.50	64.18
VISUAL-SPATIAL SKILLS				
WISC Block Design	43.75	8.02	30.00	66.67
WISC Object Assembly	42.74	7.23	23.33	56.67
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	37.34	10.73	12.59	57.21
Category Test (Total error score)	45.75	9.26	26.63	67.95

Note 1: mean performances for the right- and left-hand triasl combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 51

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A NEURO Group 7 (n=107)

	Mean (n=107)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	46.26	7.39	30.00	63.33
WISC Vocabulary	51.87	6.46	33.33	70.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	41.84	7.54	25.00	56.86
Sentence Memory	42.27	7.55	16.09	63.91
SIMPLE MOTOR SKILLS				
Grip Strength[1]	53.37	7.94	36.82	78.10
Finger Tapping[1]	53.65	9.65	30.26	81.82
COMPLEX MOTOR				
Grooved Pegboard[2]	43.05	9.45	15.84	68.40
Maze Test[2]	36.31	10.11	10.00	46.78
VISUAL-SPATIAL SKILLS				
WISC Block Design	51.99	9.05	33.33	73.33
WISC Object Assembly	54.02	9.04	30.00	73.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	51.17	8.09	17.67	64.99
Category Test (Total error score)	51.69	8.25	26.25	67.44

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 52

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A NEURO Group 8 (n=170)

	Mean (n=170)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	40.69	7.22	26.67	63.33
WISC Vocabulary	45.47	7.82	26.67	66.67
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	36.73	10.35	14.00	70.36
Sentence Memory	29.67	11.06	10.00	56.09
SIMPLE MOTOR SKILLS				
Grip Strength[1]	47.72	5.57	34.38	61.50
Finger Tapping[1]	42.74	9.97	11.52	68.80
COMPLEX MOTOR				
Grooved Pegboard[2]	30.30	11.59	10.00	59.35
Maze Test[2]	23.68	9.18	10.00	45.02
VISUAL-SPATIAL SKILLS				
WISC Block Design	44.53	7.64	23.33	66.67
WISC Object Assembly	45.59	8.33	20.00	63.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	43.87	8.88	18.77	62.08
Category Test (Total error score)	45.65	8.87	22.79	64.11

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 53

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample A
NEURO Group 9 (n=28)

	Mean (n=28)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	40.24	6.41	26.67	53.33
WISC Vocabulary	42.62	7.05	30.00	60.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	36.37	9.72	19.64	62.21
Sentence Memory	27.75	9.65	11.74	46.61
SIMPLE MOTOR SKILLS				
Grip Strength[1]	41.27	6.94	29.81	55.79
Finger Tapping[1]	30.44	11.55	10.00	57.27
COMPLEX MOTOR				
Grooved Pegboard[2]	12.04	3.44	10.00	22.09
Maze Test[2]	13.32	5.13	10.00	30.52
VISUAL-SPATIAL SKILLS				
WISC Block Design	33.69	5.76	20.00	43.33
WISC Object Assembly	32.98	8.03	16.67	46.67
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	26.33	7.21	10.03	45.79
Category Test (Total error score)	38.05	9.35	14.87	55.75

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

sufficient to disregard the validity of the nine cluster solution for Sample A with the neuropsychological variables.

The means, standard deviations, and maximum and minimum values obtained on the neuropsychological measures by the Profile 1, 2, and 3 outliers are shown in Tables 54 to 56. It is quite apparent that there are large ranges in the values for all the neuropsychological variables for each of these three outlier groups. This degree of heterogeneity was to be expected considering that the most extreme subjects were 'trimmed' from the profile samples prior to the cluster analyses. It is apparent in these tables that the heterogeneity occuring within the outliers (in terms of the range of the scores and the number of variables with large ranges) is greater than that occuring within the nine Neuro Groups.

The composition of the nine Neuro Groups with respect to sex, age, hand preference, WISC variables, and WRAT scores are presented in Tables 57 to 65. The nine Neuro subtypes do not appear to differ with respect to mean age. Groups 3, 6, and 9 have the highest percentages of females relative to males (i.e., 28%, 27%, and 43% respectively). In all other Neuro subtypes, the females represent 21% or less of the group. Groups 3 and 8 have the highest percentages of children considered left-handed on the basis of hand preference (i.e., 21% and 23% respectively). The left-

Table 54

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for the Sample A PROFILE I Outliers (n=50)

	Mean (n=50)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	39.33	9.62	26.67	63.33
WISC Vocabulary	44.33	11.86	20.00	76.67
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	36.48	13.27	16.79	67.86
Sentence Memory	28.57	15.93	10.00	64.00
SIMPLE MOTOR SKILLS				
Grip Strength[1]	47.41	9.35	32.65	76.53
Finger Tapping[1]	41.19	17.43	10.00	83.33
COMPLEX MOTOR				
Grooved Pegboard[2]	42.70	19.14	10.00	86.44
Maze Test[2]	42.76	12.42	15.41	64.81
VISUAL-SPATIAL SKILLS				
WISC Block Design	50.13	13.37	30.00	76.67
WISC Object Assembly	57.53	12.77	33.33	80.00
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	41.99	13.42	10.00	69.50
Category Test (Total error score)	45.24	12.19	10.00	69.49

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 55

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for the Sample A PROFILE II Outliers (n=23)

	Mean (n=23)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	38.84	10.28	23.33	63.33
WISC Vocabulary	44.04	12.47	23.33	70.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	36.00	13.71	14.29	67.86
Sentence Memory	27.23	15.46	10.00	51.30
SIMPLE MOTOR SKILLS				
Grip Strength[1]	53.94	16.87	31.16	85.29
Finger Tapping[1]	49.70	17.15	15.03	75.25
COMPLEX MOTOR				
Grooved Pegboard[2]	37.23	20.29	10.00	74.95
Maze Test[2]	51.41	10.93	31.29	64.36
VISUAL-SPATIAL SKILLS				
WISC Block Design	48.84	12.66	26.67	70.00
WISC Object Assembly	44.20	9.17	26.67	56.67
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	35.48	16.38	10.00	60.81
Category Test (Total error score)	43.75	16.86	10.73	64.15

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 56

Phase II Part B:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for the Sample A PROFILE III Outliers (n=13)

	Mean (n=13)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	49.49	10.79	33.33	70.00
WISC Vocabulary	50.00	11.46	26.67	63.33
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	47.76	17.92	21.43	70.68
Sentence Memory	40.88	18.56	10.00	60.43
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.64	16.46	25.50	81.46
Finger Tapping[1]	48.90	20.14	15.54	77.82
COMPLEX MOTOR				
Grooved Pegboard[2]	28.67	16.94	10.00	61.59
Maze Test[2]	21.47	15.61	10.00	54.74
VISUAL-SPATIAL SKILLS				
WISC Block Design	45.13	9.09	30.00	60.00
WISC Object Assembly	43.59	14.04	16.67	66.67
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	29.27	16.77	10.96	54.98
Category Test (Total error score)	38.90	13.97	10.00	57.72

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

Table 57

Phase II Part B:
Sample A NEURO Group 1 (n=230)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	190	40	230
Chronological Age in years	11.73 (1.59)	11.54 (1.58)	11.69 (1.58)
WISC			
Verbal IQ	91.22 (8.52)	88.43 (9.46)	90.73 (8.73)
Performance IQ	106.21 (9.89)	103.30 (10.09)	105.70 (9.96)
Full Scale IQ	98.16 (7.62)	94.98 (8.53)	97.61 (7.86)
PPVT IQ	97.97 (12.74)	94.65 (10.22)	97.40 (12.38)
WRAT (Standard Scores)			
Reading	86.86 (12.29)	88.43 (11.42)	87.13 (12.13)
Spelling	80.77 (10.54)	85.35 (9.68)	81.57 (10.52)
Aritnmetic	83.38 (7.89)	83.30 (8.26)	83.37 (7.93)
WRAT (Subtest Centiles)			
Reading %	24.42 (22.30)	25.43 (21.18)	24.60 (22.07)
Spelling %	14.79 (16.51)	19.90 (17.19)	15.68 (16.71)
Arithmetic %	16.31 (12.02)	16.53 (13.01)	16.34 (12.17)
HAND PREFERENCE			
Right	152	37	189
Left	38	3	41

Table 58

Phase II Part B:
Sample A NEURO Group 2 (n=185)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	161	24	185
Chronological Age (years)	11.00 (1.30)	10.53 (1.52)	10.94 (1.34)
WISC			
Verbal IQ	100.82 (8.78)	100.83 (8.16)	100.82 (8.68)
Performance IQ	114.91 (9.71)	118.54 (8.41)	115.38 (9.60)
Full Scale IQ	108.23 (6.71)	110.21 (6.17)	108.49 (6.66)
PPVT IQ	105.83 (12.30)	101.33 (12.30)	105.24 (12.36)
WRAT (Standard Scores)			
Reading	93.45 (13.10)	97.25 (18.47)	93.94 (12.53)
Spelling	86.41 (12.24)	92.75 (13.33)	87.23 (12.53)
Aritnmetic	87.89 (8.01)	92.25 (8.88)	88.46 (8.23)
WRAT (Subtest Centiles)			
Reading %	36.26 (25.87)	43.04 (35.48)	37.14 (27.29)
Spelling %	23.25 (21.42)	34.50 (28.83)	37.14 (22.74)
Arithmetic %	23.86 (15.25)	31.71 (19.04)	24.88 (15.95)
HAND PREFERENCE			
Right	139	21	160
Left	22	3	25

Table 59

Phase II Part B:
Sample A NEURO Group 3 (n=89)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	64	25	89
Chronological Age (years)	11.61 (1.73)	11.76 (1.65)	11.65 (1.70)
WISC			
Verbal IQ	81.42 (7.98)	81.56 (8.39)	81.46 (8.05)
Performance IQ	95.20 (9.73)	96.20 (11.51)	95.48 (10.21)
Full Scale IQ	86.77 (8.25)	87.40 (8.70)	86.94 (8.34)
PPVT IQ	87.67 (11.78)	83.16 (12.19)	86.40 (12.00)
WRAT (Standard Scores)			
Reading	80.27 (10.98)	81.40 (12.10)	80.58 (11.25)
Spelling	77.78 (9.24)	78.28 (8.26)	77.92 (8.93)
Arithmetic	79.30 (7.36)	80.24 (8.47)	79.56 (7.65)
WRAT (Subtest Centiles)			
Reading %	14.25 (15.40)	17.00 (17.47)	15.02 (15.95)
Spelling %	10.41 (10.78)	10.04 (9.40)	10.30 (10.36)
Arithmetic %	10.69 (8.57)	12.48 (10.15)	11.19 (9.02)
HAND PREFERENCE			
Right	48	22	70
Left	16	3	19

Table 60

Phase II Part B:
Sample A NEURO Group 4 (n=111)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	90	21	111
Chronological Age (years)	11.15 (1.34)	10.76 (1.51)	11.08 (1.37)
WISC			
Verbal IQ	89.87 (7.48)	89.67 (8.03)	89.83 (7.55)
Performance IQ	95.33 (8.72)	97.81 (10.79)	95.80 (9.15)
Full Scale IQ	91.79 (6.74)	92.86 (7.93)	91.99 (6.95)
PPVT IQ	96.71 (12.83)	86.14 (8.87)	94.71 (12.84)
WRAT (Standard Scores)			
Reading	88.74 (13.44)	88.81 (7.31)	88.76 (12.49)
Spelling	83.68 (12.19)	86.24 (6.55)	84.16 (11.36)
Arithmetic	81.90 (7.57)	86.33 (6.94)	82.74 (7.62)
WRAT (Subtest Centiles)			
Reading %	20.30 (24.30)	25.19 (12.93)	27.75 (22.58)
Spelling %	19.74 (20.96)	19.90 (10.38)	19.77 (19.37)
Arithmetic %	13.97 (10.77)	20.29 (11.05)	15.16 (11.06)
HAND PREFERENCE			
Right	78	19	97
Left	12	2	14

Table 61

Phase II Part B:
Sample A NEURO Group 5 (n=51)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	44	7	51
Chronological Age in years	10.93 (1.31)	10.56 (0.82)	10.88 (1.25)
WISC			
Verbal IQ	94.89 (8.38)	99.43 (10.98)	95.51 (8.80)
Performance IQ	107.16 (7.49)	102.29 (9.32)	106.49 (7.85)
Full Scale IQ	100.82 (6.69)	100.86 (6.12)	100.82 (6.55)
PPVT IQ	103.52 (13.79)	97.57 (12.30)	102.71 (13.63)
WRAT (Standard Scores)			
Reading	93.30 (13.85)	94.71 (16.00)	93.49 (13.99)
Spelling	86.77 (12.04)	95.57 (14.41)	87.98 (12.06)
Aritnmetic	84.82 (9.45)	85.86 (13.07)	84.96 (9.87)
WRAT (Subtest Centiles)			
Reading %	35.95 (27.43)	40.71 (31.62)	37.47 (27.73)
Spelling %	24.68 (20.58)	40.29 (30.96)	26.82 (22.56)
Arithmetic %	19.32 (14.86)	25.29 (19.05)	20.14 (15.40)
HAND PREFERENCE			
Right	36	6	42
Left	8	1	9

Table 62

Phase II Part B:
Sample A NEURO Group 6 (n=95)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	69	26	95
Chronological Age in years	12.08 (1.70)	11.19 (1.42)	11.83 (1.67)
WISC			
Verbal IQ	89.14 (9.35)	84.35 (9.18)	87.83 (9.50)
Performance IQ	89.88 (12.56)	91.65 (10.62)	90.37 (12.04)
Full Scale IQ	88.51 (10.54)	86.62 (9.35)	87.99 (10.21)
PPVT IQ	94.64 (10.83)	88.12 (8.28)	92.85 (10.56)
WRAT (Standard Scores)			
Reading	91.80 (12.98)	90.92 (14.68)	91.56 (13.40)
Spelling	86.16 (13.26)	86.50 (14.72)	86.25 (13.60)
Arithmetic	80.39 (10.87)	80.39 (8.63)	80.78 (9.26)
WRAT (Subtest Centiles)			
Reading %	34.55 (24.98)	33.46 (27.62)	34.25 (25.58)
Spelling %	25.21 (23.18)	25.85 (26.46)	25.39 (23.98)
Arithmetic %	12.64 (11.19)	16.38 (15.54)	13.66 (12.56)
HAND PREFERENCE			
Right	59	21	80
Left	10	5	15

Table 63

Phase II Part B:
Sample A NEURO Group 7 (n=107)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	94	13	107
Chronological Age in years	11.05 (1.63)	10.24 (1.50)	10.95 (1.63)
WISC			
Verbal IQ	99.26 (9.27)	96.62 (11.56)	98.93 (9.55)
Performance IQ	103.59 (12.69)	105.00 (11.85)	103.76 (12.54)
Full Scale IQ	101.53 (9.80)	100.77 (8.87)	101.44 (9.66)
PPVT IQ	104.23 (12.53)	96.92 (11.05)	103.35 (12.55)
WRAT (Standard Scores)			
Reading	90.18 (12.77)	97.15 (21.35)	91.03 (14.14)
Spelling	83.86 (9.71)	94.00 (16.50)	85.09 (11.17)
Arithmetic	86.03 (7.29)	90.77 (8.28)	86.61 (7.54)
WRAT (Subtest Centiles)			
Reading %	29.07 (25.14)	43.31 (40.56)	30.80 (27.58)
Spelling %	18.11 (17.85)	39.15 (33.08)	20.66 (21.24)
Arithmetic %	20.06 (12.83)	29.54 (15.83)	21.21 (13.51)
HAND PREFERENCE			
Right	80	9	89
Left	14	4	18

Table 64

Phase II Part B:
Sample A NEURO Group 8 (n=170)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	135	35	170
Chronological Age in years	11.16 (1.61)	11.22 (1.56)	11.15 (1.59)
WISC			
Verbal IQ	88.34 (10.55)	87.63 (10.55)	88.19 (10.52)
Performance IQ	90.96 (10.00)	90.03 (9.94)	90.77 (9.96)
Full Scale IQ	88.56 (9.61)	87.86 (9.95)	88.42 (9.65)
PPVT IQ	94.17 (14.19)	87.86 (13.81)	92.87 (14.30)
WRAT (Standard Scores)			
Reading	83.94 (12.49)	89.09 (15.61)	85.00 (13.31)
Spelling	79.69 (9.93)	85.29 (12.43)	80.84 (10.70)
Aritnmetic	81.13 (7.34)	82.80 (9.38)	81.47 (7.80)
WRAT (Subtest Centiles)			
Reading %	20.55 (22.14)	29.03 (28.06)	22.30 (23.64)
Spelling %	13.82 (16.52)	22.20 (22.00)	15.55 (18.04)
Arithmetic %	13.39 (10.51)	16.51 (13.16)	14.03 (11.14)
HAND PREFERENCE			
Right	106	25	131
Left	29	10	39

Table 65

Phase II Part B:
Sample A NEURO Group 9 (n=28)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	16	12	28
Chronological Age in years	11.58 (1.95)	11.05 (1.31)	11.36 (1.70)
WISC			
Verbal IQ	84.13 (7.57)	86.00 (9.89)	84.93 (8.52)
Performance IQ	68.69 (7.59)	75.42 (7.89)	71.57 (8.30)
Full Scale IQ	74.38 (5.81)	79.17 (8.59)	76.43 (7.39)
PPVT IQ	90.00 (10.52)	87.92 (8.95)	89.11 (9.58)
WRAT (Standard Scores)			
Reading	88.50 (12.81)	95.00 (18.23)	91.29 (15.40)
Spelling	85.06 (11.55)	89.17 (12.85)	86.82 (12.07)
Aritnmetic	79.81 (6.85)	79.67 (9.48)	79.75 (7.92)
WRAT (Subtest Centiles)			
Reading %	26.81 (25.76)	37.50 (27.51)	31.39 (26.57)
Spelling %	21.13 (21.41)	28.33 (22.47)	24.21 (21.76)
Arithmetic %	10.81 (7.87)	12.50 (13.24)	11.54 (10.32)
HAND PREFERENCE			
Right	13	11	24
Left	3	1	4

handers comprise 18% or less of each of the remaining Neuro subtypes. Neuro Group 2 (n=185) has the highest mean WISC FSIQ of 108.49, while Neuro Group 9 (n=28) has the lowest mean WISC FSIQ at 76.43. Neuro Groups 1, 2, and 3 exhibit mean WISC VIQ-PIQ discrepancies of 14 points in favour of the latter. Neuro Group 5 evidences a mean WISC VIQ-PIQ discrepancy of 10 points in favour of PIQ. Neuro Groups 4, 6, 7, and 8 all have mean WISC VIQ-PIQ discrepancies of less than six points in favour of PIQ. Only Neuro Group 9 (n=28) shows a mean WISC VIQ-PIQ discrepancy of 13 points in favour of VIQ. The characteristics with respect to sex, age, handedness, and WISC and WRAT scores of the three outlier groups from the analyses of Profiles 1, 2, and 3 are given in Tables 66 to 68.

In order to characterize the nine Neuro Groups and outliers in terms of degree of impairment on the neuropsychological measures, the percentages of children in each subtype with T-scores below 40 (at least one standard deviation below the mean) are presented in Tables 69 to 71. The percentages given in Tables 69 to 71 represent the average number of children showing impairment within each skill area and across all six skill areas for each subtype. It is apparent that Neuro Groups 2 and 5 contain the smallest overall percentages (9% and 11% respectively) of children with impairment on the 12 neuropsychological measures. Neuro

Table 66

Phase II Part B:
Sample A PROFILE I Outliers (n=50)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	38	12	50
Chronological Age in years	12.07 (1.58)	12.02 (1.99)	12.06 (1.66)
WISC			
Verbal IQ	88.08 (15.92)	85.33 (12.80)	87.42 (15.15)
Performance IQ	103.11 (18.20)	95.92 (14.29)	101.38 (17.48)
Full Scale IQ	94.76 (16.85)	89.42 (13.91)	93.48 (16.23)
PPVT IQ	98.45 (19.20)	86.58 (16.01)	95.60 (19.03)
WRAT (Standard Scores)			
Reading	87.74 (20.66)	87.17 (13.69)	87.60 (19.09)
Spelling	80.68 (15.09)	84.92 (14.46)	81.70 (14.90)
Aritnmetic	80.32 (11.23)	80.92 (8.58)	80.46 (10.57)
WRAT (Subtest Centiles)			
Reading %	27.05 (30.08)	26.75 (23.35)	26.98 (28.38)
Spelling %	15.79 (22.03)	23.00 (20.69)	17.52 (21.73)
Arithmetic %	14.79 (17.43)	12.67 (6.23)	14.28 (15.46)
HAND PREFERENCE			
Right	32	9	41
Left	6	3	9

Table 67

Phase II Part B:
Sample A PROFILE II Outliers (n=23)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	20	3	23
Chronological Age in years	13.12 (1.55)	14.09 (0.29)	13.25 (1.48)
WISC			
Verbal IQ	87.50 (16.85)	72.67 (2.89)	85.57 (16.50)
Performance IQ	93.25 (16.67)	75.33 (21.39)	90.91 (17.88)
Full Scale IQ	89.20 (16.55)	71.33 (12.70)	86.87 (17.01)
PPVT IQ	94.45 (20.19)	82.00 (16.52)	92.83 (19.88)
WRAT (Standard Scores)			
Reading	87.65 (17.63)	94.33 (5.51)	88.52 (16.63)
Spelling	81.45 (14.64)	89.00 (12.17)	82.52 (14.33)
Aritnmetic	79.25 (12.58)	64.67 (4.16)	77.35 (12.78)
WRAT (Subtest Centiles)			
Reading %	28.70 (28.39)	36.00 (13.08)	29.65 (26.80)
Spelling %	18.55 (24.39)	27.00 (26.89)	19.65 (24.25)
Arithmetic %	14.35 (17.12)	1.33 (0.58)	12.65 (16.53)
HAND PREFERENCE			
Right	16	2	18
Left	4	1	5

Table 68

Phase II Part B:
Sample A PROFILE III Outliers (n=13)
Characteristics: Means (Standard Deviations) By Sex

	males	females	total
n	12	1	13
Chronological Age in years	12.26	10.81	12.15
	(2.22)	---	(2.17)
WISC			
Verbal IQ	95.42	105.00	96.15
	(14.12)	---	(13.78)
Performance IQ	89.25	80.00	88.54
	(15.55)	---	(15.10)
Full Scale IQ	91.75	93.00	91.85
	(12.93)	---	(12.39)
PPVT IQ	103.67	134.00	106.00
	(13.93)	---	(15.77)
WRAT (Standard Scores)			
Reading	106.25	121.00	107.38
	(18.16)	---	(17.86)
Spelling	93.17	111.00	94.54
	(11.88)	---	(12.40)
Aritnmetic	80.58	93.00	81.54
	(5.99)	---	(6.69)
WRAT (Subtest Centiles)			
Reading %	60.67	92.00	63.08
	(32.18)	---	(32.01)
Spelling %	35.08	77.00	38.31
	(25.10)	---	(26.69)
Arithmetic %	11.33	32.00	12.92
	(7.89)	---	(9.48)
HAND PREFERENCE			
Right	10	1	11
Left	2	0	2

Group 9 (Table 71) contains the largest average proportion of children (71%) evidencing impairment on these measures. All of the children (100%) in Neuro Group 9 exhibited impairment on the measures of Complex Motor Skills. With the exception of Simple Language Skills (34% impairment), a majority of the children in Neuro Group 9 (63% or greater) were impaired in all skill areas. Neuro Groups 3, 6, and 8 appear similar with respect to overall percentages of children showing impairment; however, Group 3 exhibited a higher percentage of children with impairment on Simple Language Skills (55%) and a much lower percentage of impairment (6%) on Visual-Spatial Skills than Groups 6 or 8. In addition, Neuro Group 6 showed a higher percentage of impairment (45%) on "Higher-Order Skills than Groups 3 or 8. While Neuro Group 8 evidenced a larger percentage of impaired children (86%) on Complex Motor Skills than evident in Groups 3 and 6.

Neuro Groups 1, 4, and 7 also appear similar in terms of overall percentages of impairment; howver, Group 7 shows a greater percentage of children impaired on Complex Language and Complex Motor Skills (39% and 48% respectively) and a smaller impairment percentage on Simple Language Skills (9%) than is evident in Groups 1 and 4. There is a higher percentage of impairment in Group 1 (16 percent) for Simple Motor Skills than seen in Groups 4 and 7. Group 4 exhibits a greater percentage of below-average children on Visual-

Spatial Skills (11%) than is apparent in either Group 1 or 7. The overall percentages of impairment for the three outlier categories were very similar, as shown in Tables 69 to 71; however, there were some differences apparent between these outlier groups. The Profile 3 outliers (Table 71) had smaller percentages of impaired children on Simple and Complex Language Skills (15% and 38% respectively), and a higher percentage impairment on Complex Motor Skills (77%) than did the other outlier groups. The Profile 2 outliers (Table 70) showed the highest percentage impairment on Visual-Spatial Skills (i.e., 46%). In the following section of Part B of the Phase II results, the 'types' of children occuring in the nine Neuro Groups and outlier categories corresponding to typical exclusionary criteria and various definitions of learning disabilties are presented.

The number (percentages) of children in the nine Neuro Groups and outliers corresponding to typical exclusionary criteria which is traditionally employed in learning disability research are shown in Tables 72 to 74. The exclusionary criteria examined here include several levels of low IQ (e.g., PPVT IQ < 90, WISC FSIQ < 85) as well as categories indicative of impairment on the Sweep Hearing Test, visual and hearing anomalies, environmental deprivation, presence of brain pathology, and emotional disturbance. The number of children occuring in these

Table 69

Phase II Part B: Percentage of Children Impaired in Each Neuropsychological Skill Area for Sample A NEURO Groups 1 to 3 and the PROFILE I Outliers

	NEURO Subtypes			
	1 (n=230)	2 (n=185)	3 (n=89)	Profile I Outliers (n=50)
Simple Language Skills	21[1]	6	55	43
Complex Language Skills	75	41	81	72
Simple Motor Skills	16	4	29	32
Complex Motor Skills	10	4	36	46
Visual Spatial Skills	2	0	6	16
"Higher-Order" Skills	10	2	30	34
Mean	22[2]	9	40	41

<u>Note 1:</u> These percentages are derived from the average number of children in each skill area with T-scores less than 40 (i.e., one standard deviation below the mean).

<u>Note 2:</u> The "total" percentages are the average percentage of children in the NEURO subtype impaired across all skill areas for that subgroup.

Table 70

<u>Phase II Part B:</u>
<u>Percentage of Children Impaired in Each Neuropsychological Skill Area for Sample A NEURO Groups 4 to 6 and the PROFILE II Outliers</u>

	NEURO Subtypes			
	4 (n=111)	5 (n=51)	6 (n=95)	Profile II Outliers (n=23)
Simple Language Skills	22[1]	12	27	50
Complex Language Skills	71	45	63	70
Simple Motor Skills	2	0	15	31
Complex Motor Skills	4	0	37	42
Visual Spatial Skills	11	0	26	46
"Higher-Order" Skills	18	6	45	50
Mean	21[2]	11	36	48

<u>Note 1:</u> These percentages are derived from the average number of children in each skill area with T-scores less than 40 (i.e., one standard deviation below the mean).

<u>Note 2:</u> The "total" percentages are the average percentage of children in the NEURO subtype impaired across all skill areas for that subgroup.

Table 71

<u>Phase II Part B:</u>
<u>Percentage of Children Impaired in Each Neuropsychological Skill Area for Sample A NEURO Groups 7 to 9 and the PROFILE III Outliers</u>

	NEURO Subtypes			
	7 (n=107)	8 (n=170)	9 (n=28)	Profile III Outliers (n=13)
Simple Language Skills	91	28	34	15
Complex Language Skills	39	75	75	38
Simple Motor Skills	4	22	63	35
Complex Motor Skills	48	86	100	77
Visual Spatial Skills	5	19	77	27
"Higher-Order" Skills	10	28	75	66
Mean	192	43	71	43

<u>Note 1:</u> These percentages are derived from the average number of children in each skill area with T-scores less than 40 (i.e., one standard deviation below the mean).

<u>Note 2:</u> The "total" percentages are the average percentage of children in the NEURO subtype impaired across all skill areas for that subgroup.

categories for the entire Sample A (n=1200) were presented previously in Table 2.

It is apparent in Tables 72 to 74 that Neuro Group 9 exhibits the greatest percentage of low IQ children with respect to the WISC IQ cutoff points. Neuro Groups 1, 2, 5, and 7 evidence the smallest percentages of low IQ children regardless of the PPVT or WISC IQ cutoff. The percentages of low IQ children ocurring in Neuro Groups 3, 6, and 8 with respect to various IQ cutoff points appear very similar, although a higher percentage of children (60%) in Group 3 would be excluded from typical LD studies on the basis of the PPVT IQ < 90 criteria. Only 38% of the children in Groups 6 and 8 would traditionally be excluded by employing this IQ cutoff point.

As shown in Table 73, 45% of the children in Neuro Group 5 were considered emotionally disturbed. Neuro Groups 1, 2, and 8 contained the largest numbers of children (49, 50, and 44 respectively) thought to be emotionally disturbed; however, these children represented only 21%, 27%, and 26% of these groups. Thirteen of the children with some form of brain pathology were clustered into Neuro Group 1, although they represented only 6% of that group. Although 14 of the brain lesioned children occured in Group 8, they accounted for only 8% of the subjects in that subtype. Six of the brain lesioned children occured in Neuro Group 9 but

Table 72

Phase II Part E:
Number (Percentage) of Children in Sample A NEURO Groups 1 to 3 and the PROFILE I Outliers Corresponding to Typical Exclusionary Criteria

	Group 1 (n=230)	Group 2 (n=185)	Group 3 (n=89)	Profile I Outliers (n=50)
PPVT IQ<90	62(27)[1]	16(9)	53(60)	19(38)
WISC FSIQ<90	34(15)	0(0)	55(62)	19(38)
WISC FSIQ<85	10(4)	0(0)	35(39)	15(30)
WISC FSIQ<80	4(2)	0(0)	18(20)	12(24)
Emotionally Disturbed	49(21)	50(27)	14(16)	12(24)
Brain Lesioned	13(6)	5(3)	6(7)	3(6)
Environmental Deprivation	0(0)	2(1)	3(3)	0(0)
Hearing Anomalies	25(11)	12(6)	11(12)	9(18)
Visual Anomalies	12(5)	8(4)	5(6)	3(6)
Impairment on Sweep Hearing Test	44(19)	18(10)	24(27)	10(20)

<u>Note 1:</u> The numbers in parentheses represent the percentages of children within that group corresponding to the exclusionary criteria. For example, 62 of the 230 children (i.e., 27%) in NEURO Group 1 have a PPVT IQ < 90. Similarly, 14 of the 89 children (i.e., 16%) in NEURO Group 3 were considered emotionally disturbed.

Table 73

Phase II Part B:
Number (Percentage) of Children in Sample A NEURO Groups 4 to 6 and the PROFILE II Outliers Corresponding to Typical Exclusionary Criteria

	Group 4 (n=111)	Group 5 (n=51)	Group 6 (n=95)	Profile II Outliers (n=23)
PPVT IQ<90	41(37)[1]	10(20)	36(38)	10(43)
WISC FSIQ<90	38(34)	2(4)	56(59)	14(61)
WISC FSIQ<85	15(14)	0(0)	36(38)	12(52)
WISC FSIQ<80	4(4)	0(0)	19(20)	8(35)
Emotionally Disturbed	22(20)	23(45)	29(31)	7(30)
Brain Lesioned	1(1)	1(2)	3(3)	1(4)
Environmental Deprivation	0(0)	0(0)	2(2)	0(0)
Hearing Anomalies	8(7)	2(4)	9(9)	4(17)
Visual Anomalies	5(5)	0(0)	5(5)	2(9)
Impairment on Sweep Hearing Test	13(12)	4(8)	27(28)	8(35)

Note 1: The numbers in parentheses represent the percentages of children within that group corresponding to the exclusionary criteria. For example, 41 of the 111 children (i.e., 37%) in NEURO Group 4 have a PPVT IQ < 90. Similarly, 29 of the 95 children (i.e., 31%) in NEURO Group 6 were considered emotionally disturbed.

Table 74

Phase II Part B:
Number (Percentage) of Children in Sample A NEURO Groups 7 to 9 and the PROFILE III Outliers Corresponding to Typical Exclusionary Criteria

	Group 7 (n=107)	Group 8 (n=170)	Group 9 (n=28)	Profile III Outliers (n=13)
PPVT IQ<90	9(8)[1]	64(38)	14(50)	3(23)
WISC FSIQ<90	12(11)	86(51)	26(93)	6(46)
WISC FSIQ<85	2(2)	59(35)	24(86)	4(31)
WISC FSIQ<80	0(0)	36(21)	20(71)	3(23)
Emotionally Disturbed	34(32)	44(26)	3(11)	5(38)
Brain Lesioned	7(7)	14(8)	6(21)	2(15)
Environmental Deprivation	1(1)	2(1)	0(0)	0(0)
Hearing Anomalies	12(11)	27(16)	2(7)	2(15)
Visual Anomalies	6(6)	26(15)	3(11)	3(23)
Impairment on Sweep Hearing Test	20(19)	46(27)	7(25)	3(23)

Note 1: The numbers in parentheses represent the percentages of children within that group corresponding to the exclusionary criteria. For example, 9 of the 107 children (i.e., 8%) in NEURO Group 7 have a PPVT IQ < 90. Similarly, 3 of the 28 children (i.e., 11%) in NEURO Group 9 were considered emotionally disturbed.

accounted for 21% of the children in that subtype. The 10 children considered to be environmentally deprived appeared to occur with equal frequency across all Groups. None of these children were 'trimmed' into one of the three outlier categories. Neuro Groups 5 and 9 contained the fewest number of children with hearing anomalies. Neuro Groups 5 and 9 also contained the smallest numbers of children with visual anomalies. Although Group 9 contained only seven children with impairment on the Sweep Hearing Test, they represented 25% of that subtype. There were only 18 (10%), 13 (12%), and 4 (8%) children with Sweep Hearing Impairment in Groups 2, 4, and 5, respectively.

The number (percentage) of children in the nine Neuro Groups and corresponding outlier categories who could be considered at least low-average achievers (i.e., all WRAT standard scores greater than or equal to 85) are presented in Tables 75 to 77. Also shown in these tables are the number of children in each Neuro Group who could be characterized as learning disabled on the basis of a configurational approach adapted from Ozols and Rourke (1988), or as a result of applying various IQ-Achievement discrepancy scores. These definitions of learning disability were employed and explained previously in Phase I of the present study.

As shown in Tables 75 to 77, Neuro Group 2 contained the largest number of children (i.e., 77, or 42% of that subtype)

Table 75

Phase II Part B:
Number (Percentage) of Children in Sample A NEURO Groups 1 to 3 and PROFILE I Outliers Evidencing at least Low-Average Levels of Academic Achievement or Corresponding to Definitions of Learning Disabilities

	NEURO Groups			
	Group 1 (n=230)	Group 2 (n=185)	Group 3 (n=89)	Profile I Outliers (n=50)
Low-Average or Better Achievement by WRAT Standard Scores				
WRAT R, S, A all ≥ 85	47(20)	77(42)	12(13)	12(24)
Learning Disability Definitions.				
A) IQ-Achievement Discrepancy: At least one WRAT Centile Score ≤ 25, and WISC or PPVT IQ cutoff as follows;				
1. FSIQ ≥ 80	209(91)	143(77)	71(80)	33(66)
2. FSIQ ≥ 85	203(88)	143(77)	54(61)	30(60)
3. FSIQ ≥ 90	179(78)	143(77)	34(38)	26(52)
4. PPVT IQ ≥ 90	152(66)	130(70)	36(40)	26(52)
B) Configurational Approach (WRAT Typologies)[1]				
1. Rourke G1	71(31)	33(18)	26(29)	12(24)
2. Rourke G2	22(10)	15(8)	3(3)	2(4)
3. Rourke G3	9(4)	12(6)	1(1)	3(6)

Note 1: These 'configurational' definitions of learning disability were adapted from Ozols and Rourke (1988) as follows: for all children WISC FSIQ ≥ 85, and;

Rourke G1: WRAT R,S, and A Centiles all ≤ 16.

Rourke G2: WRAT R,S ≤ 16; $16 \leq A \leq 34$; and the Arithmetic centile score was at least 10 points higher than the Reading centile score for all G2 children.

Rourke G3: WRAT R,S ≥ 45; A ≤ 34; and the Arithmetic centile score was at least 25 points lesser than the centile scores for both Reading and Spelling.

Table 76

Phase II Part B: Number (Percentage) of Children in Sample A NEURO Groups 4 to 6 and PROFILE II Outliers Evidencing at least Low-Average Levels of Academic Achievement or Corresponding to Definitions of Learning Disabilities

	NEURO Groups			
	Group 4 (n=111)	Group 5 (n=51)	Group 6 (n=95)	Profile II Outliers (n=23)
Low-Average or Better Achievement by WRAT Standard Scores				
WRAT R, S, A all $\geq$ 85	27(24)	23(45)	24(25)	3(13)
Learning Disability Definitions.				
A) IQ-Achievement Discrepancy: At least one WRAT Centile Score $\leq$ 25, and WISC or PPVT IQ cutoff as follows;				
1. FSIQ $\geq$ 80	94(85)	40(78)	67(71)	13(57)
2. FSIQ $\geq$ 85	83(75)	40(78)	51(54)	9(39)
3. FSIQ $\geq$ 90	60(54)	38(75)	32(34)	7(30)
4. PPVT IQ $\geq$ 90	61(55)	33(65)	51(54)	11(48)
B) Configurational Approach (WRAT Typologies)[1]				
1. Rourke G1	28(25)	15(29)	15(16)	1(4)
2. Rourke G2	3(3)	0(0)	1(1)	0(0)
3. Rourke G3	3(3)	3(6)	9(9)	1(4)

Note 1: These 'configurational' definitions of learning disability were adapted from Ozols and Rourke (1988) as follows: for all children WISC FSIQ $\geq$ 85, and;

Rourke G1: WRAT R,S, and A Centiles all $\leq$ 16.

Rourke G2: WRAT R,S $\leq$ 16; 16 $\leq$ A $\leq$ 34; and the Arithmetic centile score was at least 10 points higher than the Reading centile score for all G2 children.

Rourke G3: WRAT R,S $\geq$ 45; A $\leq$ 34; and the Arithmetic centile score was at least 25 points lesser than the centile scores for both Reading and Spelling.

Table 77

Phase II Part B:
Number (Percentage) of Children in Sample A NEURO Groups 7 to 9 and PROFILE III Outliers Evidencing at least Low-Average Levels of Academic Achievement or Corresponding to Definitions of Learning Disabilities

	NEURO Groups			
	Group 7 (n=107)	Group 8 (n=170)	Group 9 (n=28)	Profile II Outliers (n=13)
Low-Average or Better Achievement by WRAT Standard Scores				
WRAT R, S, A all ≥ 85	31(29)	31(18)	6(21)	4(31)
Learning Disability Definitions.				
A) IQ-Achievement Discrepancy: At least one WRAT Centile Score ≤ 25, and WISC or PPVT IQ cutoff as follows;				
1. FSIQ ≥ 80	91(85)	123(72)	7(25)	8(62)
2. FSIQ ≥ 85	89(83)	101(59)	3(11)	7(54)
3. FSIQ ≥ 90	79(74)	71(42)	1(4)	5(38)
4. PPVT IQ ≥ 90	89(83)	98(58)	13(46)	8(62)
B) Configurational Approach (WRAT Typologies)[1]				
1. Rourke G1	28(26)	34(20)	0(0)	0(0)
2. Rourke G2	8(7)	7(4)	0(0)	0(0)
3. Rourke G3	4(4)	8(5)	1(4)	4(31)

Note 1: These 'configurational' definitions of learning disability were adapted from Ozols and Rourke (1988) as follows: for all children WISC FSIQ ≥ 85, and;

Rourke G1: WRAT R,S, and A Centiles all ≤ 16.

Rourke G2: WRAT R,S ≤ 16; 16 ≤ A ≤ 34; and the Arithmetic centile score was at least 10 points higher than the Reading centile score for all G2 children.

Rourke G3: WRAT R,S ≥ 45; A ≤ 34; and the Arithmetic centile score was at least 25 points lesser than the centile scores for both Reading and Spelling.

who could be characterized as 'normal' academic achievers on the basis of WRAT standard scores. Neuro Group 1 contained 47 children with all WRAT standard scores at least equal to or greater than one standard deviation below the mean (i.e., $\geq$ 85); however, these children accounted for only 20% of the subjects in that subtype. Although Neuro Group 5 contained 23 children considered 'normal' achievers, they represented 45% of the subjects assigned to that cluster. Approximately 25% of the children in Neuro Groups 4 and 6 (i.e., 27 and 24 subjects, respectively) could be characterized as 'normal' academic achievers. Neuro Groups 7 and 8 each contained 31 children considered at least low-average achievers on the WRAT, and they accounted for 29% and 18% of the subjects, respectively, in these two subtypes. Neuro Group 9 contained the smallest number of 'normal' academic achievers (i.e., 6 children) although they represented 21% of that subtype. Only 13% of the children in Neuro Group 3 (i.e., 12) could be characterized as 'normal' academic achievers on the basis of their WRAT standard scores.

With respect to the designation of children as LD by employing IQ-Achievement discrepancy criteria, it is clear in Tables 75 to 77 that Neuro Group 1 contained the greatest numbers of these LD children regardless of WISC or PPVT IQ cutoff point. Most of these LD children in Neuro Group 1 (i.e., 78%), Group 2 (i.e., 77%), Group 5 (i.e., 75%), and Group 7 (i.e., 74%) evidenced WISC FSIQs greater than or equal to 90. Neuro Group 9 contained the fewest number (and overall lowest group percentage) of LD children determined by the WISC FSIQ-Achievement criteria. Although Neuro Group 9 contained only 13 of these LD children with PPVT IQ $\geq$ 90, they represented 46% of the subjects in that subtype.

Examination of the number of children in each Neuro Group (see Tables 75 to 77) designated as LD using the PPVT IQ or various WISC IQ cutoff scores revealed some comparisons worth noting. For example, in a majority of the Neuro subtypes more children would be considered LD by using the WISC FSIQ $\geq$ 85 as a cutoff point compared with employing the PPVT IQ $\geq$ 90 criteria. However, within Neuro Groups 6, 7, and 8 the number of children identified as LD was virtually identical when either the PPVT IQ $\geq$ 90 or WISC FSIQ $\geq$ 85 cutoffs were used. It was also apparent for these three Neuro Groups that more children would be categorized as LD with the PPVT IQ $\geq$ 90 criteria than with the same WISC cutoff score.

This was also the case for Neuro Group 9 where nearly twice as many children would be labelled LD with the PPVT cutoff criteria compared to the WISC FSIQ $\geq$ 80 cutoff score. Approximately the same number of children in Neuro Groups 3 and 4 were designated LD on the basis of either a WISC or

PPVT IQ $\geq$ 90. For Neuro Groups 1, 2, and 5, fewer children were considered LD by using the PPVT IQ $\geq$ 90 criteria compared with the same WISC cutoff point.

Considering the children designated as LD on the basis of the WRAT typologies it is apparent in Tables 75 to 77 that Neuro Group 1 contains the greatest number of the 'Rourke G1' type (i.e., 71, or 31% of that subtype). The 'Rourke G1' type children were found to account for at least 25% of the subjects in Neuro Groups 3, 4, 5, and 7. Children with the G1 configuration of WRAT scores accounted for 16% to 20% of the members of Neuro Groups 2, 6, and 8. Only Neuro Group 9 contained no 'Rourke G1' type children. Neuro Group 1 also contained the largest number of 'Rourke G2' type children (i.e., 22, or 10% of that subtype). These 'Rourke G2' children accounted for 8% and 7% of the subjects in Neuro Groups 2 and 7, respectively. Three to four percent of the subjects in Neuro Groups 3, 4, and 8 were categorized as 'Rourke G2' types. None of the 'Rourke G2' children were found in Neuro Groups 5 and 9, while only one such child occured in Neuro Group 6. The 'Rourke G3' type children occured in all nine Neuro groups. The largest number of these children were found in Neuro Group 2 (i.e., 12, or 6% of that subtype). Neuro Groups 1, 6, and 8 contained 9 (i.e., 10%), 9 (i.e., 9%), and 8 (i.e., 5%), respectively, of the children classified as 'Rourke G3'. All the other

Neuro groups contained only four or fewer of the 'Rourke G3' type children.

As shown in Tables 75 to 77, the three outlier categories contained relatively few children (i.e., 19, or 22% across all three) who coud be characterized as 'normal' achievers according to the WRAT standard scores. Approximately 50% of the children assigned to these outliers could be labelled LD on the basis of the IQ-Achievement discrepancy criteria. Only 15 children in these three outlier groups could be classified as 'Rourke G1 or G2' types, while only 8 could be categorized as 'Rourke G3' types.

It was apparent from the Phase II Part B analyses that nine subtypes emerged with varying degrees of impairment and different mean profiles (determined by visual inspection) with respect to neuropsychological strengths and weaknesses. Of particular importance was the emergence of one rather severely impaired subtype (i.e., Neuro Group 9) containing a relatively large percentage of low IQ children. Two other subtypes (i.e., Neuro Groups 2 and 5) exhibited relatively few neuropsychological impairments and contained no children with WISC FSIQs < 85. In the following section the results of the Phase III cluster analyses are described.

Phase III: Cluster Analysis of the Sample B Subsamples on the Twelve Measures of Neuropsychological Abilities

In this part of the results the cluster analyses of the Sample B Subsamples 1 to 4 are presented. Each of these four subsamples contained 70 children selected from Sample B (n=882) on the basis of WISC FSIQ levels as depicted in Figure 1. These four subsamples were individually cluster analyzed on the 12 measures of neuropsychological abilities. The procedure suggested by Lorr (1983) to remove profile elevation and cluster on the basis of profile shape was employed for each of the Sample B Subsamples. The purpose of the Phase III cluster analysis was to determine if WISC FSIQ level would influence the neuropsychological ability structure and number of subtypes which emerged. Therefore, the characteristics (e.g., sex, age, and all other variable scores) of each subtype resulting from the cluster analyses of Sample B Subsamples 1 through 4 are not reported.

The findings of each of these four cluster analyses are presented as follows: (1) the cluster fusion coefficients 'pseudo F and T' for Ward's hierarchical agglomerative cluster analytic method is depicted graphically and a particular solution is suggested; (2) then the cross-method agreement between Ward's technique (which was the target method) and the other three cluster procedures is displayed; (3) for each of the Sample B Subsamples, two split-sample replication attempts (sample sizes N=50 and N=35) are presented; and (4) the individual profiles resulting from the cluster analysis of each subsample are plotted with their respective split-sample replication profiles.

<u>Sample B Subsample 1: WISC FSIQ (70-80)</u>

The raw scores for all 12 neuropsychological variables were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The T-score means, standard deviations, and maximum and minimum values for the Sample B Subsample 1 (n=70) neuropsychological variables are presented in Table 78.

The plots of the pseudo F and T cluster coefficients for Ward's method are displayed in Figure 61. The fusion plots for the other three cluster methods are displayed in Figures 62 to 64. Although there are relative drops in 'pseudo T' in these Figures indicating more than a six-cluster partition, none were found with acceptable levels of cross-method agreement and were not considered further. As seen in Figure 61, there were possible solutions corresponding to relative rises in 'pseudo F' indicating a 2, 3, 4, or 5 cluster partition. This was also apparent in Figures 62 to

Table 78

Phase III:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample B Subsample 1 (WISC FSIQ 70-80)

	Mean (n=70)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	36.71	5.91	23.33	56.67
WISC Vocabulary	38.81	6.22	23.33	50.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	33.26	10.46	14.29	66.07
Sentence Memory	27.23	10.81	10.00	51.30
SIMPLE MOTOR SKILLS				
Grip Strength[1]	45.88	6.58	26.56	66.75
Finger Tapping[1]	40.47	10.95	15.49	68.80
COMPLEX MOTOR				
Grooved Pegboard[2]	32.45	13.83	10.00	58.33
Maze Test[2]	34.15	16.23	10.00	62.45
VISUAL-SPATIAL SKILLS				
WISC Block Design	39.67	6.83	23.33	53.33
WISC Object Assembly	39.57	8.34	16.67	63.33
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	37.74	10.61	14.70	57.69
Category Test (Total error score)	41.04	8.78	12.80	57.84

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

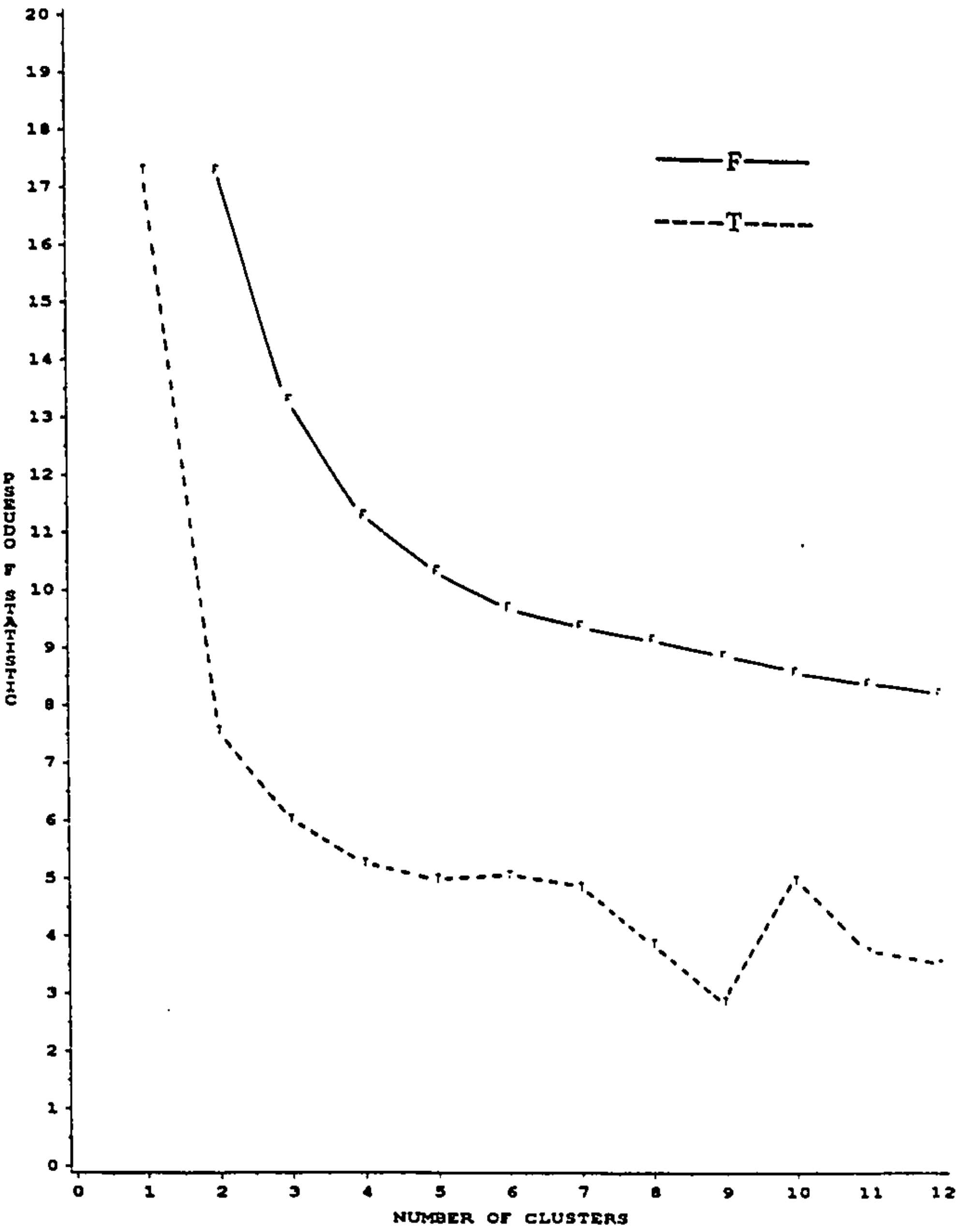


Figure 61. Phase III: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Sample B Subsample 1 (n=70) with TRIM=2, K=4.

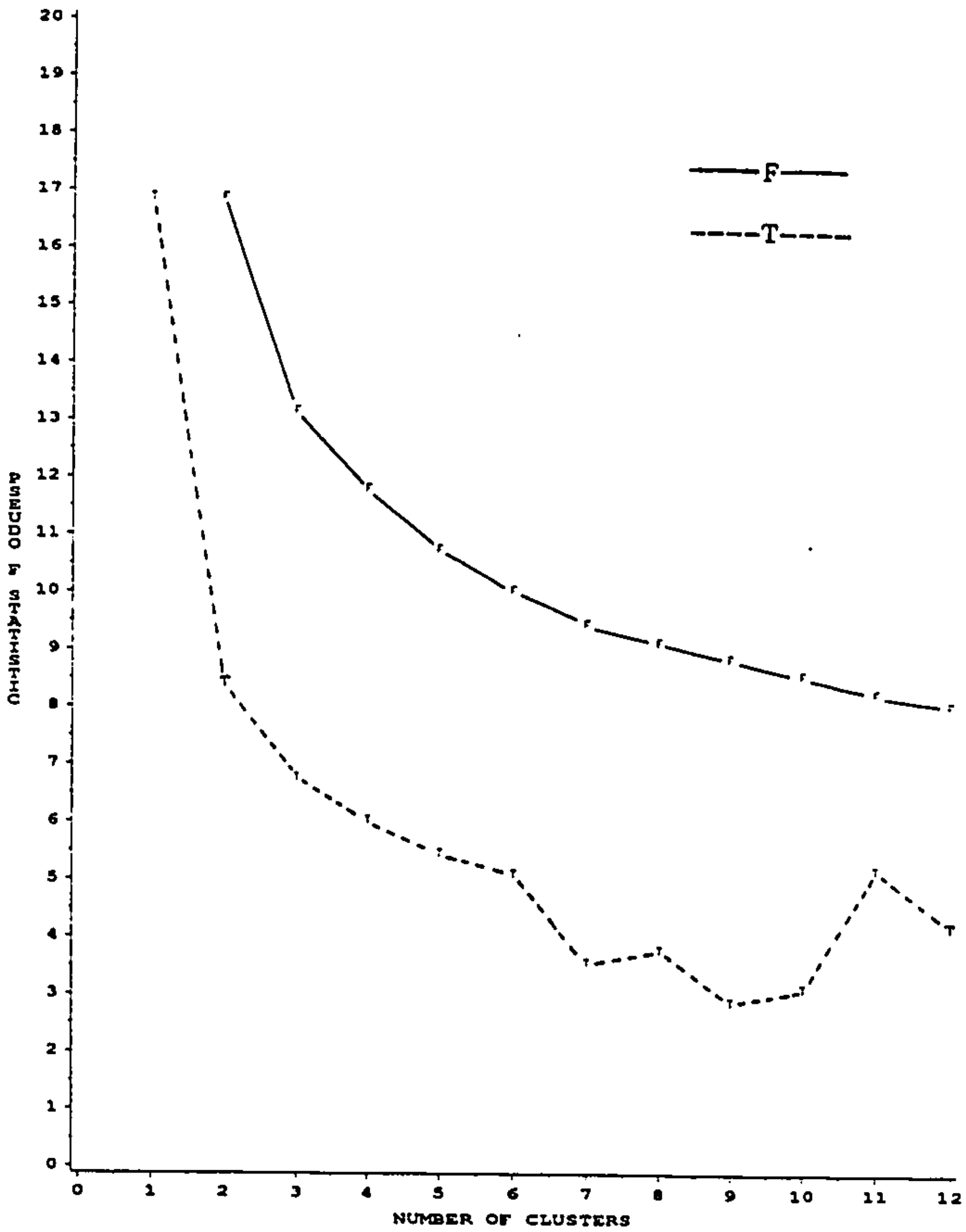


Figure 62. Phase III: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Sample B Subsample 1 (n=70) with TRIM=2, K=4.

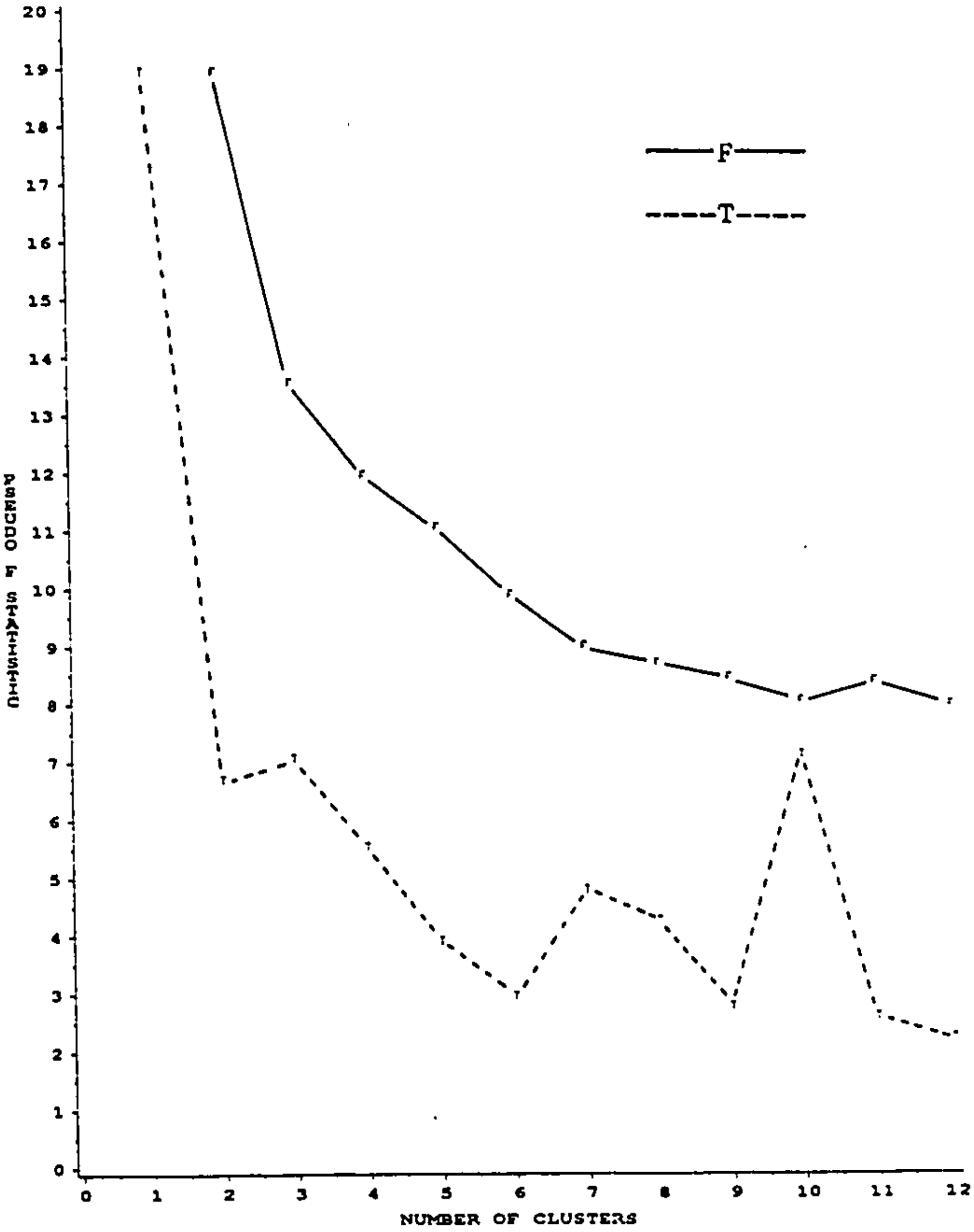


Figure 63. Phase III: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Sample B Subsample 1 (n=70) with TRIM=2, K=4.

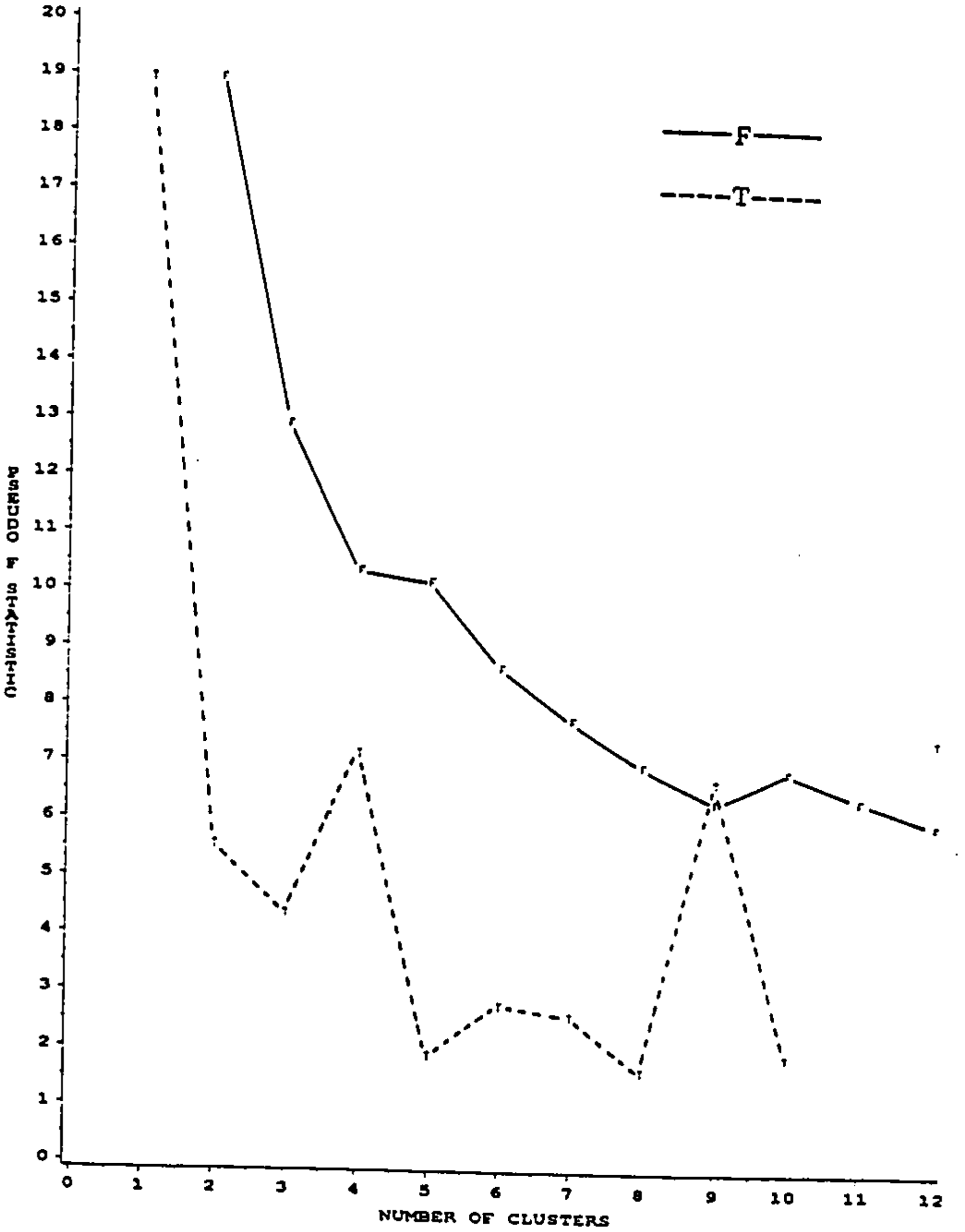


Figure 64. Phase III: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Sample B Subsample 1 (n=70) with TRIM=2, K=4.

64. However, the solution that produced the best levels of cross-method agreement was the four-cluster solution. Since it was apparent in all fusion coefficient plots it was considered the best choice for further consideration.

The misclassification analysis for the four-cluster solution of Sample B Subsample 1 is presented in Table 79. Ward's method (TRIM=2, K=4) was the target solution. Two children were removed as outliers and the remaining 68 classified into four subtypes. It is readily apparent in Table 79 that there was excellent agreement between Ward's method and the other three cluster techniques. Only 9% (overall) of the children in Ward's four-cluster partition were misclassified by the flexible-beta technique, while 10% and 13% were misclassified by the complete and average linkage methods, respectively.

The two internal validation samples (N=50 and N=35) were clustered using an identical TRIM=2 value to discard two percent of the most extreme subjects. With sample N=50 a K=4 value was used. For sample N=35, a K=3 value was employed.

The misclassification analyses for these internal validity samples are shown in Tables 80 and 81. There was very good overall agreement between the Ward's solution and the other three cluster methods for sample N=50 (see Table 80). However, the average linkage technique did not recover Ward's subtypes 3 or 4 within acceptable limits. With respect

Table 79

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Sample B Subsample 1 N=70 FSIQ 70-80)
(Neuropsychological Variables)

	Ward's Cluster Groups				
Cluster analysis method	1 (n=26)	2 (n=31)	3 (n=7)	4 (n=4)	Total (n=68)
Flexible-Beta Method	3 (12)	3 (10)	0 (0)	0 (0)	6 (9)
Complete Linkage	3 (12)	2 (6)	2 (29)	0 (0)	7 (10)
Average Linkage	0 (0)	3 (10)	2 (29)	4 (100)	9 (13)

Table 80

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=50 for Subsample 1)
(FSIQ 70-80 Neuropsychological Variables)

	Ward's Cluster Groups				
Cluster analysis method	1 (n=23)	2 (n=11)	3 (n=5)	4 (n=10)	Total (n=49)
Flexible-Beta Method	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Complete Linkage	10 (43)	2 (18)	0 (0)	0 (0)	12 (24)
Average Linkage	0 (0)	2 (18)	2 (40)	7 (70)	11 (22)

Table 81

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=35 for Subsample 1)
(FSIQ 70-80 Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=11)	2 (n=12)	3 (n=7)	4 (n=4)	Total (n=34)
Flexible-Beta Method	0 (0)	0 (0)	4 (57)	0 (0)	4 (12)
Complete Linkage	1 (9)	0 (0)	4 (57)	0 (0)	5 (15)
Average Linkage	1 (9)	12 (100)	6 (86)	0 (0)	19 (56)

to sample N=35 (Table 81), only the average linkage method failed to recover the Ward's subtypes in terms of the overall misclassification percentage. It was also apparent in Table 81 that none of the three cluster methods accurately recovered the third Ward subtype.

The four cluster profiles which emerged from the analysis of Sample B Subsample 1 are displayed in Figure 65. These four clusters appeared to be quite different both in terms of profile shape and elevation. The individual profiles of each Ward subtype #1 which emerged from Subsample 1 and validation samples N=50 and N=35 were plotted together in Figure 66.

With the exception of the elevation in the mean MAZE score for the sample N=35 subtype #1, it was apparent that this subtype was replicated across two spilt-samples. The individual profiles of the other Ward subtypes and relevant validation sample subtypes are graphically represented in Figures 67 to 69. As seen in Figure 67, Ward's subtype #2 was not well replicated by the subtype which emerged from the validation sample N=50. However, subtype #2 was recovered with several minor variations in elevation by the subtype from sample N=35. Ward's subtype #3, shown in Figure 68, was accurately reproduced by clusters from both internal validity samples. It was evident in Figure 69 that Ward's subtype #4 was accurately reproduced only by the analysis of

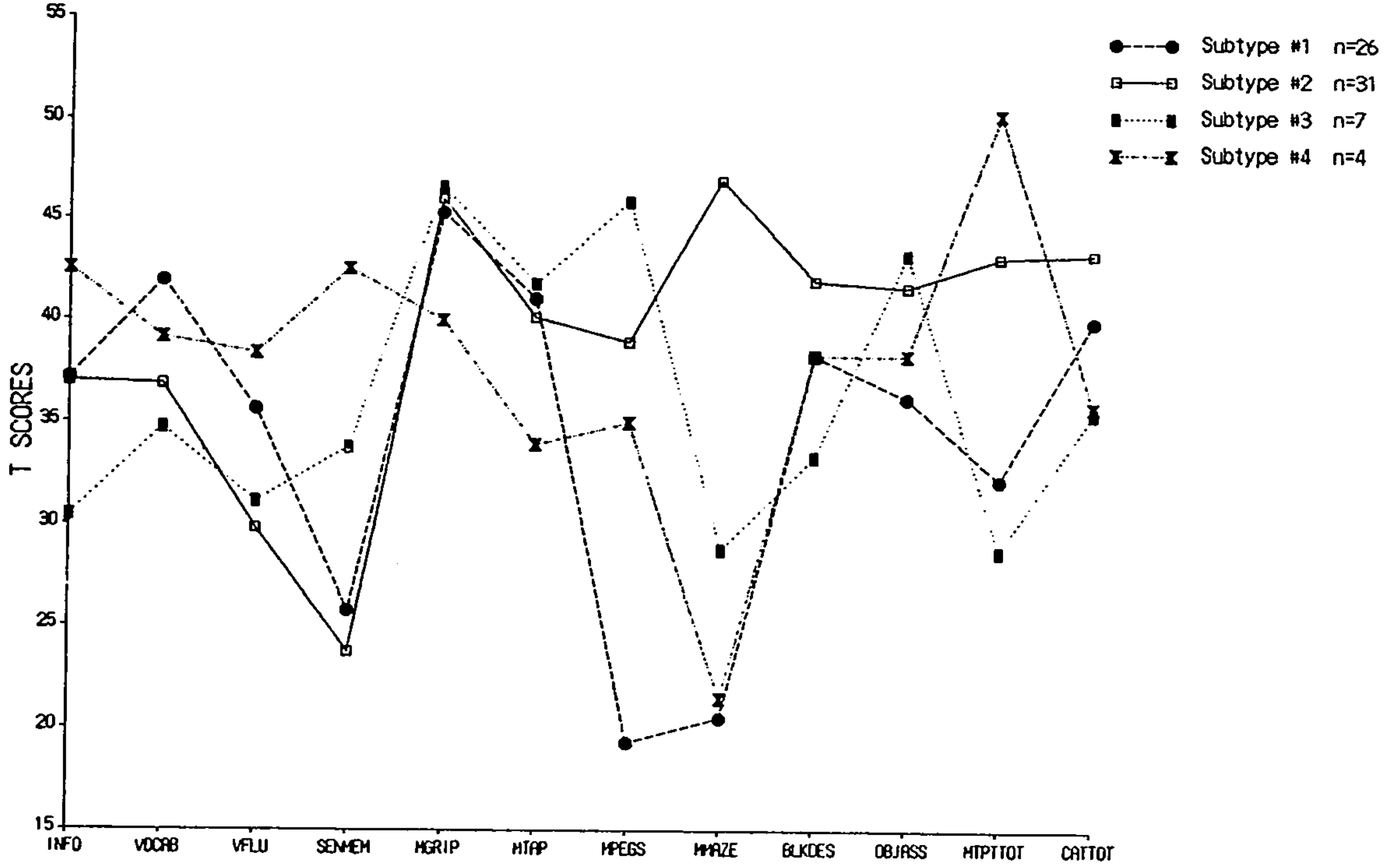


Figure 65. Plot of the four subtypes which emerged from Ward's cluster analysis of Sample B Subsample 1 (n=70).

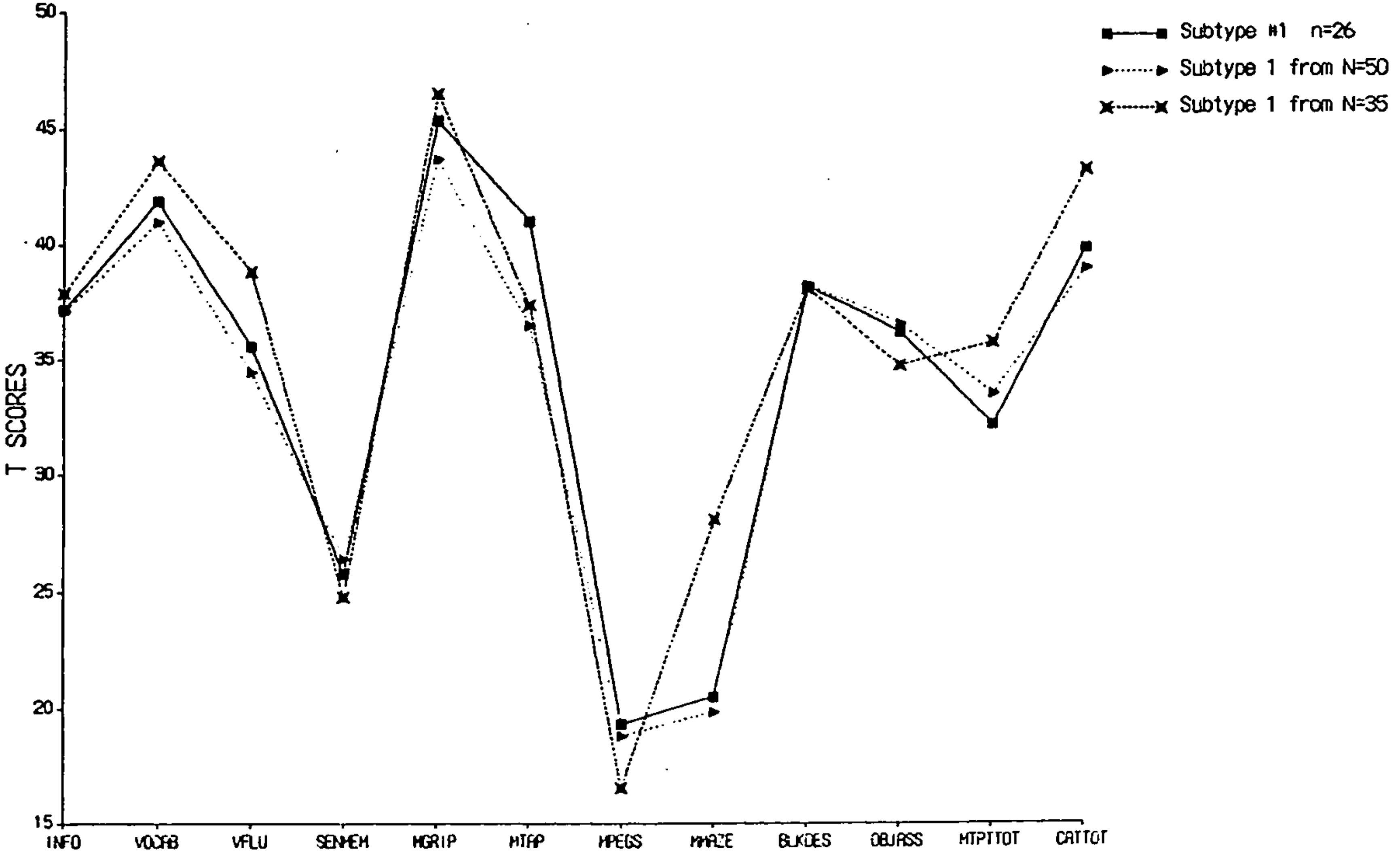


Figure 66. Composite plot of all subtype 1 mean profiles from the cluster analyses of Sample B Subsample 1 and split-samples N=50 and N=35.

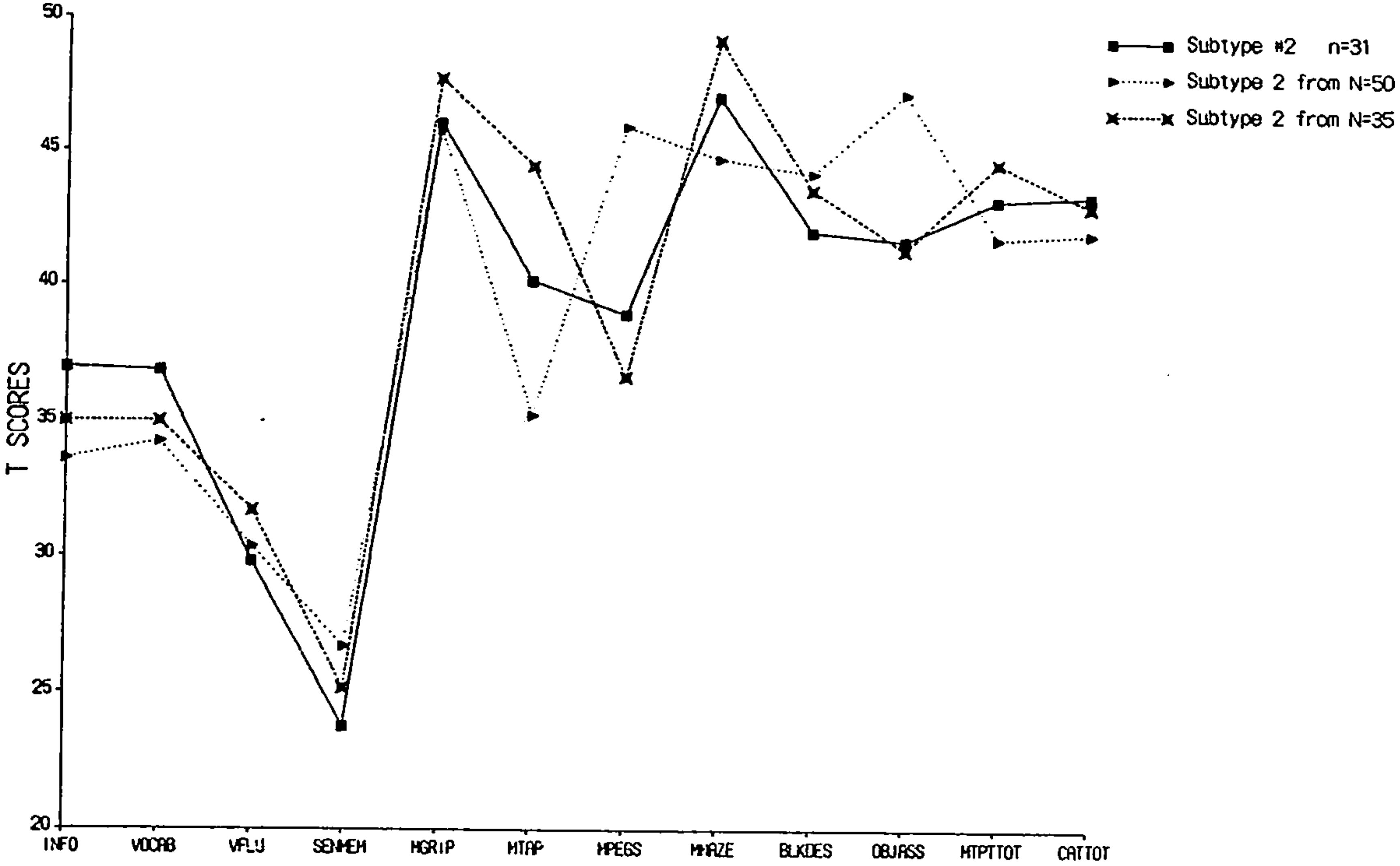


Figure 67. Composite plot of all subtype 2 mean profiles from the cluster analyses of Sample B Subsample 1 and split-samples N=50 and N=35.

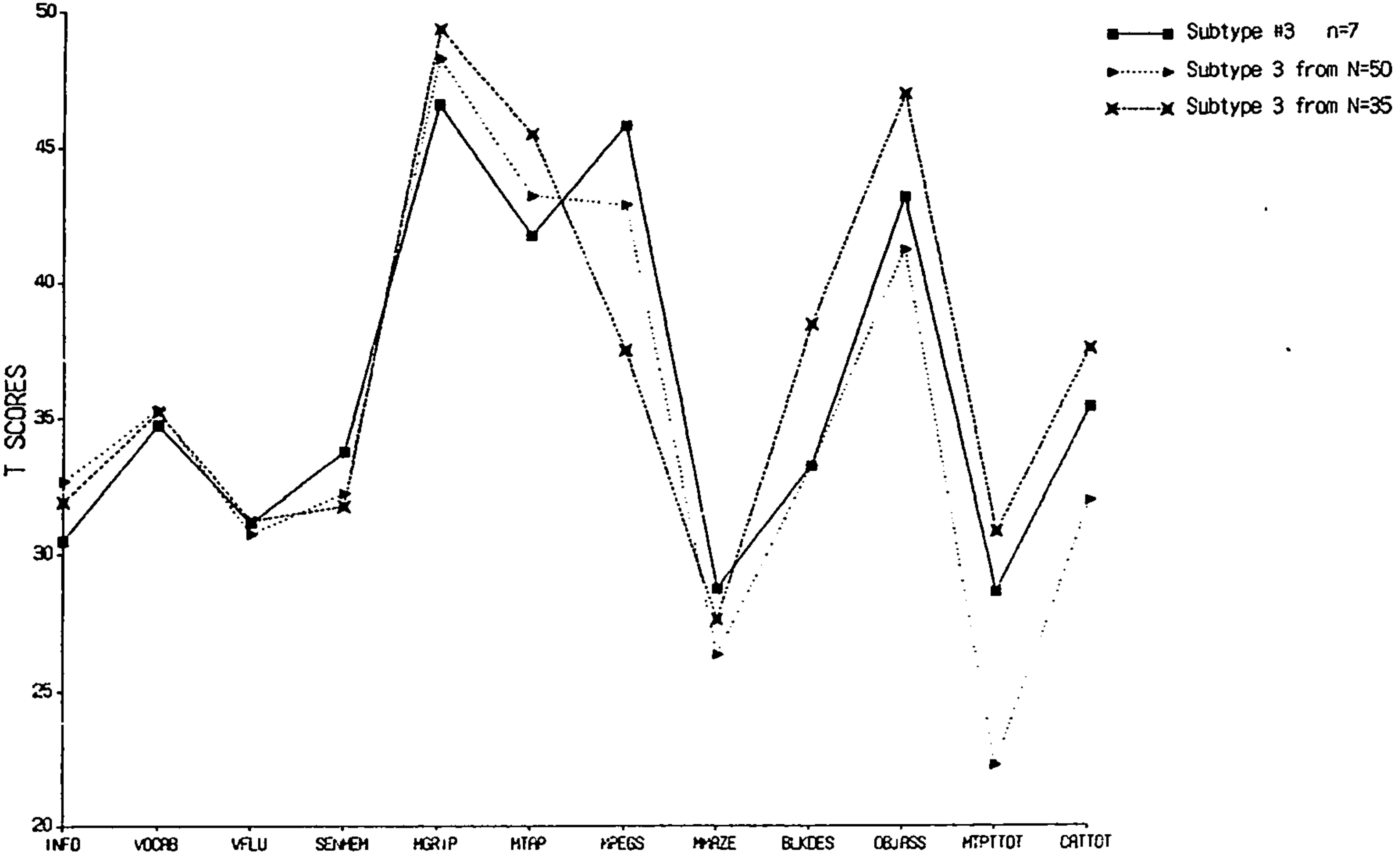


Figure 68. Composite plot of all subtype 3 mean profiles from the cluster analyses of Sample B Subsample 1 and split-samples N=50 and N=35.

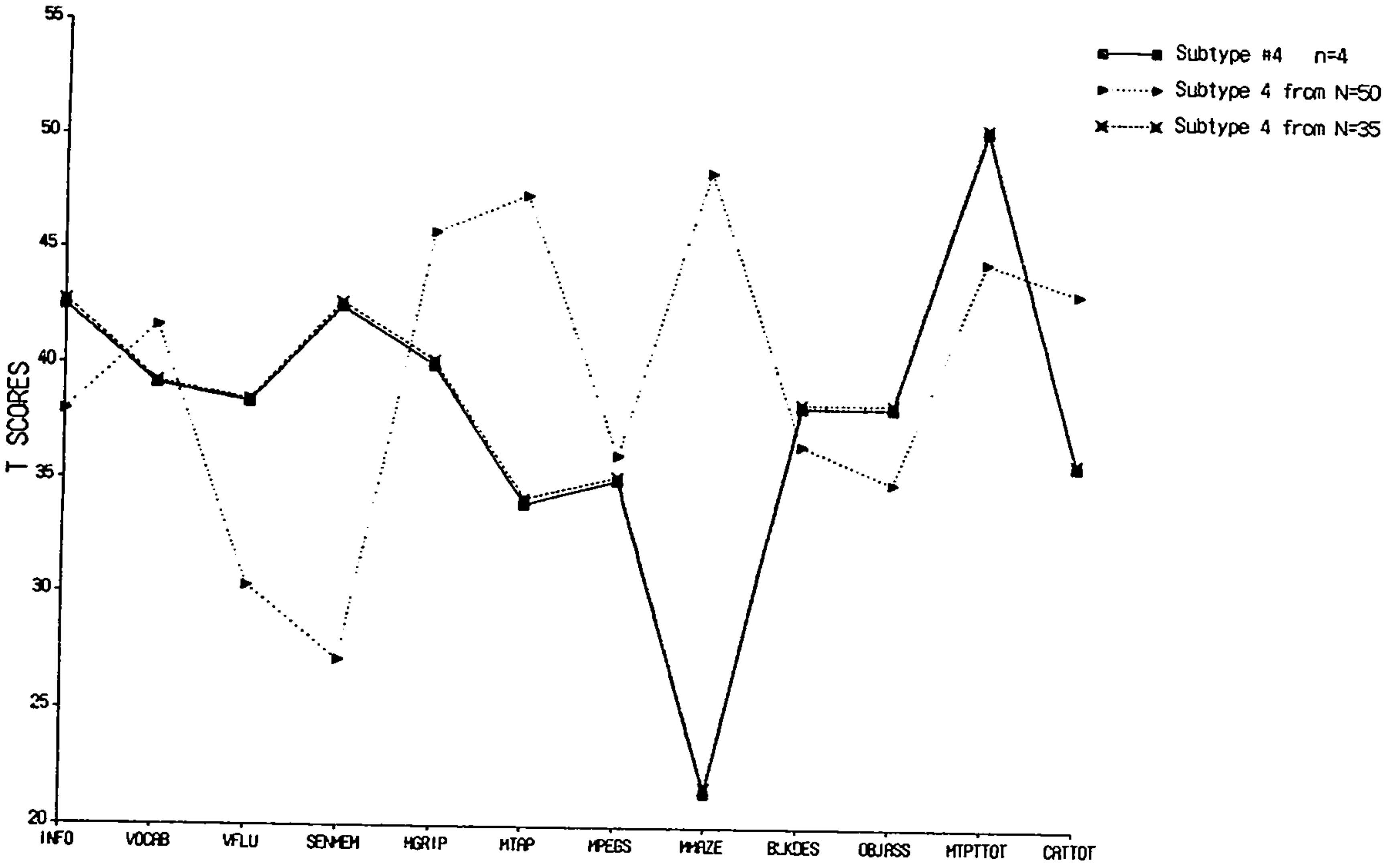


Figure 69. Composite plot of all subtype 4 mean profiles from the cluster analyses of Sample B Subsample 1 and split-samples N=50 and N=35.

sample N=35.

In summary, Sample B Subsample 1 (WISC FSIQ 70-80) was clustered into four subtypes with good agreement between the Ward's solution and the other cluster methods. Ward's subtypes #1 and #3 were accurately recovered from internal validity samples N=50 and N=35. Ward's subtypes #2 and #4 were accurately recovered only from sample N=35.

Sample B Subsample 2: WISC FSIQ (81-90)

The raw scores for all 12 neuropsychological variables were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The T-score means, standard deviations, and maximum and minimum values for the Sample B Subsample 2 (n=70) neuropsychological variables are presented in Table 82.

The plots of the pseudo F and T cluster coefficients for Ward's method are displayed in Figure 70. The fusion plots for the other three cluster methods are displayed in Figures 71 to 73. Although there are relative drops in 'pseudo T' in these Figures indicating more than a six-cluster partition, none were found with acceptable levels of cross-method agreement and were not considered further. As seen in Figures 70 to 73 there were possible solutions corresponding to relative rises in 'pseudo F' indicating a 2, 3, 4, or 5 cluster partition. However, the solution that produced the best levels of cross-method agreement was the

Table 82

Phase III:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample B Subsample 2 (WISC FSIQ 81-90)

	Mean (n=70)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	40.00	5.92	30.00	56.67
WISC Vocabulary	43.76	5.95	33.33	60.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	36.34	9.76	16.79	67.86
Sentence Memory	31.71	11.91	10.00	60.43
SIMPLE MOTOR SKILLS				
Grip Strength[1]	49.54	5.48	39.46	69.82
Finger Tapping[1]	45.36	11.02	20.08	79.32
COMPLEX MOTOR				
Grooved Pegboard[2]	40.99	13.36	10.00	67.00
Maze Test[2]	45.76	14.37	10.00	64.36
VISUAL-SPATIAL SKILLS				
WISC Block Design	45.95	8.43	30.00	63.33
WISC Object Assembly	46.38	8.35	26.67	70.00
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	45.43	8.83	10.00	58.53
Category Test (Total error score)	45.43	8.07	22.15	61.15

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

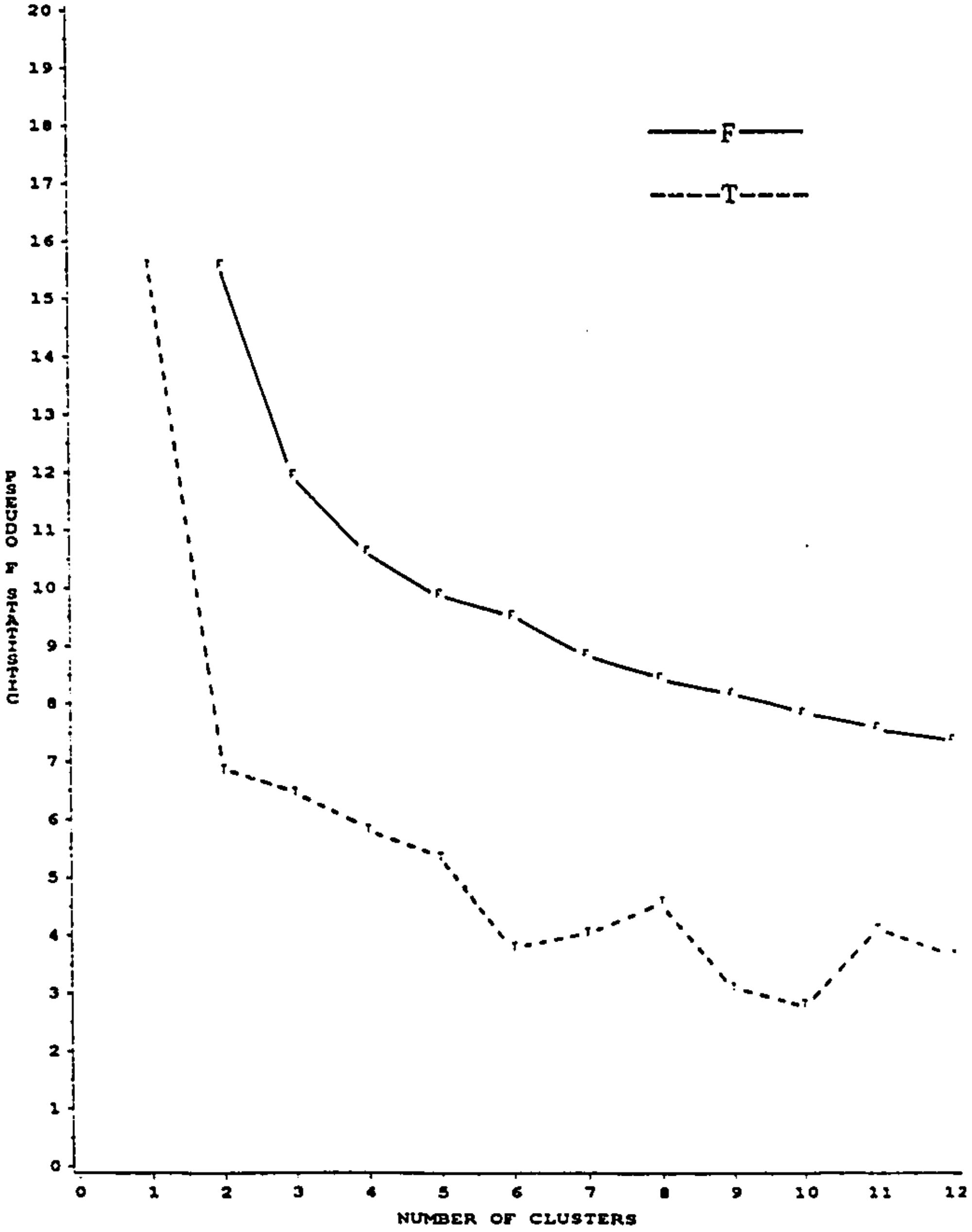


Figure 70. Phase III: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Sample B Subsample 2 (n=70) with TRIM=2, K=4.

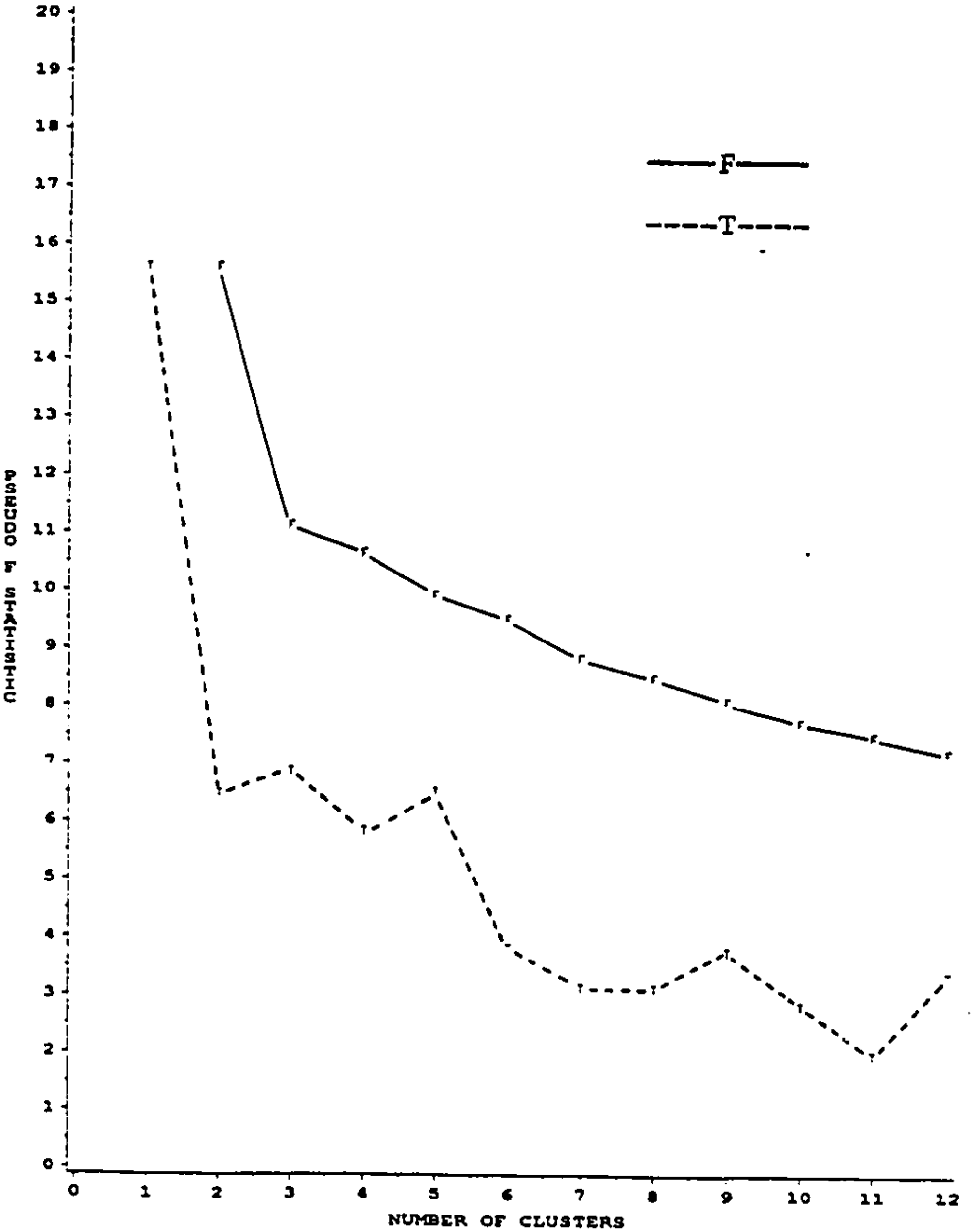


Figure 71. Phase III: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Sample B Subsample 2 (n=70) with TRIM=2, K=4.

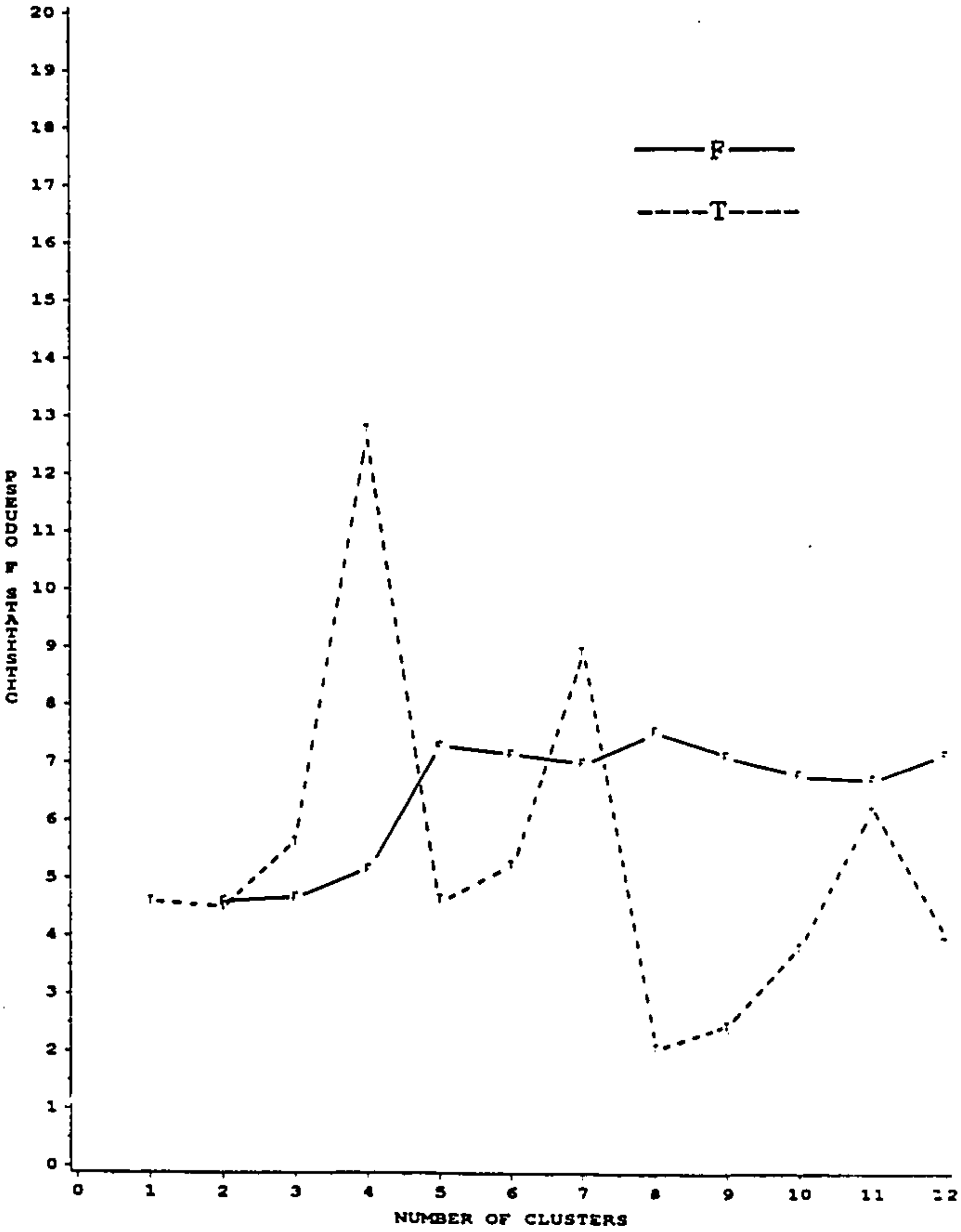


Figure 72. Phase III: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Sample B Subsample 2 (n=70) with TRIM=2, K=4.

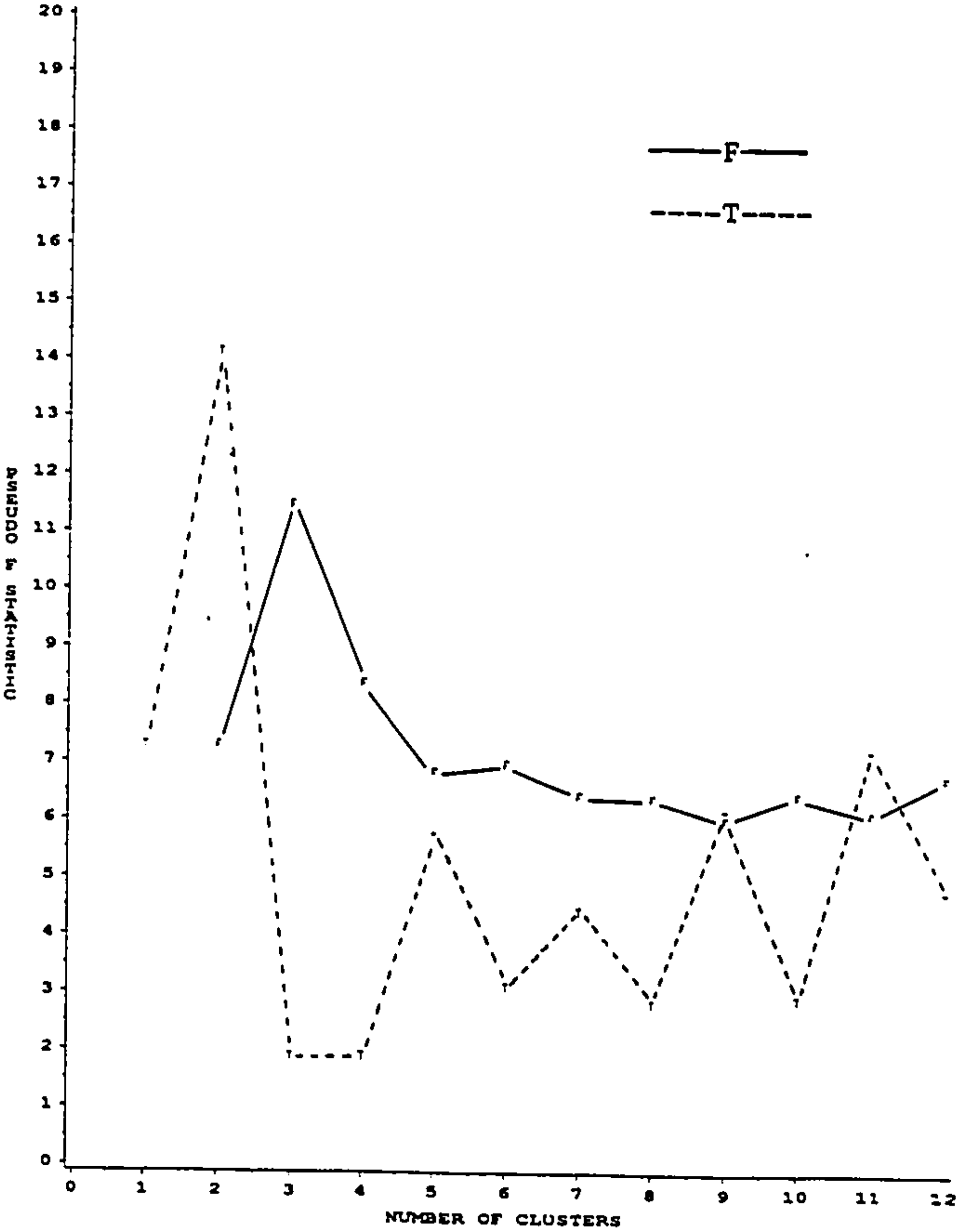


Figure 73. Phase III: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Sample B Subsample 2 (n=70) with TRIM=2, K=4.

four-cluster solution. Since it was apparent in all fusion coefficient plots it was considered the best choice for further consideration.

The misclassification analysis for the four-cluster solution of Sample B Subsample 2 is presented in Table 83. Ward's method (TRIM=2, K=4) was the target solution. Two children were removed as outliers and the remaining 68 classified into four subtypes. It is apparent in Table 83 that there was excellent agreement between Ward's method and the flexible-beta technique. Only 6% (overall) of the children in Ward's four-cluster partition were misclassified by the flexible-beta technique. However, the overall agreement between Ward's method and the other two cluster analytic techniques exceeded the 30% misclassification limit. In terms of misclassifications for the individual Ward clusters, complete linkage recovered subtypes #1 and #2, while average linkage recovered only subtype #2 adequately.

The two internal validation samples (N=50 and N=35) were cluster analyzed using an identical TRIM=2 value to discard 2% of the most extreme subjects. With sample N=50 a K=4 value was used. For sample N=35, a K=3 value was employed.

The misclassification analyses for these internal validity samples are shown in Tables 84 and 85. There was very good overall agreement between the Ward's solution and

Table 83

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Sample B Subsample 2 N=70 FSIQ 81-90)
(Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=35)	2 (n=15)	3 (n=12)	4 (n=6)	Total (n=68)
Flexible-Beta Method	4 (11)	0 (0)	0 (0)	0 (0)	4 (6)
Complete Linkage	6 (17)	2 (13)	8 (67)	6 (100)	24 (35)
Average Linkage	12 (34)	3 (20)	8 (67)	6 (100)	29 (43)

Table 84

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=50 for Subsample 2)
(FSIQ 81-90 Neuropsychological Variables)

	Ward's Cluster Groups				
Cluster analysis method	1 (n=17)	2 (n=9)	3 (n=10)	4 (n=13)	Total (n=49)
Flexible-Beta Method	1 (6)	0 (0)	1 (10)	0 (0)	2 (4)
Complete Linkage	1 (6)	3 (33)	1 (10)	1 (8)	6 (12)
Average Linkage	0 (0)	0 (0)	5 (50)	11 (85)	16 (35)

Table 85

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=35 for Subsample 2)
(FSIQ 81-90 Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=13)	2 (n=8)	3 (n=6)	4 (n=7)	Total (n=34)
Flexible-Beta Method	1 (8)	0 (0)	0 (10)	0 (0)	1 (4)
Complete Linkage	7 (54)	0 (0)	0 (0)	5 (71)	12 (35)
Average Linkage	0 (0)	0 (0)	0 (0)	2 (29)	2 (6)

the flexible-beta and complete linkage methods for sample N=50 (see Table 84). Although the average linkage technique did recover Ward's subtypes #1 and #2 within acceptable limits, the overall misclassification rate (i.e., 35%) was too high. With respect to sample N=35 (Table 85), only the complete linkage method failed to recover the Ward's subtypes in terms of the overall misclassification percentage. It was also apparent in Table 85 that all four of the Ward's clusters were accurately recovered by at least two cluster-analytic methods.

The four cluster profiles which emerged from the analysis of Sample B Subsample 2 are displayed in Figure 74. These four clusters appeared to be quite different both in terms of profile shape and elevation. The individual profiles of each Ward subtype #1 which emerged from Subsample 2 and validation samples N=50 and N=35 were plotted together in Figure 75. It was readily apparent that this subtype was replicated across two spilt-samples. The individual profiles of the other Ward subtypes and relevant validation sample subtypes are graphically represented in Figures 76 to 78.

Although there was some differences in elevation for Sentence Memory as seen in Figure 76, Ward's subtype #2 was well replicated by the subtypes which emerged from validation samples N=50 and N=35. Ward's subtype #3, shown in

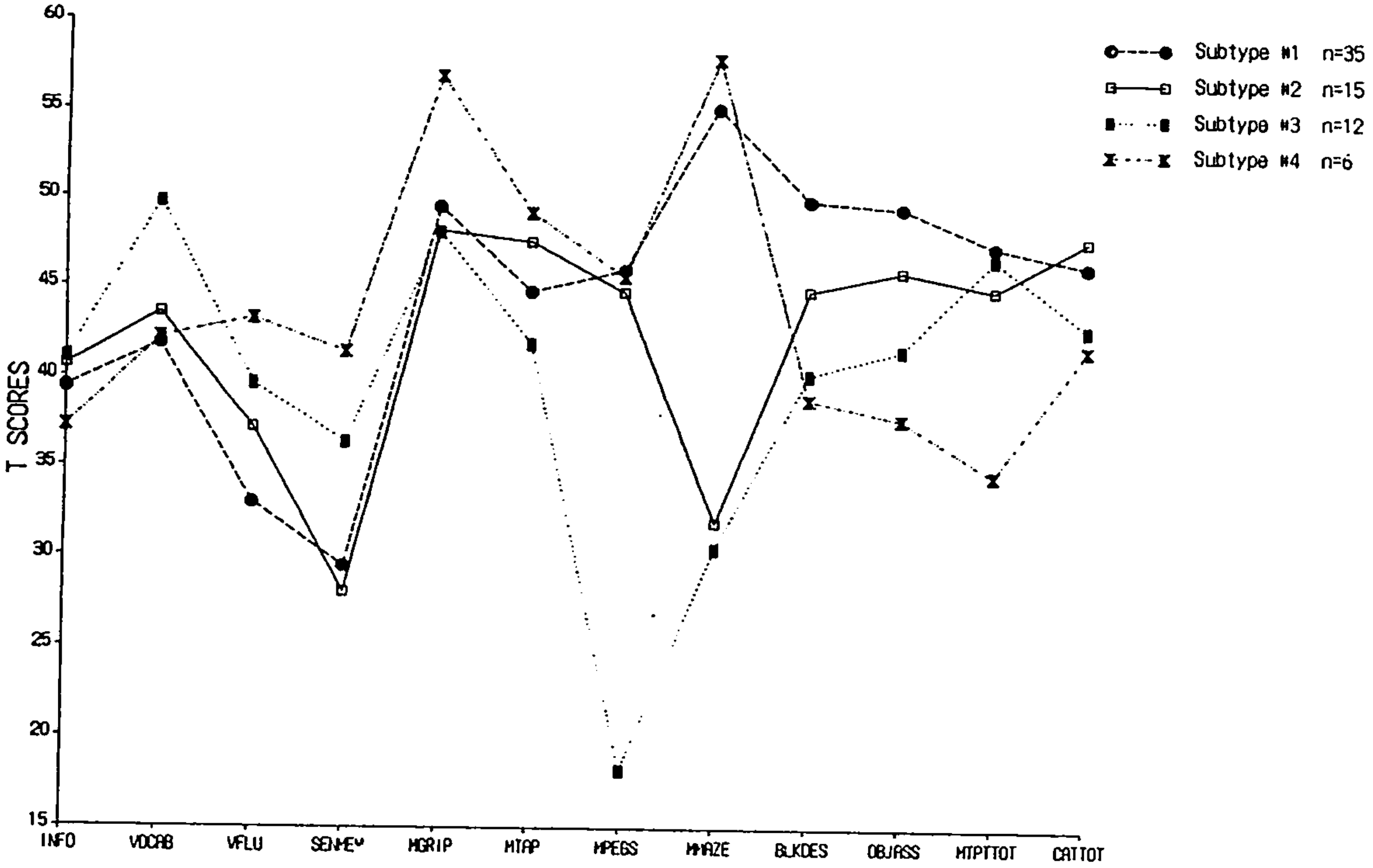


Figure 74. Plot of the four subtypes which emerged from Ward's cluster analysis of Sample B Subsample 2 (n=70).

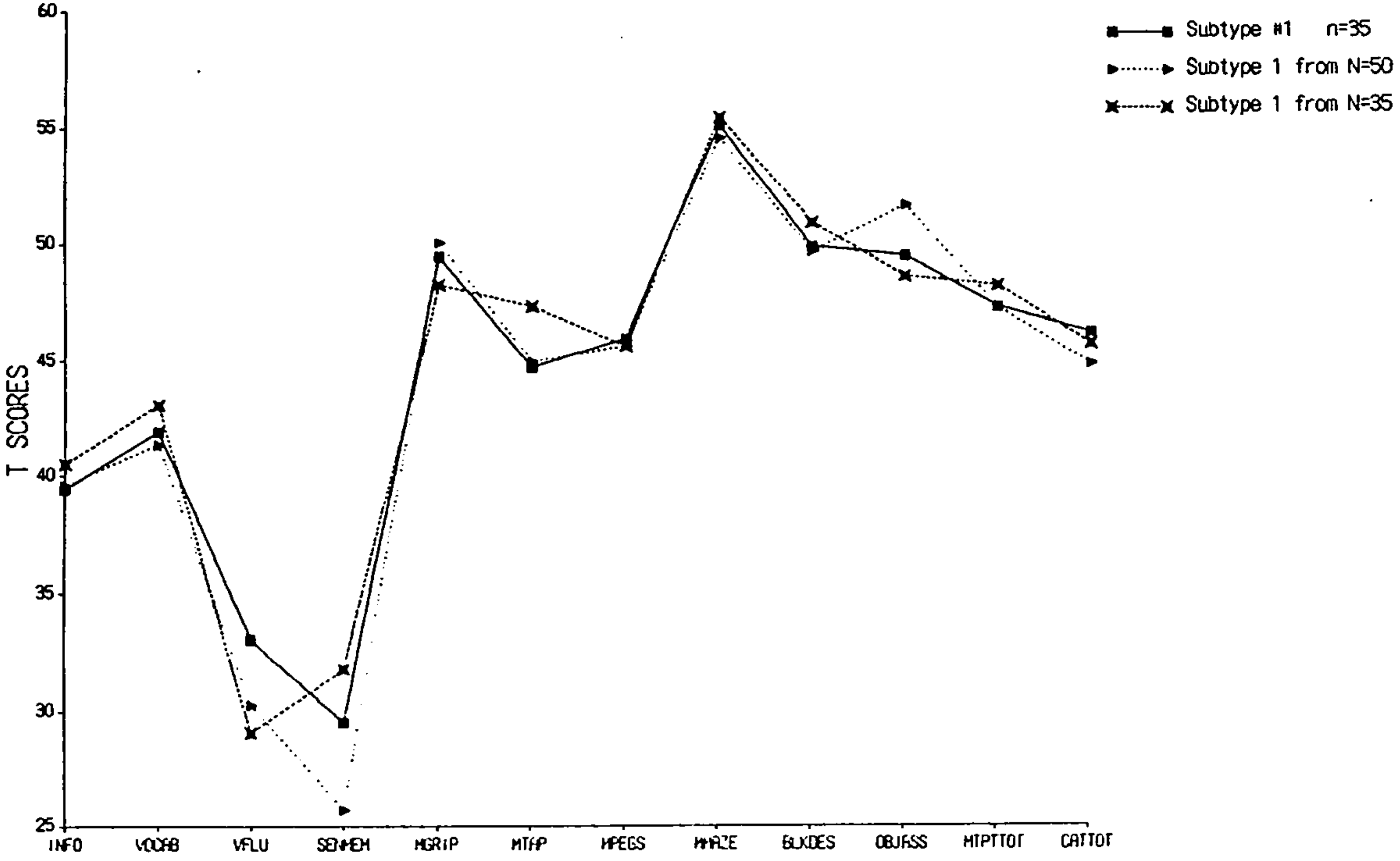


Figure 75. Composite plot of all subtype 1 mean profiles from the cluster analyses of Sample B Subsample 2 and split-samples N=50 and N=35.

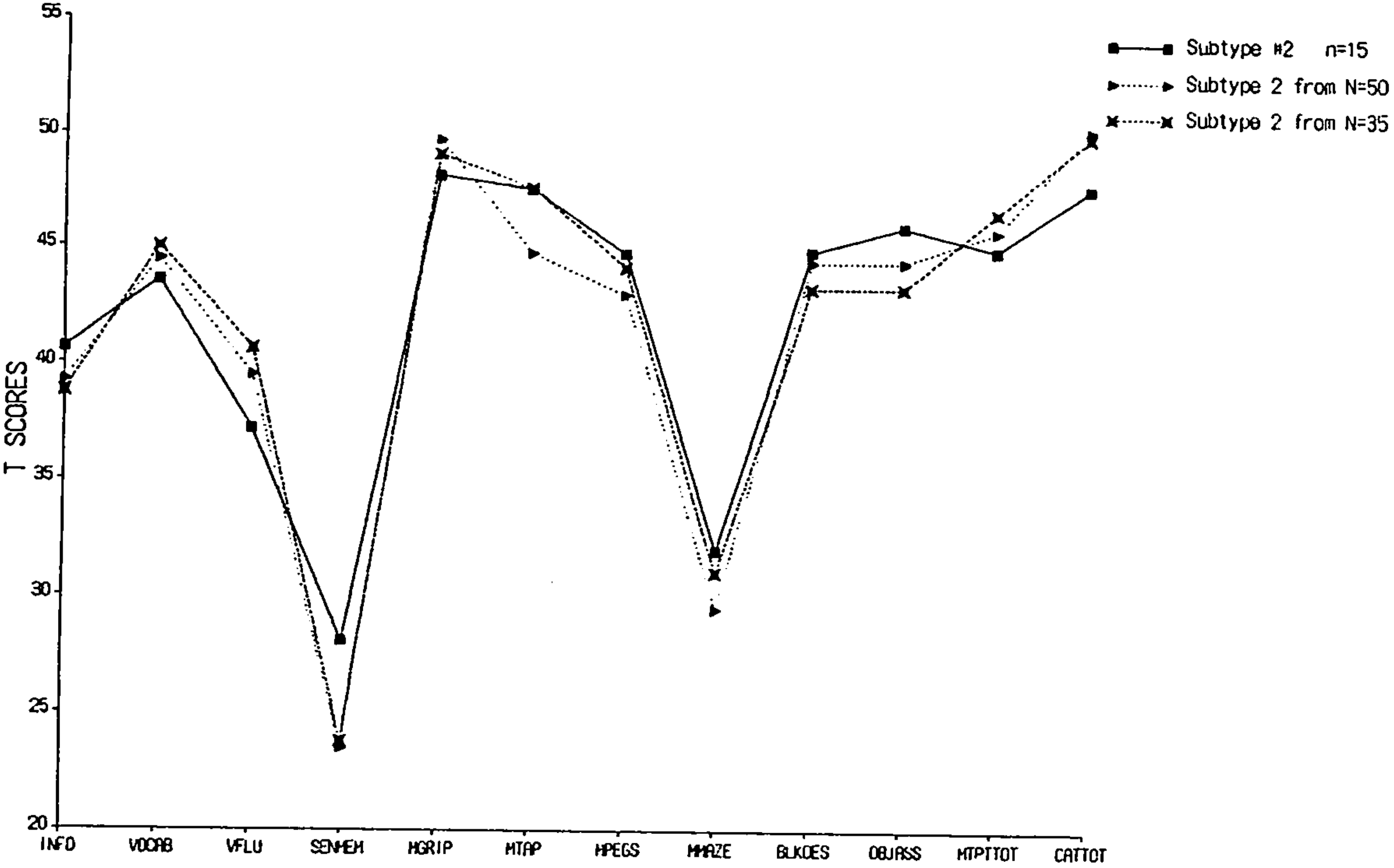


Figure 76. Composite plot of all subtype 2 mean profiles from the cluster analyses of Sample B Subsample 2 and split-samples N=50 and N=35.

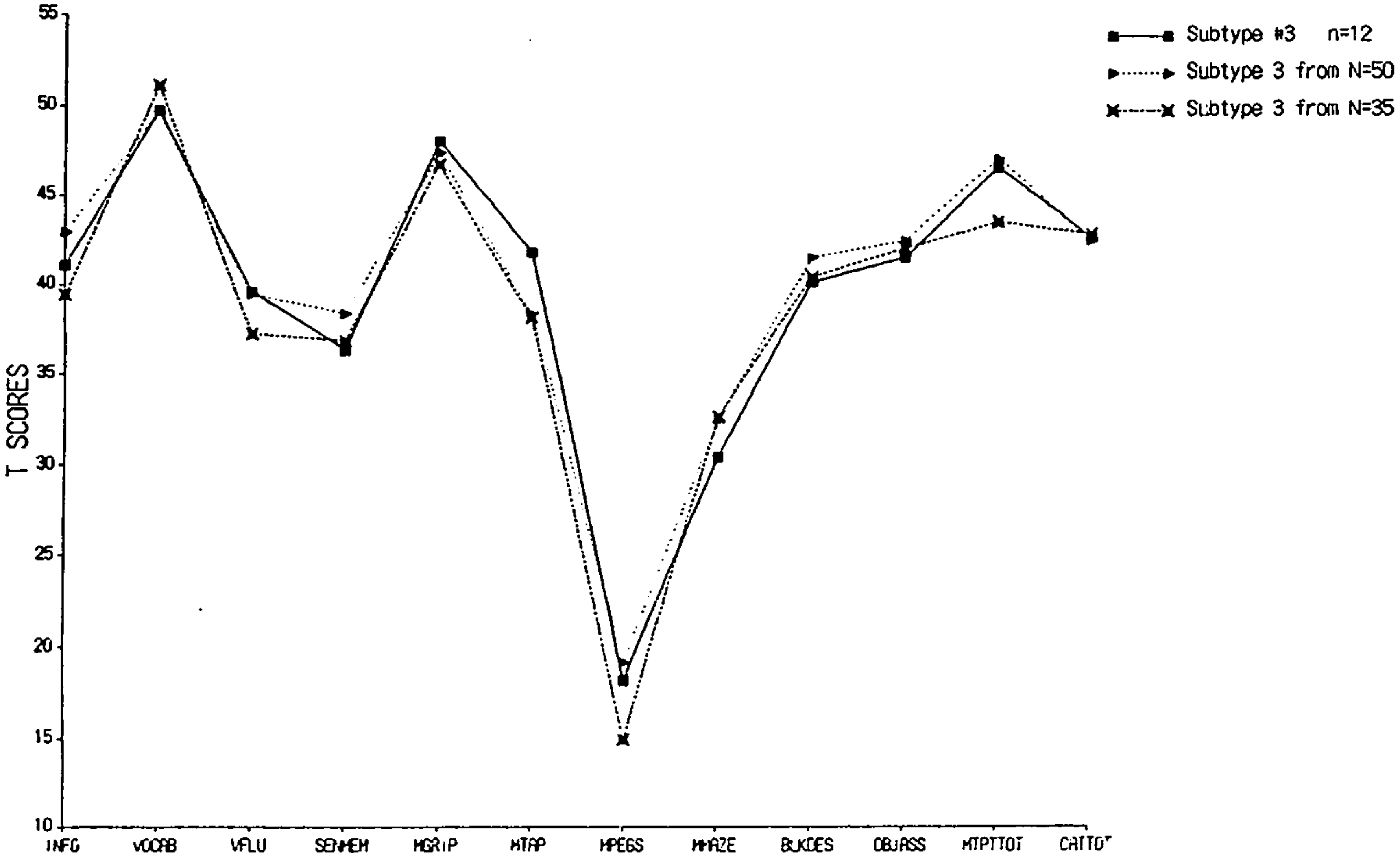


Figure 77. Composite plot of all subtype 3 mean profiles from the cluster analyses of Sample B Subsample 2 and split-samples N=50 and N=35.

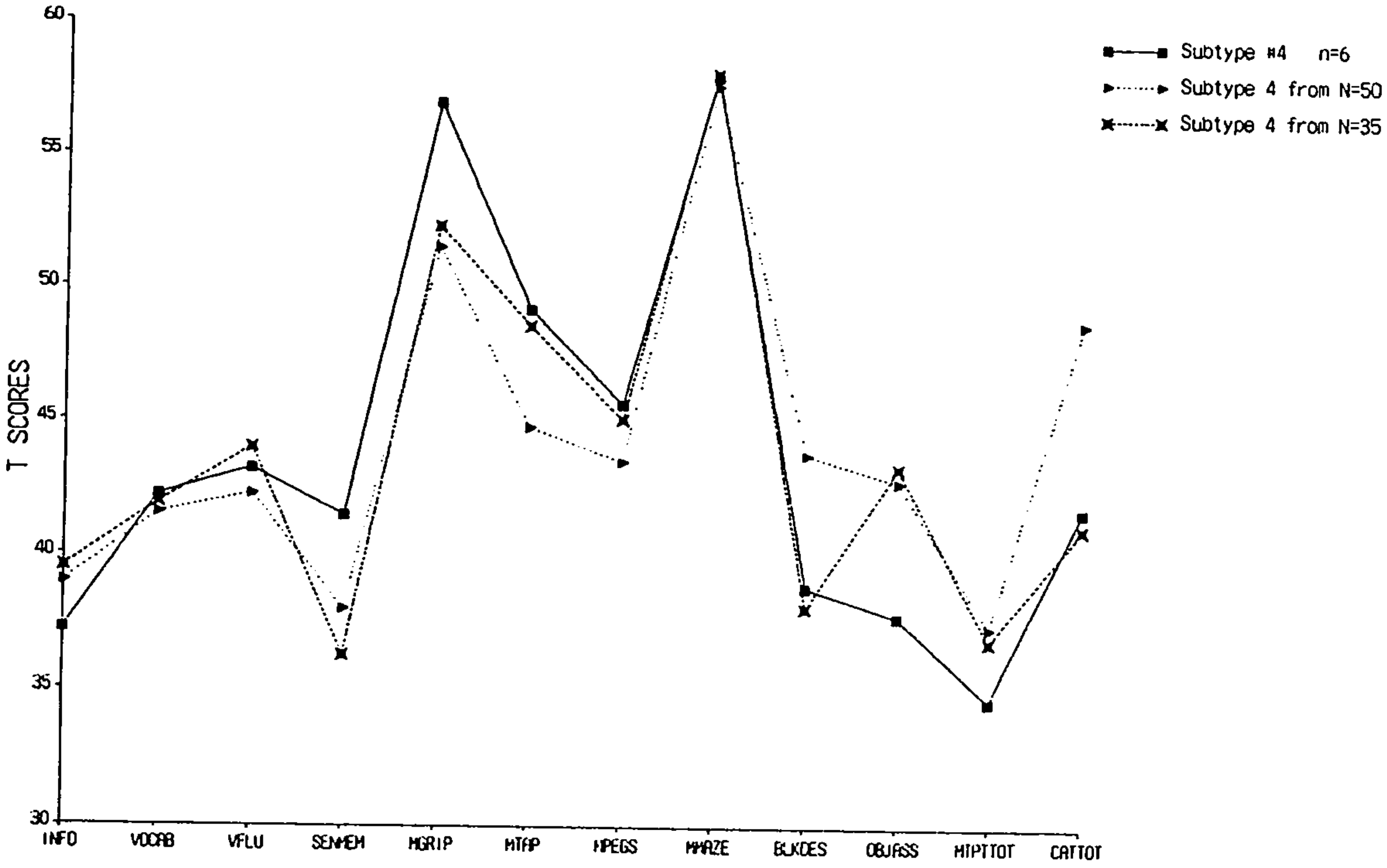


Figure 78. Composite plot of all subtype 4 mean profiles from the cluster analyses of Sample B Subsample 2 and split-samples N=50 and N=35.

Figure 77, was accurately reproduced by clusters from both internal validity samples. The profile shape of Ward's subtype #4 was accurately reproduced by the analysis of samples N=50 and N=35. However, there were differences in the elevation of the three profiles compared in Figure 78. These differences were not considered significant since elevation was removed prior to the cluster analyses in order to emphasize profile shape.

In summary, Sample B Subsample 2 (WISC FSIQ 81-90) was clustered into four subtypes with good agreement between the Ward's solution and the other cluster methods. All four of the Ward's subtypes were accurately recovered from both internal validity samples N=50 and N=35.

Sample B Subsample 3: WISC FSIQ (91-100)

The raw scores for all 12 neuropsychological variables were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The T-score means, standard deviations, and maximum and minimum values for the Sample B Subsample 3 (n=70) neuropsychological variables are presented in Table 86.

The plots of the pseudo F and T cluster coefficients for Ward's method are displayed in Figure 79. The fusion plots for the other three cluster methods are displayed in Figures 80 to 82. Although there are relative drops in 'pseudo T' in these Figures indicating more than a five-

Table 86

Phase III:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample B Subsample 3 (WISC FSIQ 91-100)

	Mean (n=70)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	41.81	6.41	23.33	56.67
WISC Vocabulary	46.62	6.36	33.33	60.00
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	39.69	10.37	14.29	72.93
Sentence Memory	37.44	11.39	11.83	59.57
SIMPLE MOTOR SKILLS				
Grip Strength[1]	50.41	6.86	36.35	78.63
Finger Tapping[1]	49.67	9.53	25.78	73.59
COMPLEX MOTOR				
Grooved Pegboard[2]	44.43	13.85	10.00	86.44
Maze Test[2]	46.92	14.64	10.00	65.40
VISUAL-SPATIAL SKILLS				
WISC Block Design	49.67	7.55	36.67	70.00
WISC Object Assembly	50.92	8.49	33.33	66.67
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	48.96	7.92	25.09	60.16
Category Test (Total error score)	48.94	8.07	24.27	67.44

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

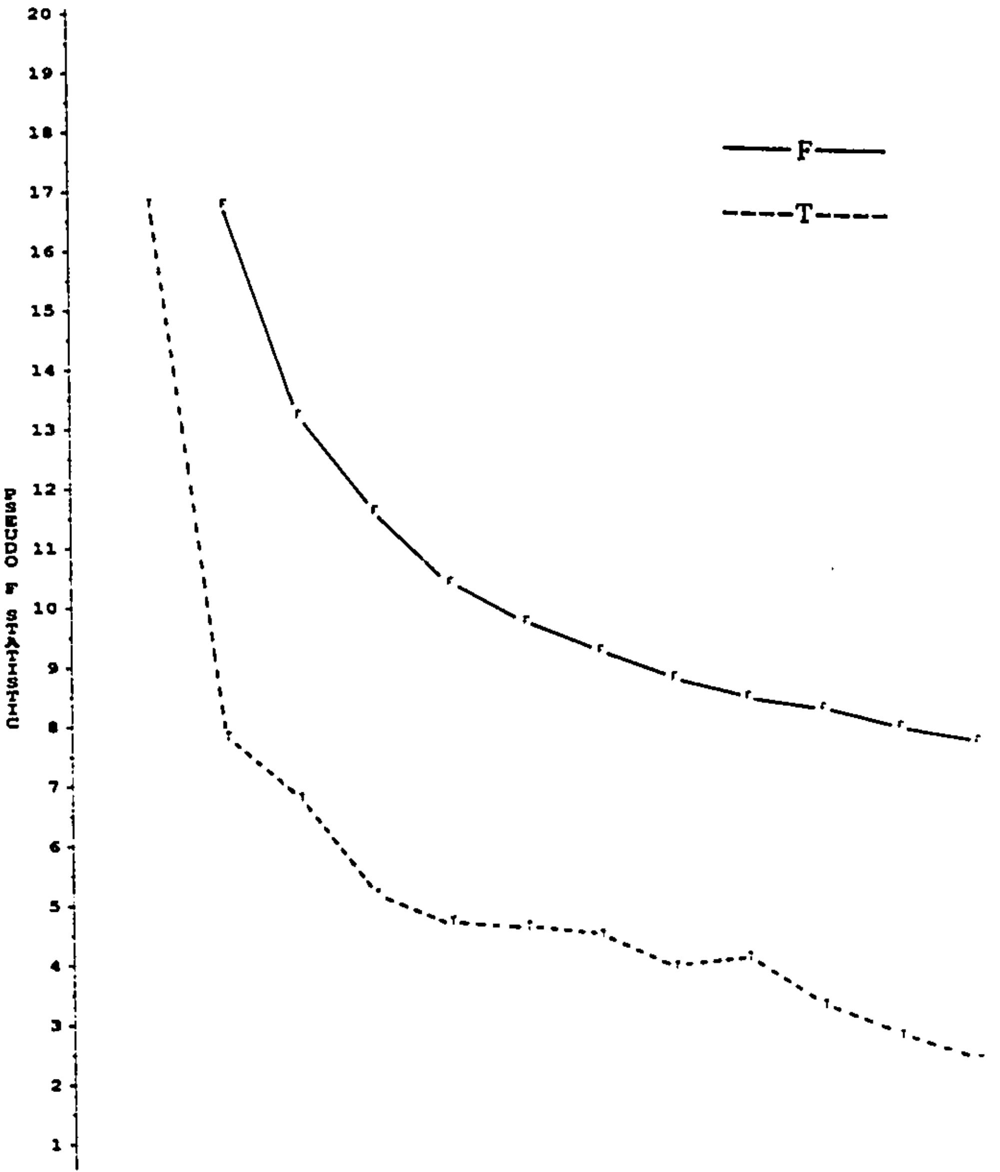


Figure 79. Phase III: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Sample B Subsample 3 (n=70) with TRIM=5, K=4.

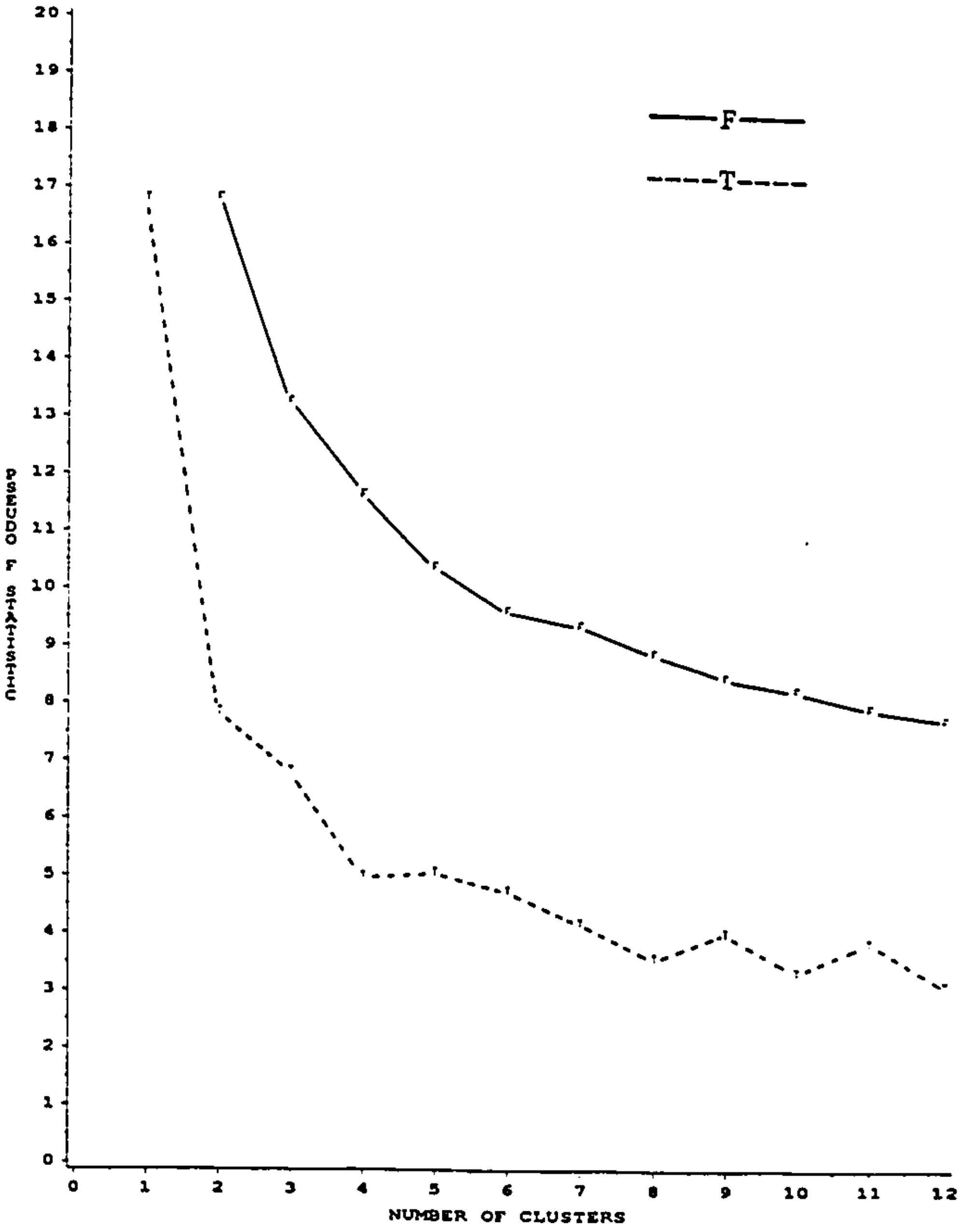


Figure 80. Phase III: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Sample B Subsample 3 (n=70) with TRIM=5, K=4.

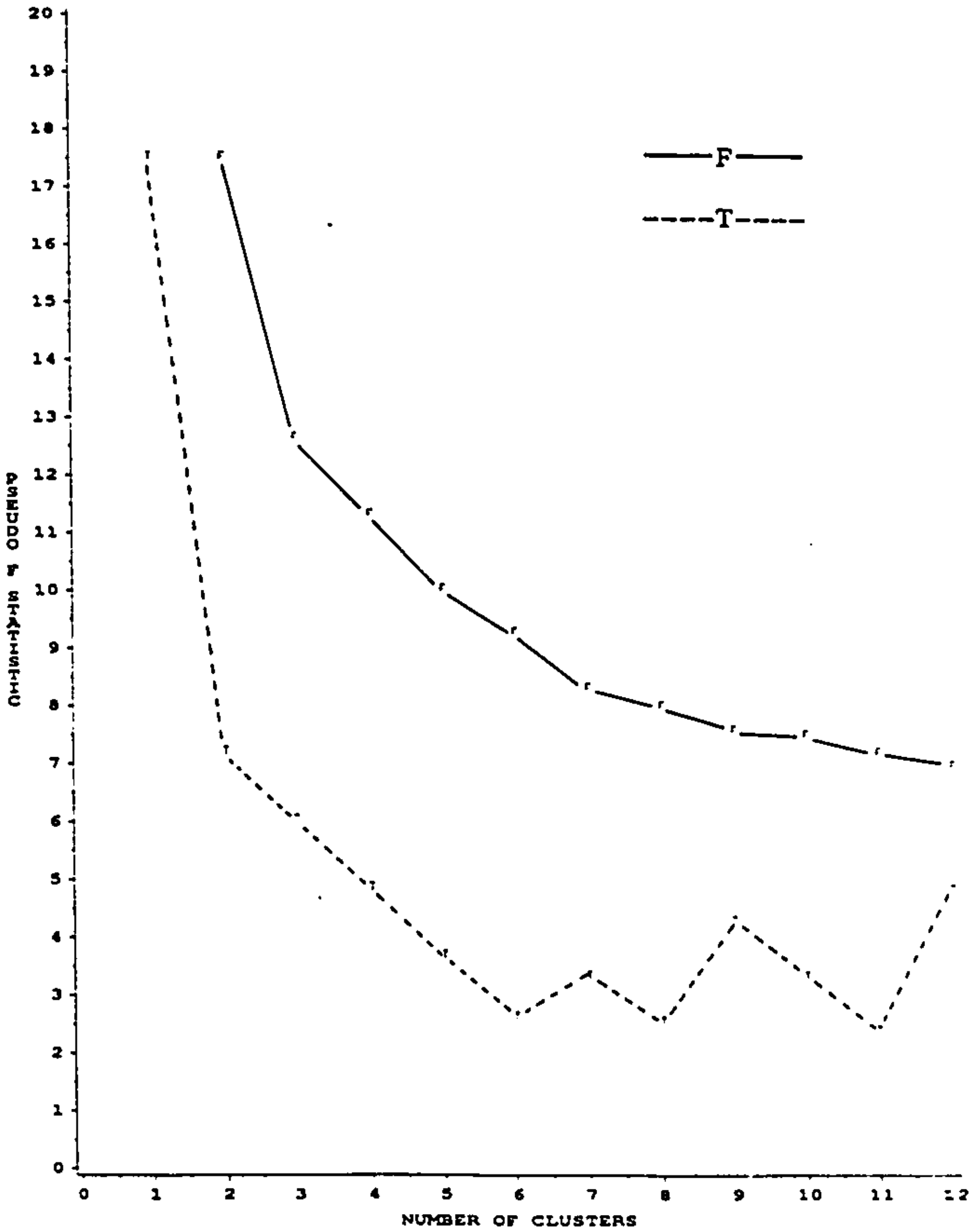


Figure 81. Phase III: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Sample B Subsample 3 (n=70) with TRIM=5, K=4.

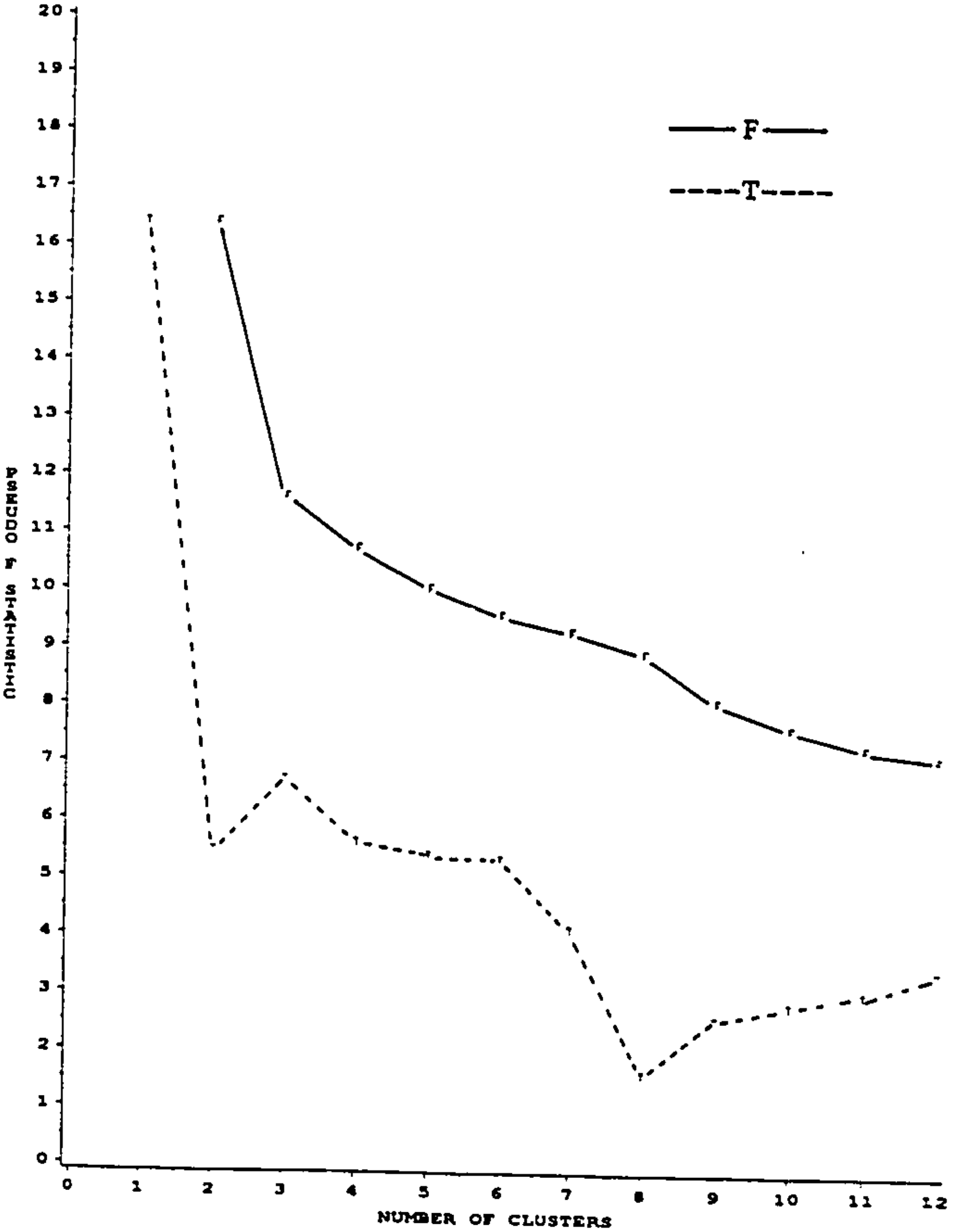


Figure 82. Phase III: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Sample B Subsample 3 (n=70) with TRIM=5, K=4.

cluster partition, none were found with acceptable levels of cross-method agreement and were not considered further. As seen in Figures 79 to 82 there were possible solutions corresponding to relative rises in 'pseudo F' indicating a 2, 3, or 4 cluster partition. However, the solution which produced the best levels of cross-method agreement was the four-cluster solution. Since it was apparent in all fusion coefficient plots it was considered the best choice for further consideration in the present study.

The misclassification analysis for the four-cluster solution of Sample B Subsample 3 is presented in Table 87. Ward's method (TRIM=5, K=4) was the target solution. Four children were removed as outliers and the remaining 66 classified into four subtypes. It is apparent in Table 87 that there was excellent agreement between Ward's method and the flexible-beta technique. None of the children in Ward's four-cluster partition were misclassified by the flexible-beta technique. There was a high (26%) but acceptable misclassification rate between Ward's method and the average linkage technique. However, the overall agreement between Ward's method and the complete linkage cluster-analytic technique was unacceptable (30% misclassified). In terms of misclassifications for the individual Ward clusters, complete linkage recovered subtypes #1 and #4, while average linkage recovered subtypes #1 and #2 adequately.

Table 87

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Sample B Subsample 3 N=70 FSIQ 91-100)
(Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=24)	2 (n=18)	3 (n=17)	4 (n=7)	Total (n=66)
Flexible-Beta Method	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Complete Linkage	1 (4)	10 (55)	9 (53)	0 (0)	20 (30)
Average Linkage	1 (4)	2 (11)	10 (60)	4 (57)	17 (26)

Table 88

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=50 for Subsample 3)
(FSIQ 91-100 Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=16)	2 (n=15)	3 (n=11)	4 (n=5)	Total (n=47)
Flexible-Beta Method	6 (38)	0 (0)	0 (0)	0 (0)	6 (13)
Complete Linkage	0 (0)	10 (67)	0 (0)	3 (60)	13 (28)
Average Linkage	0 (0)	0 (0)	3 (27)	3 (60)	6 (13)

Table 89

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=35 for Subsample 3)
(FSIQ 91-100 Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=13)	2 (n=9)	3 (n=9)	4 (n=2)	Total (n=33)
Flexible-Beta Method	0 (0)	6 (67)	0 (0)	0 (0)	6 (18)
Complete Linkage	4 (30)	5 (55)	0 (0)	0 (0)	9 (27)
Average Linkage	0 (0)	7 (78)	0 (0)	0 (0)	7 (21)

The two internal validation samples (N=50 and N=35) were clustered using an identical TRIM=5 value to discard 5% of the most extreme subjects. With sample N=50 a K=4 value was used. For sample N=35, a K=3 value was employed.

The misclassification analyses for these internal validity samples are shown in Tables 88 and 89. There was very good overall agreement (13% misclassified) between the Ward's solution and the flexible-beta and average linkage methods for sample N=50 (see Table 88). Although the complete linkage technique did not recover Ward's subtypes #2 and #4 within acceptable limits, the overall misclassification rate (i.e., 28%) was within acceptable limits. With respect to sample N=35 (Table 89), all three cluster methods adequately recovered the Ward's subtypes in terms of the overall misclassification percentage. However, it was also apparent in Table 89 that none of the other cluster methods accurately recovered Ward's subtype #2.

The four cluster profiles which emerged from the analysis of Sample B Subsample 3 are displayed in Figure 83. These four clusters appeared to be quite different both in terms of profile shape and elevation. The individual profiles of each Ward subtype #1 which emerged from Subsample 3 and validation samples N=50 and N=35 were plotted together in Figure 84. It was readily apparent that this subtype was replicated across two spilt-samples with some

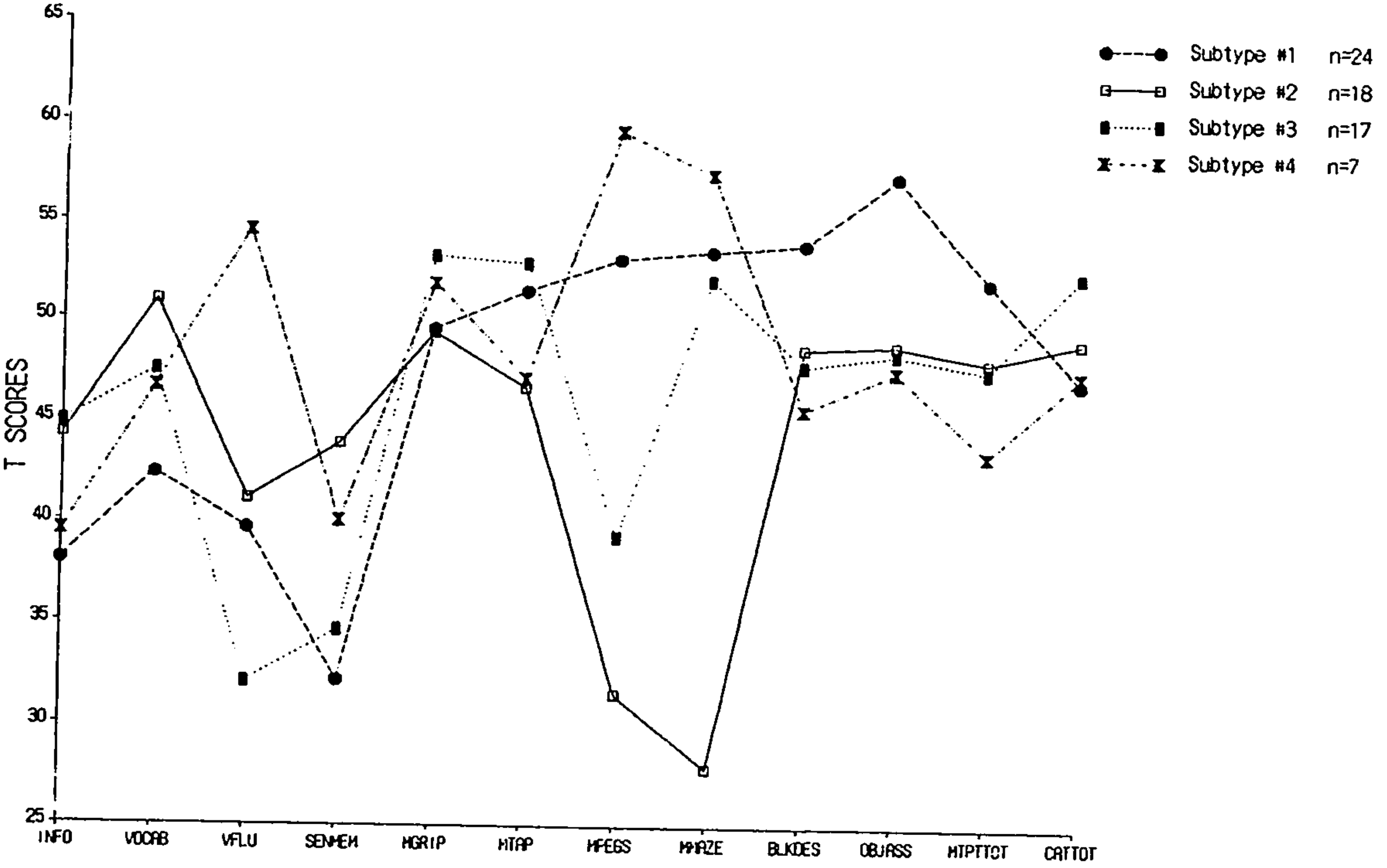


Figure 83. Plot of the four subtypes which emerged from Ward's cluster analysis of Sample B Subsample 3 (n=70).

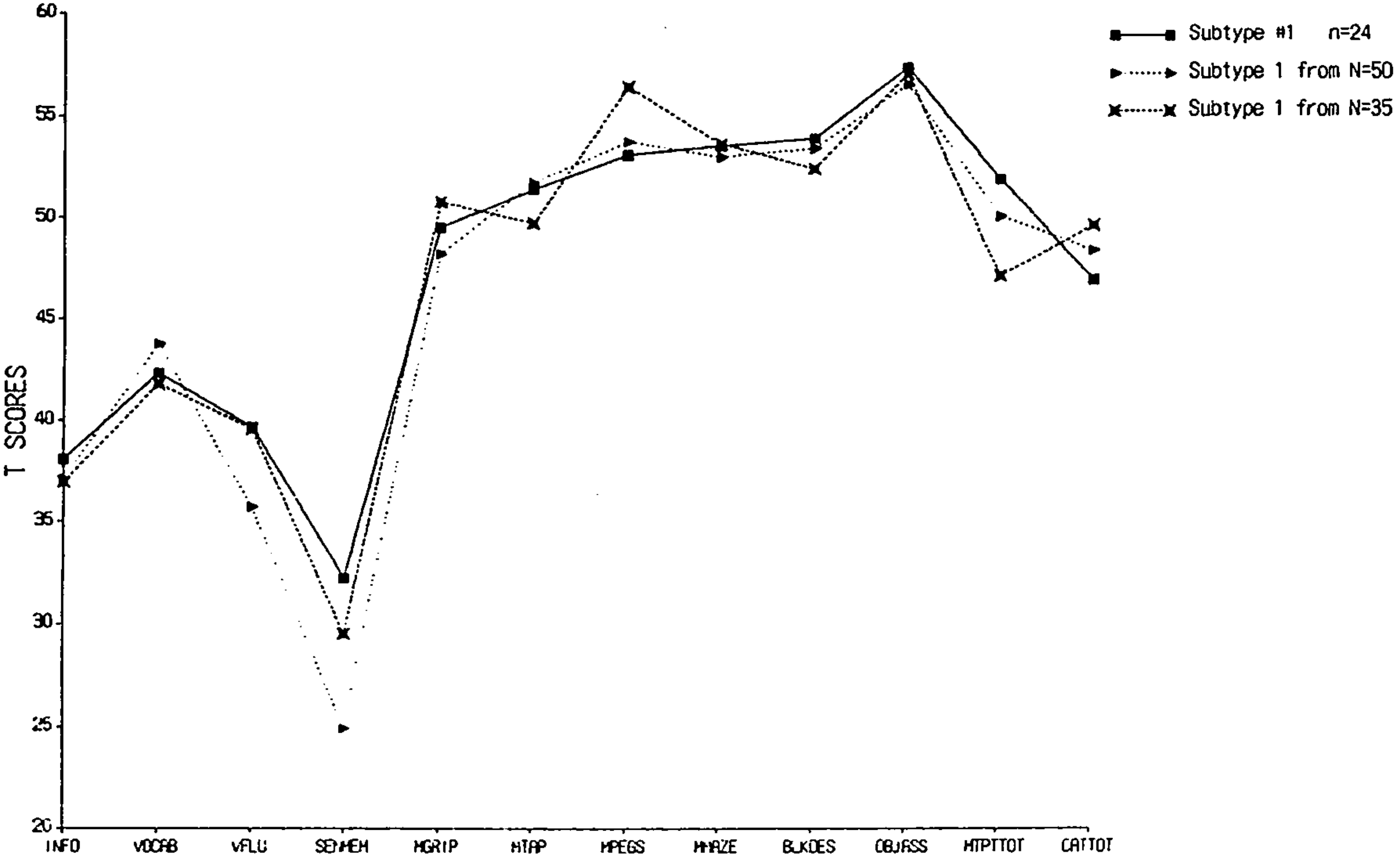


Figure 84. Composite plot of all subtype 1 mean profiles from the cluster analyses of Sample B Subsample 3 and split-samples N=50 and N=35.

minor differences in profile elevation. The individual profiles of the other Ward subtypes and relevant validation sample subtypes are displayed in Figures 85 to 87.

As seen in Figure 85, Ward's subtype #2 was well replicated by the subtypes which emerged from validation samples N=50 and N=35. Ward's subtype #3, shown in Figure 86, was most accurately reproduced by the cluster profile from internal validity sample N=35. The cluster profile from sample N=50 was also quite accurate but showed some deviations in elevation on the measures of complex language abilities. The profile shape and elevation of Ward's subtype #4 (Figure 87) were accurately reproduced by the analysis of sample N=50. However, cluster profile which emerged from the analysis of sample N=35 was most unlike Ward's subtype #4.

In summary, Sample B Subsample 3 (WISC FSIQ 91-100) was cluster analyzed into four subtypes with good agreement between the Ward's solution and the other cluster methods. Ward's subtypes #1 and #2 were accurately recovered from internal validity samples N=50 and N=35. Ward's subtype #3 was most accurately recovered from validation sample N=35, while Ward's subtype #4 was only recovered from the analysis of sample N=50.

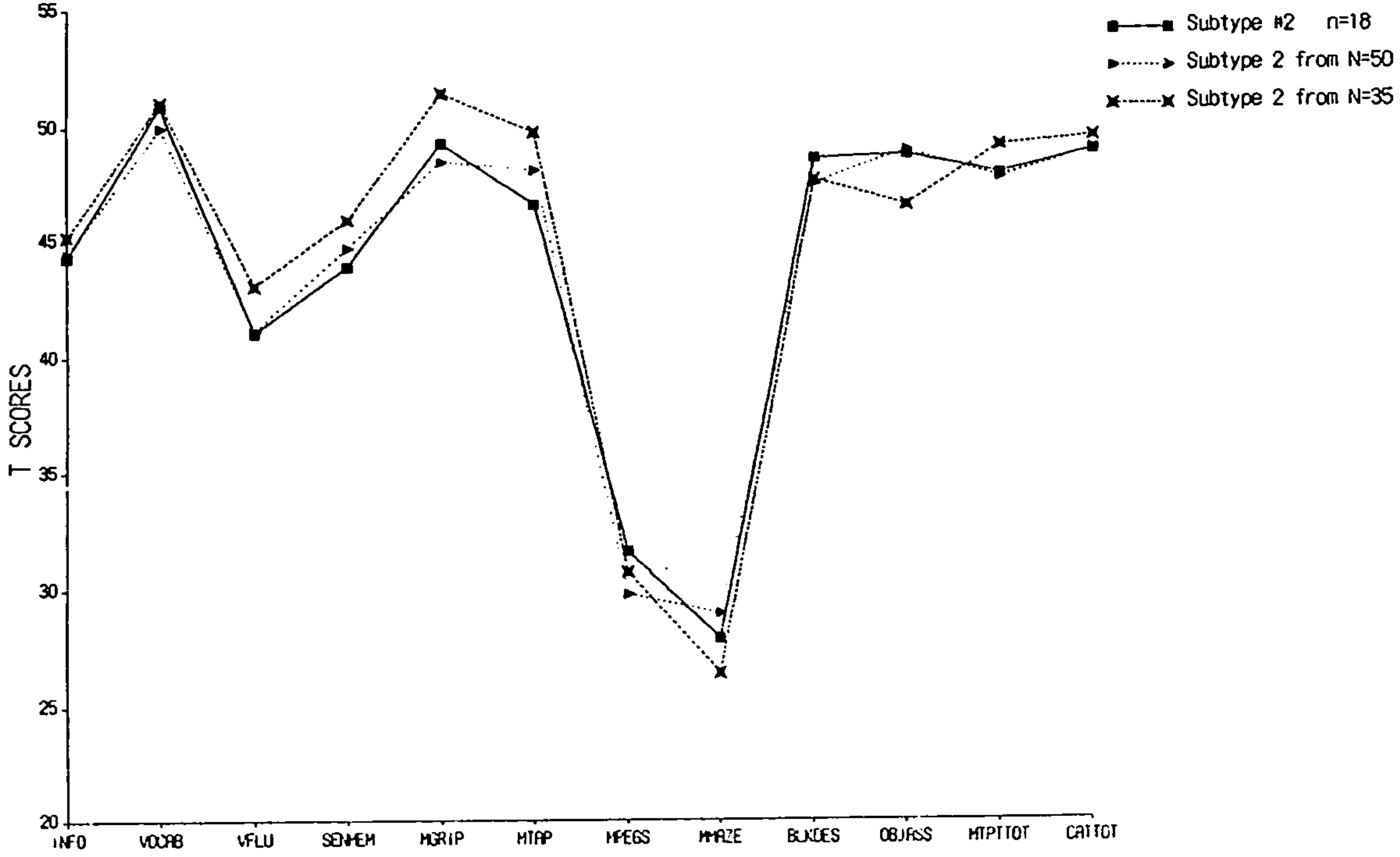


Figure 85. Composite plot of all subtype 2 mean profiles from the cluster analyses of Sample B Subsample 3 and split-samples N=50 and N=35.

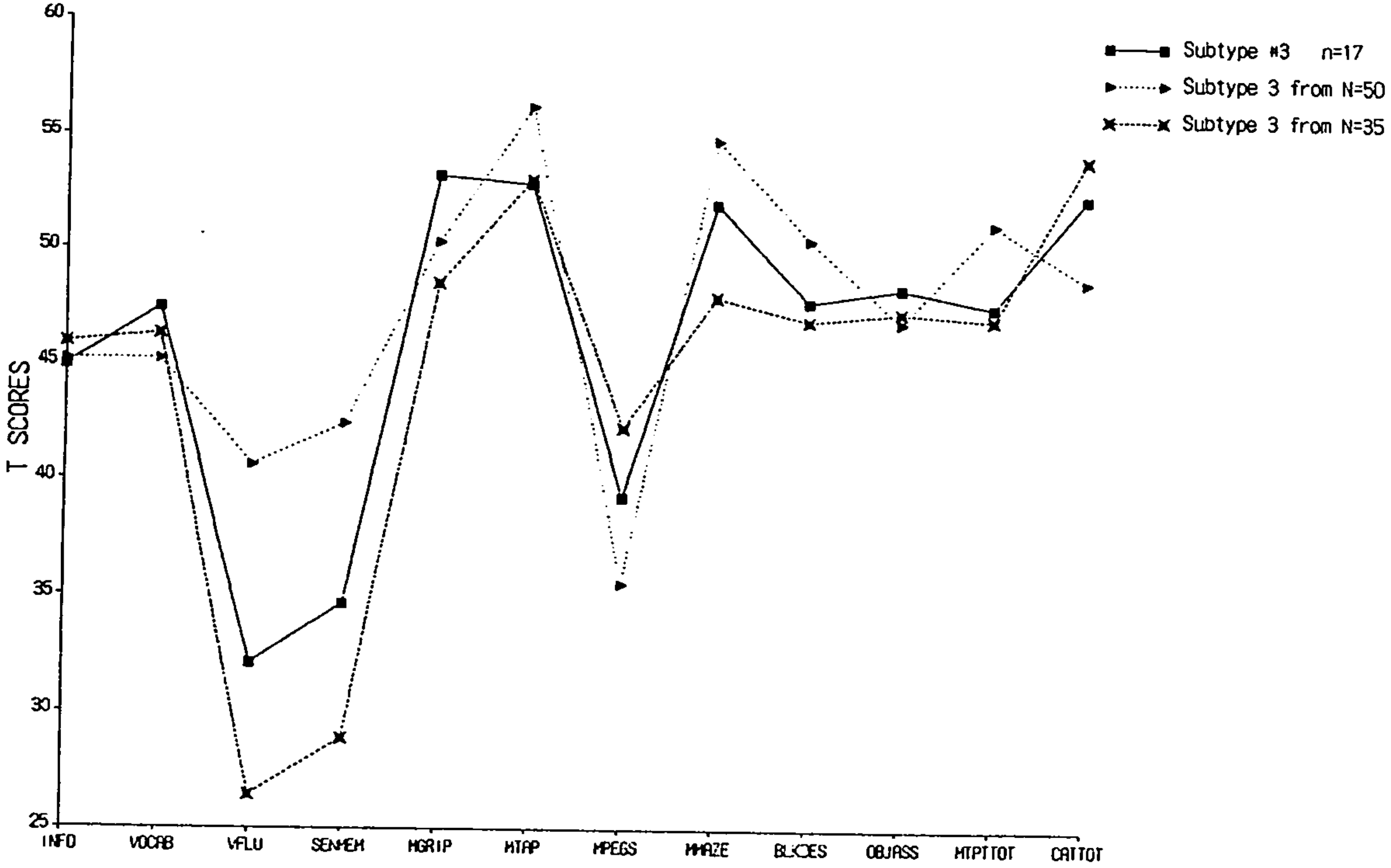


Figure 86. Composite plot of all subtype 3 mean profiles from the cluster analyses of Sample B Subsample 3 and split-samples N=50 and N=35.

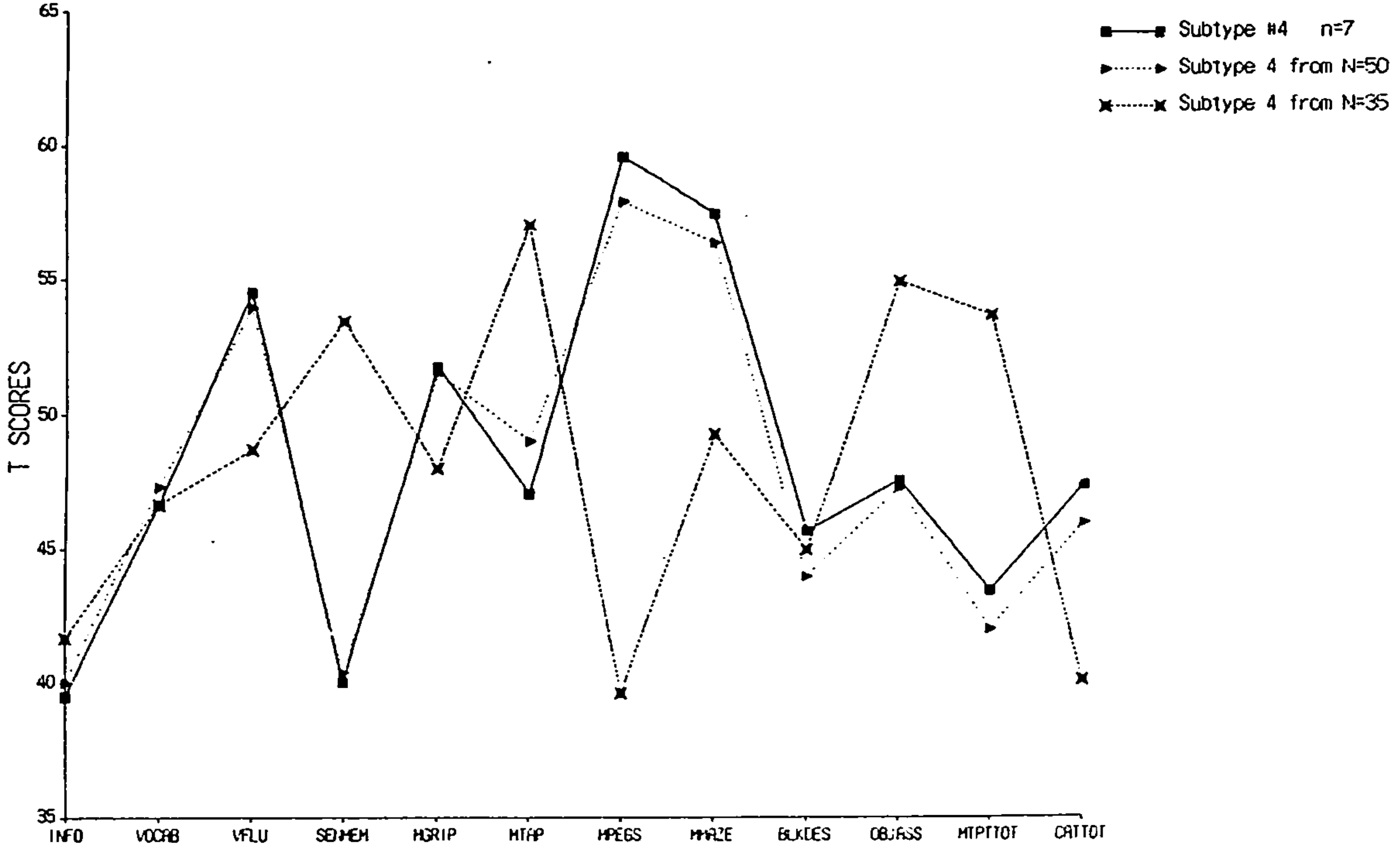


Figure 87. Composite plot of all subtype 4 mean profiles from the cluster analyses of Sample B Subsample 3 and split-samples N=50 and N=35.

Sample B Subsample 4: WISC FSIQ (101-110)

The raw scores for all 12 neuropsychological variables were initially transformed into T-score equivalents prior to the hierarchical agglomerative cluster analyses. The T-score means, standard deviations, and maximum and minimum values for the Sample B Subsample 4 (n=70) neuropsychological variables are presented in Table 90.

The plots of the pseudo F and T cluster coefficients for Ward's method are displayed in Figure 88. The fusion plots for the other three cluster methods are displayed in Figures 89 to 91. Although there are relative drops in 'pseudo T' in these Figures indicating more than a five-cluster partition, none were found with acceptable levels of cross-method agreement and were not considered further. As seen in Figures 88 to 91 there were possible solutions corresponding to relative rises in 'pseudo F' indicating a 2, 3, or 4 cluster partition. However, the solution which produced the best levels of cross-method agreement was the four-cluster solution. Since it was apparent in all fusion coefficient plots it was considered the best choice for further consideration in the present study.

The misclassification analysis for the four-cluster solution of Sample B Subsample 4 is presented in Table 91. Ward's method (TRIM=5, K=4) was the target solution. Four children were removed as outliers and the remaining 66

Table 90

Phase III:
Neuropsychological Measures; Means, Standard Deviations, Minimum and Maximum Values (T-Scores) for Sample B Subsample 4 (WISC FSIQ 101-110)

	Mean (n=70)	Standard Deviation	Minimum Value	Maximum Value
SIMPLE LANGUAGE SKILLS				
WISC Information	46.10	6.83	30.00	66.67
WISC Vocabulary	51.62	6.36	36.67	63.33
COMPLEX LANGUAGE SKILLS				
Verbal Fluency	38.75	8.91	16.07	63.54
Sentence Memory	40.02	10.78	11.83	60.43
SIMPLE MOTOR SKILLS				
Grip Strength[1]	50.90	5.69	35.76	65.50
Finger Tapping[1]	52.59	10.08	28.70	76.22
COMPLEX MOTOR				
Grooved Pegboard[2]	47.56	10.83	14.50	69.33
Maze Test[2]	50.30	13.10	10.13	66.76
VISUAL-SPATIAL SKILLS				
WISC Block Design	55.24	7.39	36.67	76.67
WISC Object Assembly	57.90	9.29	40.00	80.00
HIGHER ORDER or "EXECUTIVE" ABILITIES				
Tactual Performance Test (Mean of total time)	50.42	8.78	22.80	63.23
Category Test (Total error score)	51.90	8.17	34.65	66.41

Note 1: mean performances for the right- and left-hand trials combined

Note 2: mean time scores for the right- and left-hand trials combined

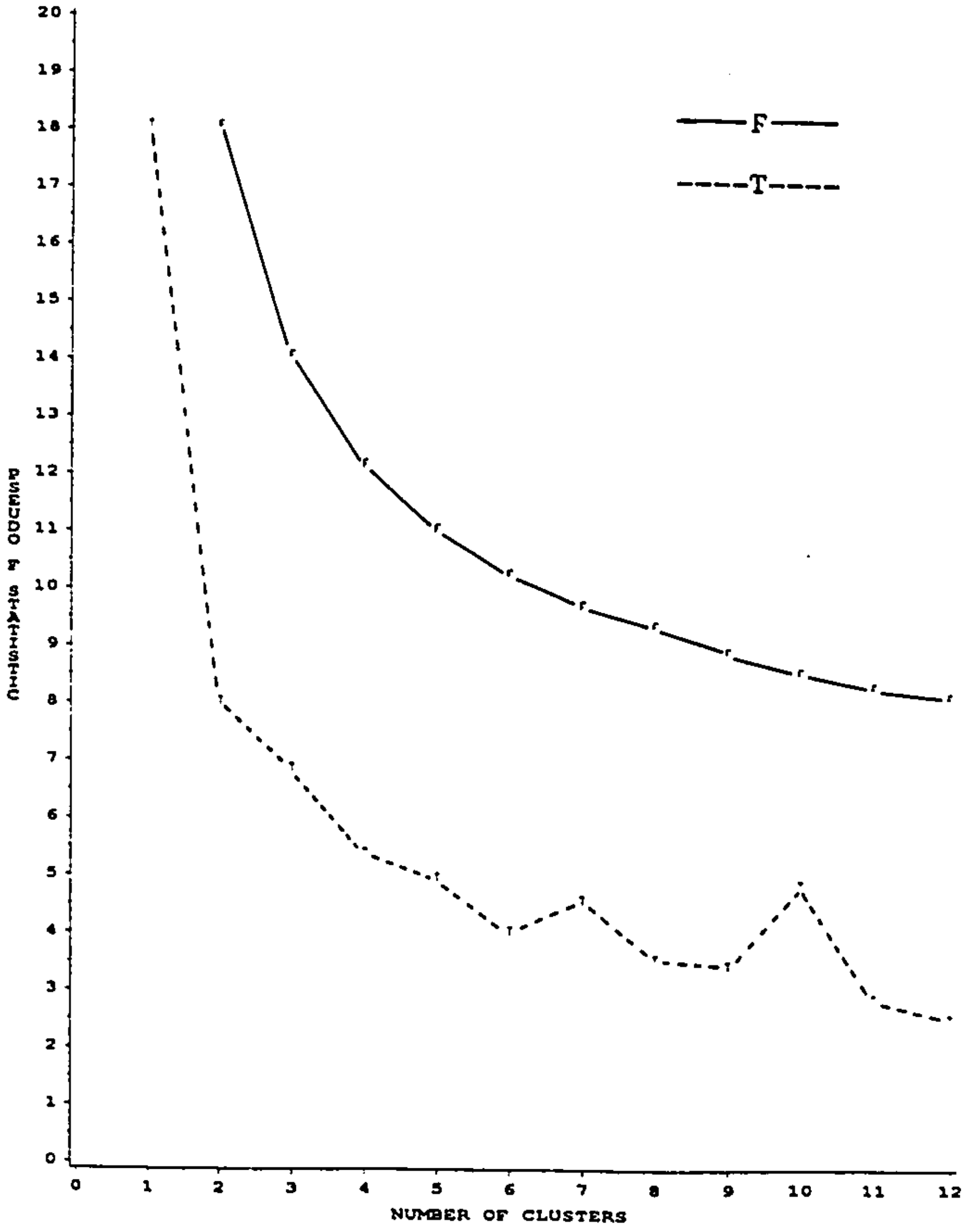


Figure 88. Phase III: Plot of Psuedo F and T Fusion Coefficients for Ward's Cluster Analysis of Sample B Subsample 4 (n=70) with TRIM=5, K=4.

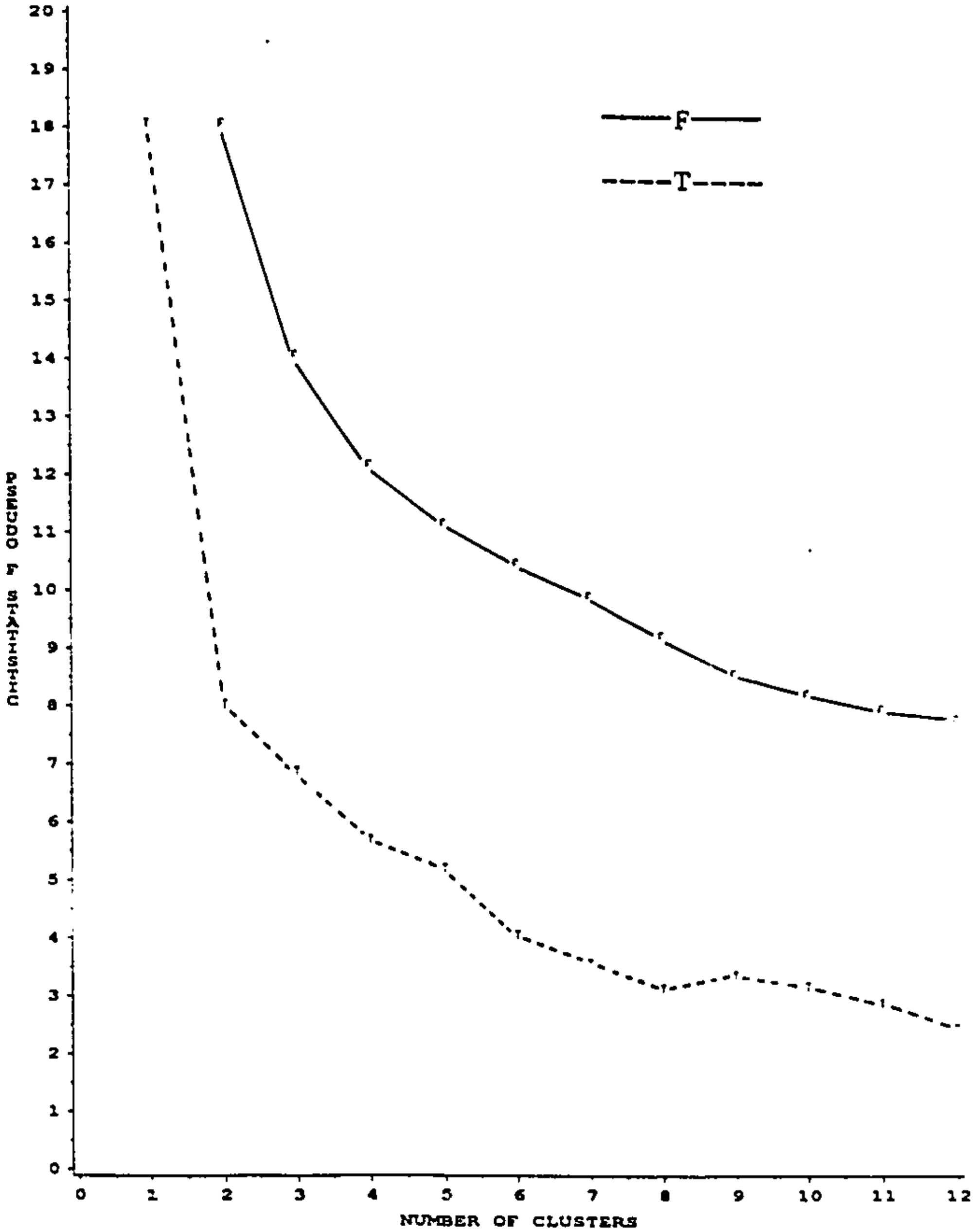


Figure 89. Phase III: Plot of Psuedo F and T Fusion Coefficients for Flexible-Beta Cluster Analysis of Sample B Subsample 4 (n=70) with TRIM=5, K=4.

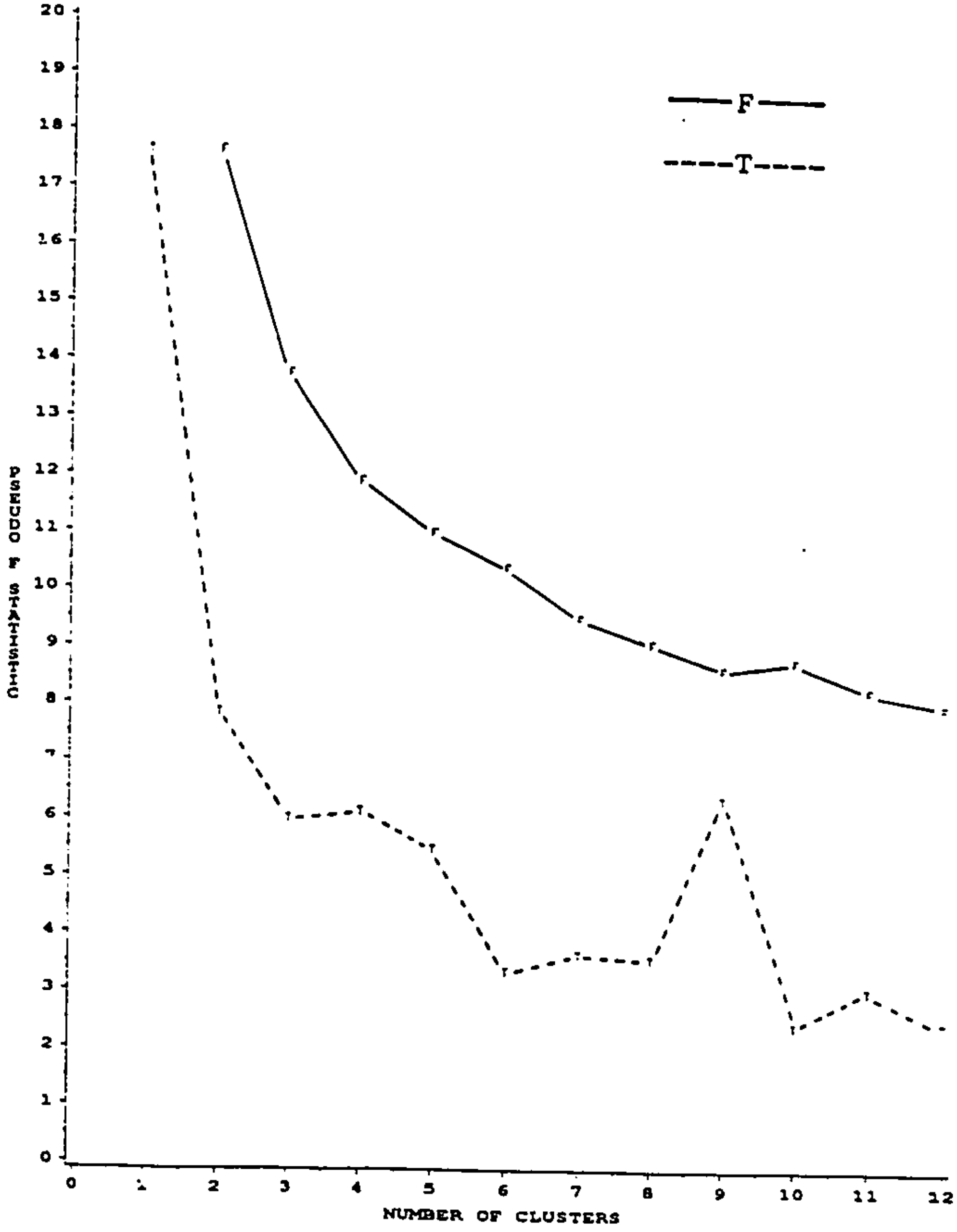


Figure 90. Phase III: Plot of Psuedo F and T Fusion Coefficients for Complete Linkage Cluster Analysis of Sample B Subsample 4 (n=70) with TRIM=5, K=4.

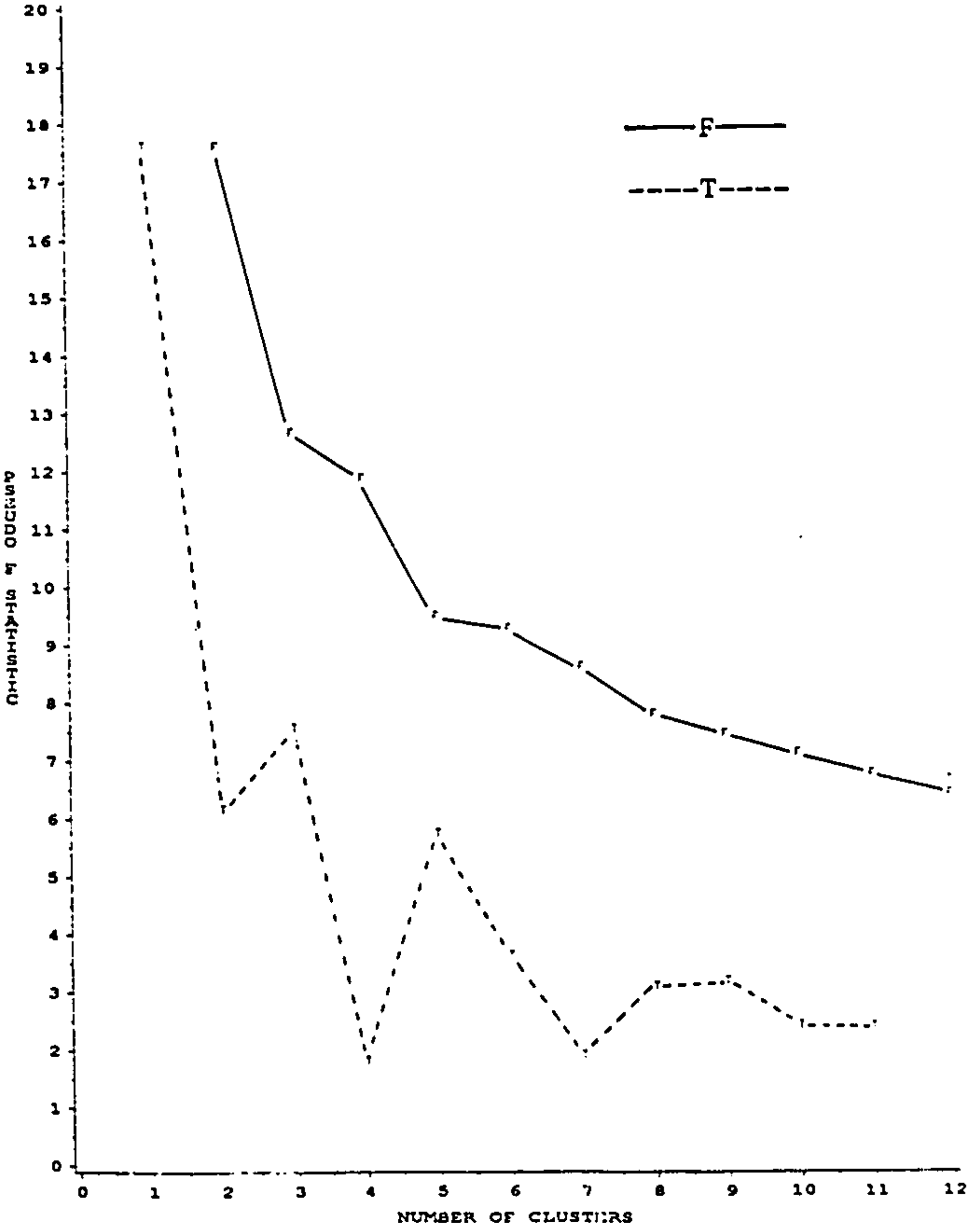


Figure 91. Phase III: Plot of Psuedo F and T Fusion Coefficients for Average Linkage Cluster Analysis of Sample B Subsample 4 (n=70) with TRIM=5, K=4.

Table 91

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Sample B Subsample 4 N=70 FSIQ 101-110)
(Neuropsychological Variables)

	Ward's Cluster Groups				
Cluster analysis method	1 (n=37)	2 (n=9)	3 (n=15)	4 (n=5)	Total (n=66)
Flexible-Beta Method	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Complete Linkage	11 (30)	0 (0)	2 (13)	0 (0)	13 (20)
Average Linkage	0 (0)	1 (11)	2 (13)	0 (0)	3 (5)

classified into four subtypes. It is apparent in Table 91 that there was excellent agreement between Ward's method and the flexible-beta technique. None of the children in Ward's four-cluster partition were misclassified by the flexible-beta technique. Very good agreement was also apparent between Ward's solution and the clusters which emerged from the average linkage method. There was a relatively high (20%) but acceptable misclassification rate between Ward's method and the average linkage technique. In terms of misclassifications for the individual Ward clusters, only subtype #1 was not adequately recovered by the complete linkage technique.

The two internal validation samples (N=50 and N=35) were clustered using an identical TRIM=5 value to discard 5% of the most extreme subjects. With sample N=50 a K=4 value was used. For sample N=35, a K=3 value was employed.

The misclassification analyses for these internal validity samples are shown in Tables 92 and 93. There was very good overall agreement (13% misclassified) between the Ward's solution and the flexible-beta linkage method for sample N=50 (see Table 92). Although the complete linkage technique did not recover Ward's subtype #1 and the average linkage method did not recover Ward's subtype #2 within acceptable limits, the overall misclassification rates (i.e., 28% and 23% respectively) were within acceptable

Table 92

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=50 for Subsample 4)
(FSIQ 101-110 Neuropsychological Variables)

	Ward's Cluster Groups				
Cluster analysis method	1 (n=25)	2 (n=7)	3 (n=10)	4 (n=5)	Total (n=47)
Flexible-Beta Method	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Complete Linkage	11 (44)	2 (29)	2 (20)	0 (0)	13 (28)
Average Linkage	4 (16)	7 (100)	0 (0)	0 (0)	11 (23)

Table 93

Phase III:
Number (Percentage) of Children in each of the Ward's Cluster Groups Misclassified by the other Hierarchical Agglomerative Cluster Methods
(Internal Validation Sample N=35 for Subsample 4)
(FSIQ 101-110 Neuropsychological Variables)

Cluster analysis method	Ward's Cluster Groups 1 (n=15)	2 (n=10)	3 (n=5)	4 (n=3)	Total (n=33)
Flexible-Beta Method	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Complete Linkage	6 (40)	4 (40)	0 (0)	0 (0)	10 (30)
Average Linkage	13 (87)	0 (0)	0 (0)	0 (0)	13 (39)

limits. With respect to sample N=35 (Table 93), only the flexible-beta cluster method adequately recovered the Ward's subtypes in terms of the overall misclassification percentage. As regards the individual Ward's clusters, however, only subtype #1 was not recovered perfectly (i.e., no misclassifications) by more than one cluster method.

The four cluster profiles which emerged from the analysis of Sample B Subsample 4 are displayed in Figure 92. With the exception of nearly identical mean scores on Grip Strength, these four clusters appeared to be quite different both in terms of profile shape and elevation. The individual Ward subtype #1 profiles which emerged from Subsample 4 and validation samples N=50 and N=35 were plotted together in Figure 93. It was readily apparent that this subtype was replicated across two spilt-samples with some minor differences in profile elevation. The individual profiles of the other Ward subtypes and relevant validation sample subtypes are graphically represented in Figures 94 to 96.

As seen in Figure 94, Ward's subtype #2 was well replicated (with some minor variations in profile elevation) by the subtypes which emerged from validation samples N=50 and N=35. Ward's subtype #3, shown in Figure 95, was most accurately reproduced by the cluster profile from internal validity sample N=50. The cluster profile from sample N=35 was also quite accurate with respect to shape but showed some deviations in elevation on the mean scores for Object Assembly and the Category Test. The profile shape and elevation of Ward's subtype #4 (Figure 96) were accurately reproduced by the analyses of the internal validity samples N=50 and N=35.

In summary, Sample B Subsample 4 (WISC FSIQ 101-110) was cluster analyzed into four subtypes with good agreement between the Ward's solution and the other cluster methods. Ward's subtypes #1, #2 and #4 were accurately recovered from internal validity samples N=50 and N=35. Ward's subtype #3 was most accurately recovered from validation sample N=50.

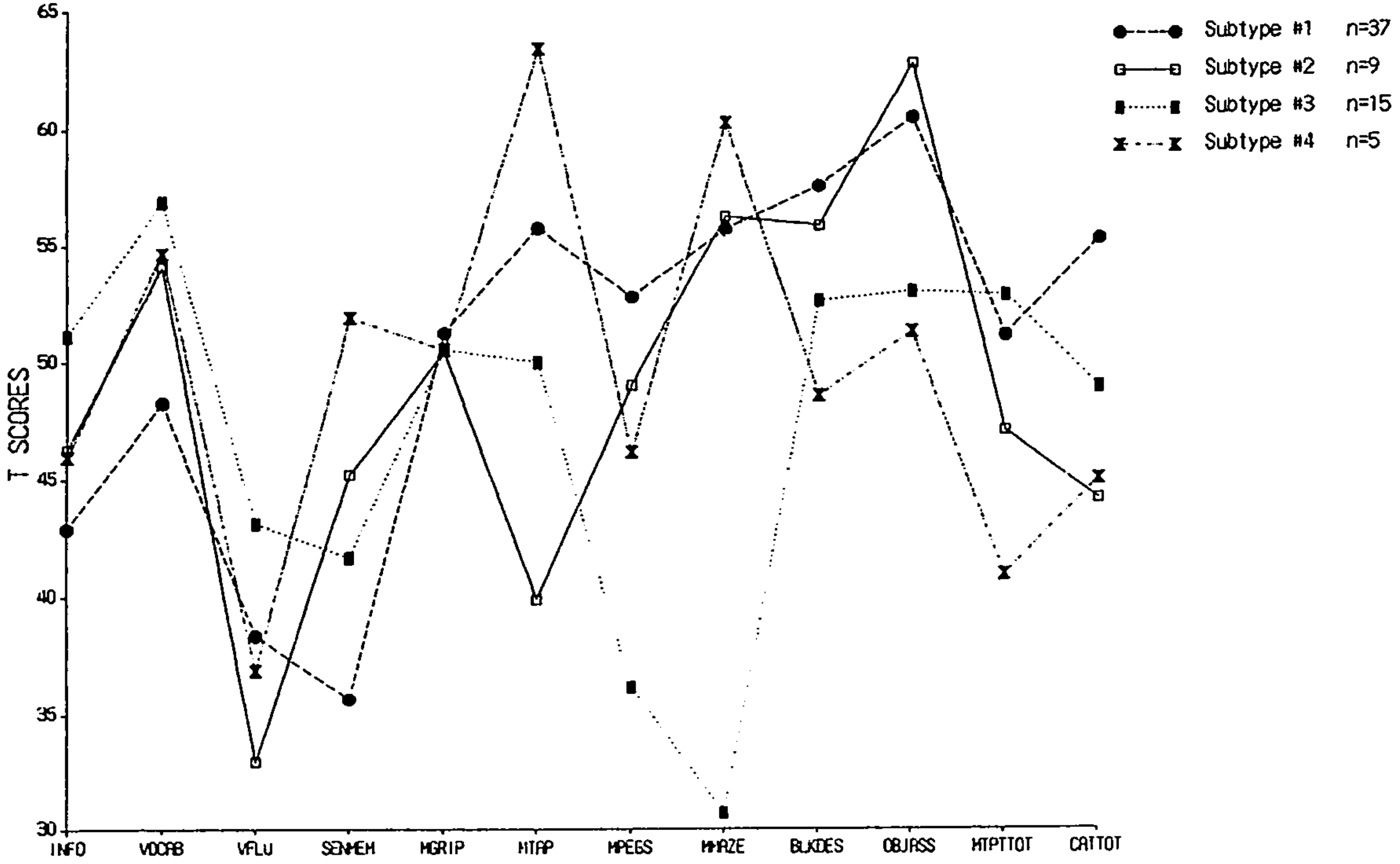


Figure 92. Plot of the four subtypes which emerged from Ward's cluster analysis of Sample B Subsample 4 (n=70).

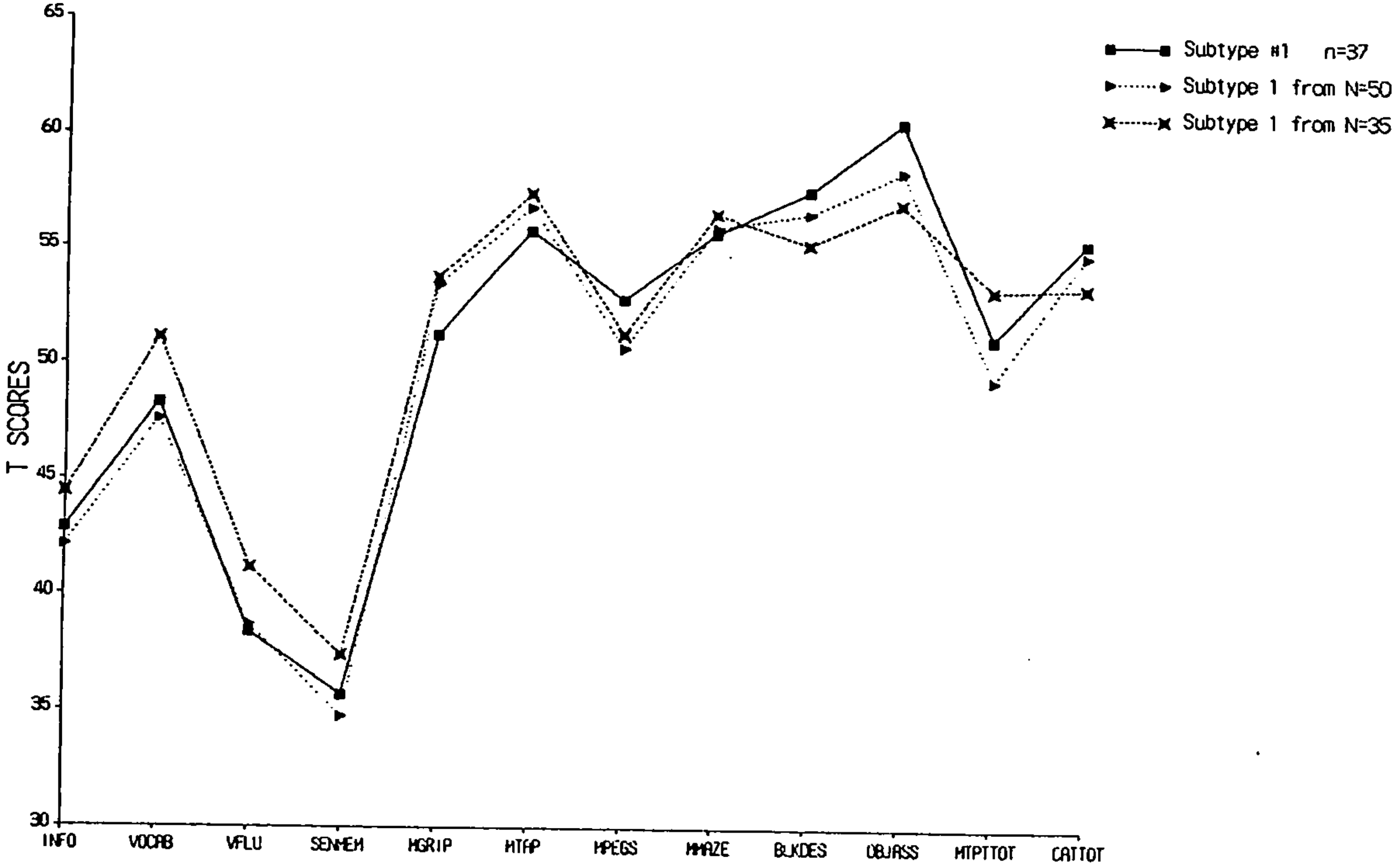


Figure 93. Composite plot of all subtype 1 mean profiles from the cluster analyses of Sample B Subsample 4 and split-samples N=50 and N=35.

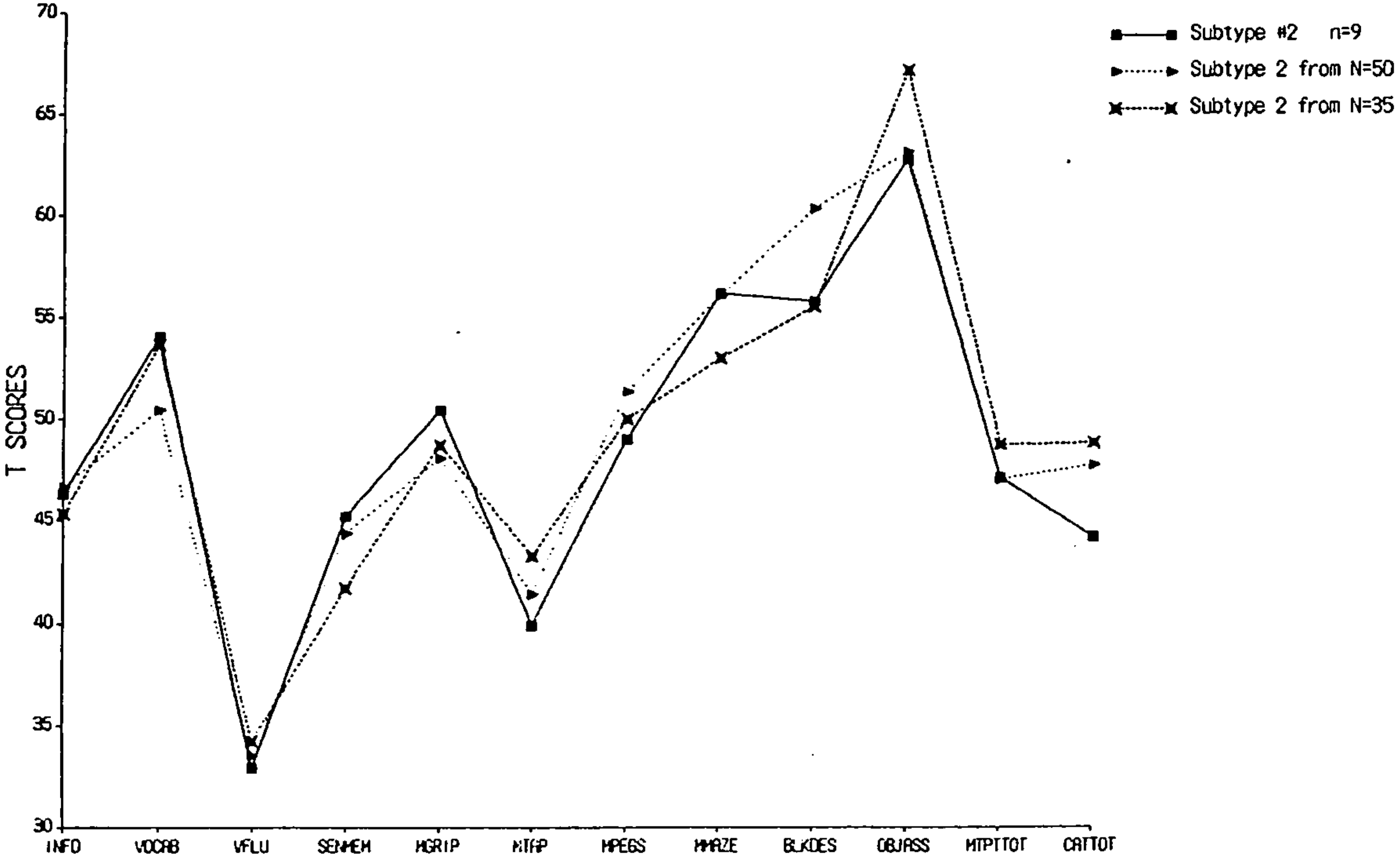


Figure 94. Composite plot of all subtype 2 mean profiles from the cluster analyses of Sample B Subsample 4 and split-samples N=50 and N=35.

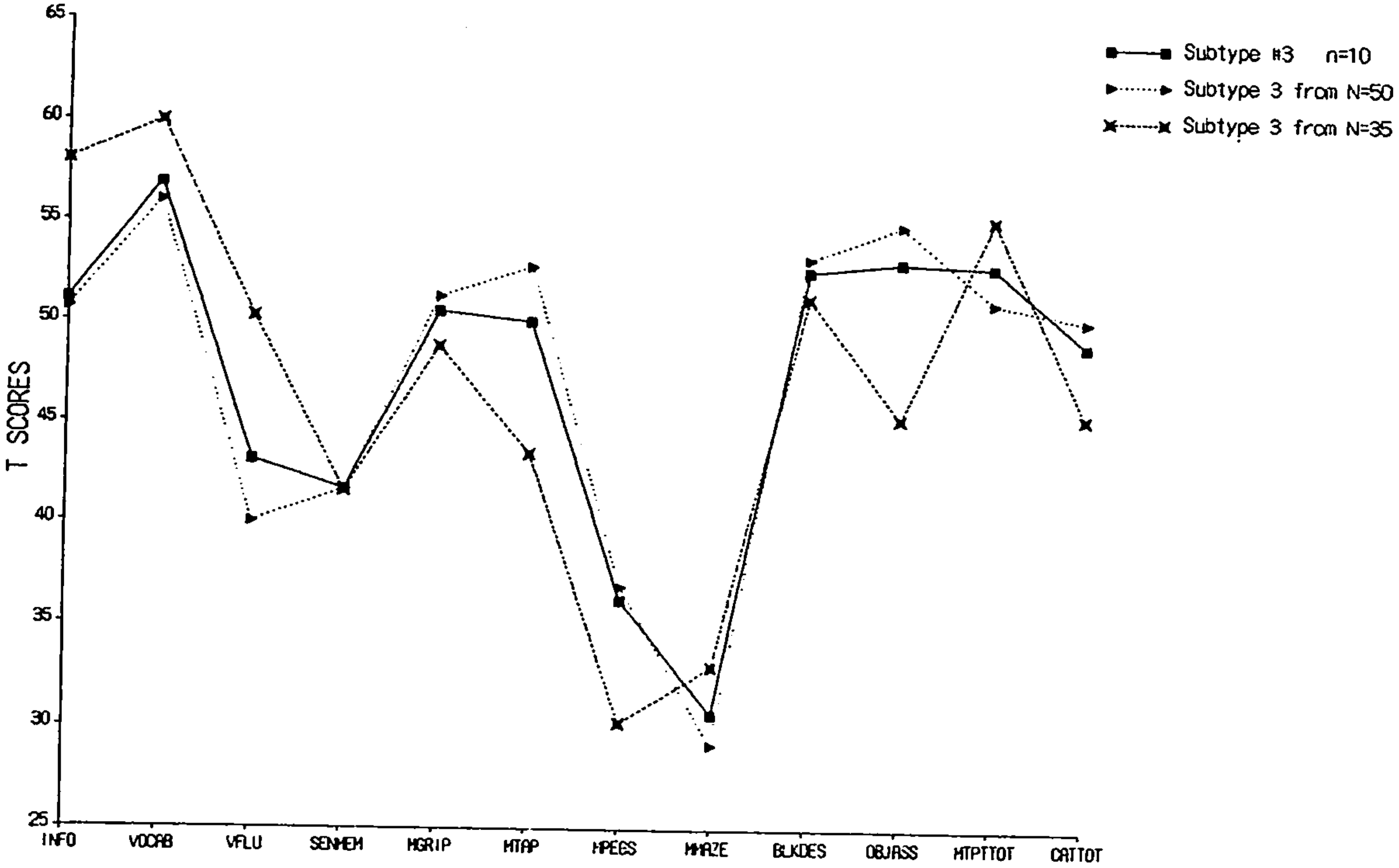


Figure 95. Composite plot of all subtype 3 mean profiles from the cluster analyses of Sample B Subsample 4 and split-samples N=50 and N=35.

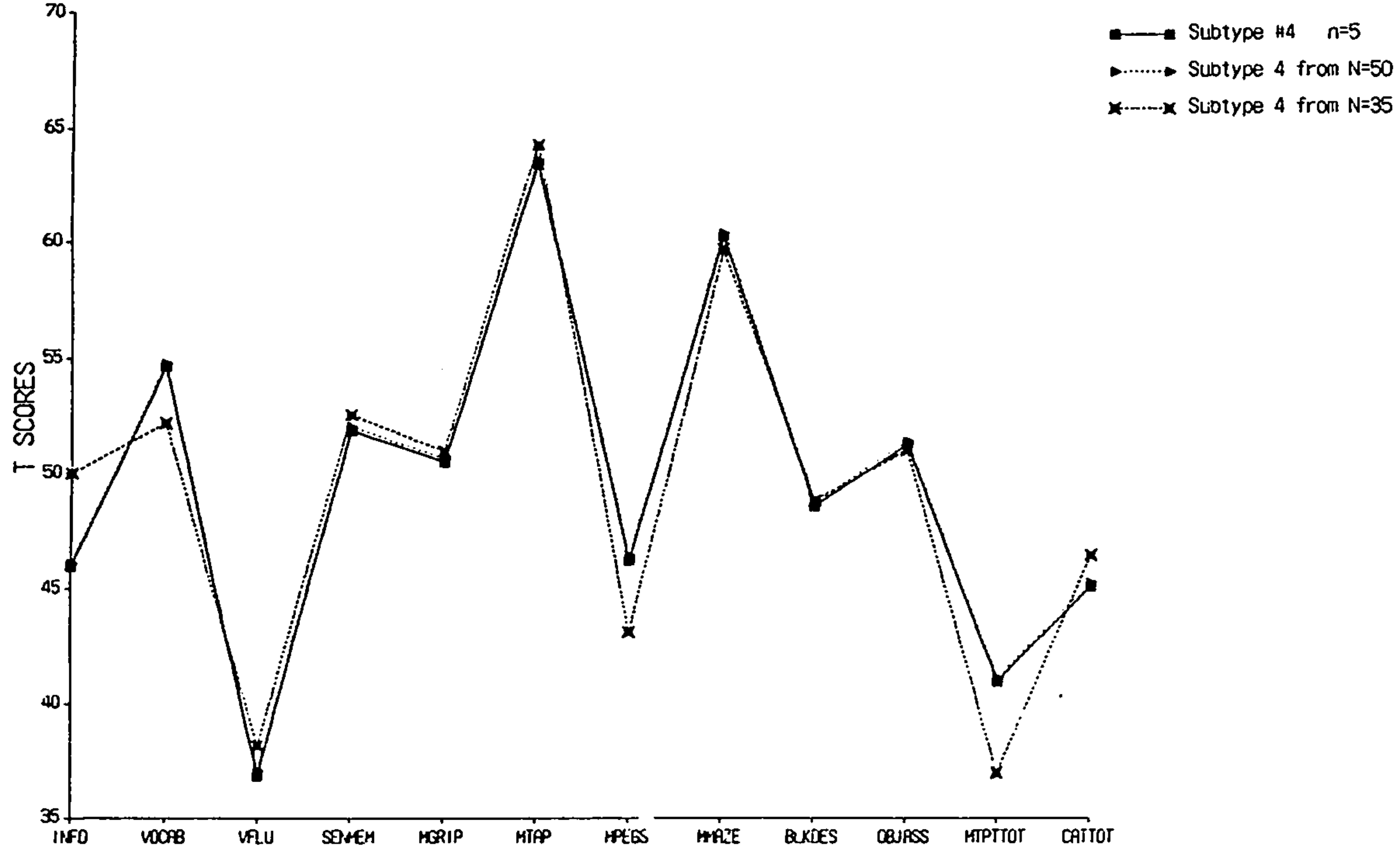


Figure 96. Composite plot of all subtype 4 mean profiles from the cluster analyses of Sample B Subsample 4 and split-samples N=50 and N=35.

Comparisons of the Subtypes that Emerged from the Phase III Cluster Analyses

In this section the 16 subtypes are compared to each other primarily by visual inspection. The four Sample B Subsamples were cluster analyzed using Lorr's (1983) procedure to emphasize profile shape. This was done to determine if similar subtype profiles would result from different samples selected on the basis of different levels of WISC FSIQ. Therefore, overall profile shape was considered primary in these comparisons, although differences in profile elevation are readily apparent and were considered. To facilitate these comparisons all 16 subtypes were labelled for easy reference. For example, the first subgroup which emerged from Subsample 1 was labelled subtype #1-1, the second subgroup from Subsample 1 was labelled subtype #1-2, and so forth. In this coding scheme, the third subgroup to emerge from Subsample 2 was labelled subtype #2-3, and the fourth was labelled subtype #2-4. The third subgroup from Subsample 3 was labelled subtype #3-3, and the first subgroup to emerged from Subsample 4 was labelled subtype #4-1. All subtypes were labelled in this manner to facilitate identification. In addition, a second coding scheme was employed to compare these subtypes across the six areas of neuropsychological abilities. To accomplish this, the two neuropsychological variable scores (in T-score form) within each neuropsychological skill area were averaged. This mean performance score for each neuropsychological skill area was then assigned a classification (e.g., A=average performance) according to the following code. Mean T-scores above 60 points were designated 'Above Average' (i.e., AA); above 55 and including 60 points were labelled 'High Average' (i.e., HA); the mean T-scores from 45 to 55 inclusive were designated 'Average' (i.e., A); scores below 45 but including 40 points were designated 'Low Average' (i.e., LA); mean T-scores from below 40 and including 30 points were labelled as 'Below Average' (i.e., BA); from below 30 and including 20 points were designated as 'Impaired' (i.e., I); and, all mean T-scores below 20 points were labelled 'Severely Impaired' (i.e., SI).

The reader should be reminded that this classification was done for the purposes of the present study, was essentially arbitrary, and may not reflect the common usage of T-scores in the literature. For example, the mean of the T-score distribution is 50 with a standard deviation of 10 ponts, thus the average range is generally considered to lie between 60 and 40. A classification scheme such as this may also tend to obscure relevant differences between dissimilar performances on the two variables; so that one poor performance is attenuated by an average or above performance on the other variable within the same skill domain. All 16 profiles were coded with this method and the resulting classifications are displayed in Table 94. Comparisons of 'like' profiles were decided on the basis of the information in Table 94 and by examination of the individual subtype profiles in Figure 65, Figure 74, Figure 83, and Figure 92. The information displayed in these figures was generally given more 'weight' when deciding profile similarity.

The classification scheme shown in Table 94 provides a summary of profile similarities and differences at a glance. It is readily apparent in Table 94 that as WISC FSIQ level increases, the number of lower classification levels (e.g., I, BA) decreases and the number of higher classification levels increases (e.g., A, HA). For example, the Subsample 1 subtypes exhibit more low-average (LA), below-average (BA), and impaired (SI, I) classification levels than did any other set of subtypes Only subtype #1-4 from this low IQ range achieved a T-score > 50 on one variable (i.e., MTPTTOT, see Figure 65). The Subsample 2 subtypes evidenced more average (A) classification levels than did the Subsample 1 subtypes. Consistent with the trend of higher classification with greater WISC FSIQ, the Subsample 3 and 4 subtypes exhibited fewer below-average and low-average classification levels, and attained more average and high-average (HA) levels of categorization. However, making this comparison between the

Table 94

Phase III: Level of Impairment in Each Neuropsychological Skill Area for the Sample B Subsample NEURO Groups 1-1 to 4-4

	Skill Areas					
	Simple Language	Complex Language	Simple Motor	Complex Motor	Visual Spatial	"Higher-Order" (Executive)
Subtype Identification[1]						
FSIQ (70-80)						
#1-1	BA[2]	BA	LA	SI	BA	BA
#1-2	BA	I	LA	LA	LA	LA
#1-3	BA	BA	LA	BA	BA	BA
#1-4	LA	LA	BA	I	BA	A
FSIQ (81-90)						
#2-1	LA	BA	A	A	A	A
#2-2	LA	BA	A	BA	A	A
#2-3	A	BA	A	I	LA	LA
#2-4	BA	LA	A	A	LA	LA
FSIQ (91-100)						
#3-1	LA	BA	A	A	A	A
#3-2	A	LA	A	I	A	A
#3-3	A	BA	A	A	A	A
#3-4	LA	A	A	HA	A	A
FSIQ (101-110)						
#4-1	A	BA	A	A	HA	A
#4-2	A	BA	A	A	HA	LA
#4-3	A	LA	A	BA	A	A
#4-4	A	LA	HA	A	A	LA

Note 1: The subtypes are identified as follows:
Subsample 1 Subtype 1 is #1-1; Subsample 2 Subtype 1 is #2-1; Subsample 3 Subtype 4 is #3-4; etc.

Note 2: AA=above-average; HA=high-average; A=average; LA=low-average; BA=below-average; I=impaired; SI=severely impaired.

Subsample 3 and Subsample 4 subtypes was somewhat more complex. For example, the Subsample 3 subtypes attained more average classification levels and fewer below-average and low-average classification levels than did the Subsample 4 subtypes. On the other hand, the Subsample 4 subtypes attained more high-average levels of classification.

With respect to the 'range' of possible classification levels achieved by any set of subtypes; the Subsample 1 subtypes ranged from Severely Impaired to Average (5 levels), the Subsample 2 subtypes ranged from Impaired to Average (4 levels), the Subsample 3 subtypes ranged from Impaired to High-Average (5 levels), and the Subsample 4 subtypes ranged from Below-Average to High-Average (4 levels). This suggested that there was more variability between the six areas of neuropsychological skills occuring within the WISC FSIQ ranges 70 to 80 (Subsample 1) and 91 to 100 (Subsample 3).

At first glance, there appears to be a high degree of similarity in the classification levels attained by subtype #2-1 and subtype #3-1 (see Table 94). Examination of these subtype profiles in Figure 74 and Figure 83 confirmed that they exhibited the same basic profile shape. Although differing in elevation, subtype #1-2 and subtype #4-1 also exhibited this same profile shape (see Figure 65 and Figure 92). These four subtypes were labelled 'Shape A' and their classification levels are displayed together in Table 95. Subtype #2-2 exhibits somewhat similar classification levels (see Table 94). However, inspection of Figure 74 revealed that subtype #2-2 differed greatly from subtype #2-1 with respect to the obtained mean MAZE variable score. The levels of classification of subtype #2-2 are displayed in Table 95 under the 'Shape A' patterns. Further inspection of Table 94 suggested that subtype #3-2 and subtype #4-3 would exhibit similar profile shapes. This was confirmed by visual comparison of these subtype profiles in Figures 83 and 92. As shown in Figure 65 and Figure 74, subtype #1-1 and subtype #2-3 also exhibited profile shapes similar to subtype #3-2. These four subtypes were referred to as 'Shape B' and their classification levels are given in Table 95. Subtype #2-2 (Figure 74) also evidenced some similarities in profile shape compared with subtype #2-3. Therefore, the classification levels attained by this subgroup in the neuropsychological skill areas are also displayed in Table 95 following the 'Shape B' patterns. The classification patterns for the remaining subtypes are shown in Table 95. Comparisons of these patterns and visual inspection of their respective profiles yielded no further evidence of significant profile similarity.

In summary, these comparisons revealed evidence for two basic profile shapes which occured within all four subsample

Table 95

Phase III: Levels of Classification in Each Neuropsychological Skill Area for Subtypes with Similar Profile Shape

	Skill Areas					
	Simple Language	Complex Language	Simple Motor	Complex Motor	Visual Spatial	"Higher-Order" (Executive)
Subtype Identification[1]						
Shape A						
#1-2	BA[2]	I	LA	LA	LA	LA
#2-1	LA	BA	A	A	A	A
#3-1	LA	BA	A	A	A	A
#4-1	A	BA	A	A	HA	A
Subtypes similar to Shape A						
#2-2	LA	BA	A	BA	A	A
#4-2	A	BA	A	A	HA	LA
Shape B						
#1-1	BA	BA	LA	SI	BA	BA
#2-3	A	BA	A	I	LA	LA
#3-2	A	LA	A	I	A	A
#4-3	A	LA	A	BA	A	A
Subtypes similar to Shape B						
#2-2	LA	BA	A	BA	A	A
Remaining subtypes						
#1-3	BA	BA	LA	BA	BA	BA
#1-4	LA	LA	BA	I	BA	A
#2-4	BA	LA	A	A	LA	LA
#3-3	A	BA	A	A	A	A
#3-4	LA	A	A	HA	A	A
#4-4	A	LA	HA	A	A	LA

Note 1: The subtypes are identified as follows: Subsample 1 Subtype 1 is #1-1; Subsample 2 Subtype 1 is #2-1; Subsample 3 Subtype 4 is #3-4; etc.

Note 2: AA=above-average; HA=high-average; A=average; LA=low-average; BA=below-average; I=impaired; SI=severely impaired.

WISC FSIQ ranges. A total of 8 of the 16 subtype profiles which emerged from the Phase III cluster analyses could be assigned to one of these two profile shapes (Shape A or Shape B). Two other subtype profiles were thought to exhibit some similarities to these basic profile shapes. The six remaining profiles were considered too different from the other ten subtype profiles and from each other to form any more same 'shape' categories.

CHAPTER IV

DISCUSSION

The purpose of the present study was to investigate the subtypal composition of various samples of learning disabled children selected on the basis of WISC Full Scale IQ levels. Of primary importance to this research effort was to determine if low IQ children, normally excluded from traditional learning disability studies, would be assigned to a separate and distinct group(s) by means of cluster analytic methods. A second goal of the present research was to determine if the number of subtypes and the abilitiy structure of these subtypes would change with variations in WISC Full Scale IQ levels. Two samples of children were selected for these purposes and the cluster analyses were carried out in three phases.

Four agglomerative hierarchical clustering techniques (Ward's, Flexible-beta, Complete and Average Linkage) were employed in each of these three phases. The optimal number of clusters were determined by inspection of the cluster fusion coefficients and by the degree of cross-method agreement between the four cluster-analytic methods. Ward's technique (Ward, 1963) was employed as the target solution in all cluster analyses. Squared Euclidean distance was used as the similarity measure. However, in Phase II (Part A) and in Phase III, Lorr's (1983) procedure was employed to emphasize the contribution of profile 'shape' in the formation of subtypes.

Internal validation of the resultant subtypes involved replication of these clusters with subsets of the data. For Phase I and Phase II (Part A), three random selections of the original data (N=1000, N=800, and N=600) were constructed for the split-sample replication attempts. In Phase III, two random selections (N=50 and N=35) of the data were drawn from each of the original samples (n=70). The profiles of the clusters emerging from the original samples and the replication split-samples were overlayed and compared by visual inspection.

Phase I

In Phase I a large sample of children (i.e., Sample A, n=1200) were selected from a database of over 4800 children referred (primarily due to academic difficulties) for neuropsychological assessment. Other 'types' of children (e.g., emotionally disturbed) were retained as members of Sample A. An attempt was made in the Phase I analyses to provide statistical rather than a priori determinations of "normal", learning disabled, and low IQ children. For this analysis, the WRAT Reading, Spelling, and Arithmetic standard scores were (following T-score conversion) subjected to the four agglomerative hierarchical clustering techniques.

The cluster-analytic methods applied to the Sample A academic measures (i.e., WRAT scores) suggested the presence of four subtypes. Cluster analysis of the three internal validation samples revealed very similar subgroup profiles with respect to the academic variables. Concurrent (external) validation of the Sample A WRAT Groups involved the use of multivariate analysis of variance and a subsequent multiple comparison procedure on 12 measures of neuropsychological skills and abilities. These 12 variables were thought to represent a sufficient range of simple and complex neuropsychological skill areas as identified by Francis (1985, 1988). Application of the multivariate statistical techniques suggested that the four WRAT Groups did differ on many of the measures not utilized in the classification process (i.e., the 12 neuropsychological variables). These findings suggested that the four WRAT subtypes were reliable and distinct from each other.

Although the internal and external validity of this subtypal solution appeared to be sufficiently demonstrated, the profiles of these WRAT Groups on the neuropsychological variables were difficult to interpret (see Figure 23). In this case these profiles exhibited differences in elevation, but not remarkable differences in their patterns of neuropsychological performances (i.e., profile shape). This was a unique finding which has not been reported in the literature to date. In order to characterize and better describe these subtypes, the percentage of children who evidenced impairment within the six neuropsychological skill areas was calculated for each WRAT Group.

The WRAT Groups and outliers were also examined to determine how many of their members could be considered: (1) 'normal' academic achievers; or (2) learning-disabled on the basis of a configurational approach (i.e., Rourke's WRAT typology), and various IQ-Achievement discrepancy definitions. The number of children corresponding to different 'types' (e.g., low IQ) occuring within each WRAT Group and the outlier category was also determined.

Description of the Phase I WRAT Subtypes

WRAT Group 1. Group 1 (n=460) was the largest subtype to emerge from the cluster analysis of Sample A. WRAT Reading (i.e., word recognition) skills were in the low-average range, while Spelling and Arithmetic skills were slightly below-average. The average age of these children was 11.28 years. Although WISC Full Scale, Verbal, and

Performance IQs were within normal limits, Group 1 evidenced a 10 point Verbal-Performance IQ split in favour of the latter. Peabody Picture Vocabulary IQ was within the average range.

A majority of the Group 1 children (i.e., 60 %) evidenced below-average complex language skills. Eighteen percent of these children exhibited below-average simple language skills. Simple motor skills were below-average in 12% of the Group 1 children while 28% exhibited below-average performances on complex motor skills. Only 8% of the Group 1 children evidenced below-average performances on visual-spatial skills and 17% were below-average on tasks thought to assess "higher-order" functioning.

Few of the Group 1 children could be characterized as Rourke G1 (14%) or G2 (4%) types, and none were categorized within the Rourke G3 arithmetic-disabled type. Only 23% exhibited low-average or better performances on all WRAT subtests (i.e., 'normal' academic achievers). However, with various IQ cutoff points, a large majority of these children (72% to 90%) were considered learning disabled on the basis of IQ-Achievement discrepancy criteria. Depending on the measure of psychometric intelligence (i.e., PPVT or WISC) and the IQ cutoff score, 7% to 26 % of these children were considered 'low-IQ'. Although 23% were determined to be emotionally disturbed, none of the other categories of children (e.g., visual anomalies present) usually excluded from learning disability studies were overly represented in this subtype.

In summary, WRAT Group 1 appeared to be a 'complex-language' deficit subtype which exhibited relatively few extreme deficiencies in other neuropsychological skill areas. Somewhat inconsistent with this depiction was the finding that 28% of this subgroup evidenced below-average performances on complex motor skills.

WRAT Group 2. Group 2 (n=382) was the second largest group to emerge from the cluster analysis of Sample A. WRAT Reading and Spelling were well below-average and Arithmetic (although below-average) was slightly better developed. The average age of these children was 11.62 years. WISC Full Scale and Performance IQs were within normal limits but Verbal IQ was in the low-average range. Group 2 evidenced a 12 point Verbal-Performance IQ discrepancy in favour of the latter. This was the largest such split occuring in any of the four WRAT subtypes. Peabody Picture Vocabulary IQ was within normal limits as well but lower than any other subtype.

A large majority of these Group 2 children (i.e., 76%) exhibited at least below-average (or worse) performances in complex language skills. Approximately 37% of the children in this subtype exhibited at least below-average skills in the simple language and complex motor domains. With the exception of higher-order skills, this subtype contained a greater percentage of children exhibiting at least below-average performances in all areas of neuropsychological functioning.

More than one-half of the children (i.e., 53%) in Group 2 were categorized as Rourke G1 types. Twelve percent were categorized as Rourke G2 types while none were considered arithmetic disabled according to the Rourke G3 typology criteria. It was noteworthy that none of the Group 2 children were classified as at least low-average or better academic achievers.

The various IQ-Achievement discrepancy criteria revealed that between 54% to 80% of this subtype could be considered learning disabled. Group 2 contained the largest group percentages of low-IQ children, ranging from 20% to 46% depending on the IQ cutoff and intelligence test employed. If the WISC and a Full Scale IQ of 80 were applied, exactly 80% were considered learning disabled according to IQ-Achievement discrepancy (see Table 30) and the other 20% would be considered "low functioning" children (see Table 29).

Group 2 evidenced the smallest percentage of emotionally disturbed children (i.e., 14%) compared with the other WRAT subtypes. None of the other categories of children usually excluded from typical learning disability studies were overly represented in this subtype. In summary, WRAT Group 2 appeared to be a "mixed deficit" subtype with very poor performances in evidence on simple and complex-language skills, complex-motor skills and on 'higher-order' skills. Group 2 appeared to contain significantly more low-IQ children than did any other WRAT subtype.

WRAT Group 3. Group 3 (n=254) was the third largest subtype to emerge from the cluster analysis of Sample A. WRAT Reading skills were average, Spelling skills were slightly poorer but still within normal limits, and Arithmetic skills were in the low-average range. The average age of these children was 11.26 years. All IQ scores were well within the average range. There was a small Verbal IQ-Performance IQ discrepancy of 4 points in favour of the latter. Fifty-two percent of these children exhibited below-average performances on complex-language skills while only 12% evidenced below-average performances on simple language skills. Group 3 evidenced the largest percentage of children (27%) with below-average performances on 'higher-order' skills and the second highest percentage (11%) with below-average visual-spatial performances.

None of these children could be categorized as

Rourke G1 or G2 types but 10% were considered arithmetic-disabled according to the Rourke G3 classification. Many of the children in Group 3 (48%) were considered at least low-average academic achievers on the basis of their obtained WRAT standard scores. However, with various IQ cutoff points, 50% to 67% of the children in Group 3 were classified as learning disabled with respect to the IQ-Achievement discrepancy definitions. Depending on the IQ cutoff point chosen, 7% to 24% of the Group 3 children could be considered low-functioning (i.e., low-IQ). Compared with the first two subtypes, many children (39%) in Group 3 were thought to be emotionally disturbed. None of the other exclusionary categories were overly represented in this subtype.

In summary, Group 3 also appeared to be a 'mixed deficit' subtype which exhibited deficient complex-language, complex-motor and 'higher-order' skills. It was also the case that many Group 3 children were considered to be emotionally disturbed.

WRAT Group 4. Group 4 (n=56) was the smallest subtype to emerge from the cluster analysis of Sample A. WRAT Reading skills were above-average, Spelling skills were average to high-average and Arithmetic skills were average but significantly below Reading and Spelling performances. The average age of these children was 11.00 years. All IQ scores were well within the average range. There was no appreciable Verbal IQ-Performance IQ discrepancy. Compared to the other WRAT subtypes, relatively few of the Group 4 children (33%) evidenced below-average performances in complex-language skills and only 5% exhibited below-average performances in simple-language skills. Only 9% exhibited impairment in visual-spatial skills and 15% were impaired on tasks designed to assess 'higher-order' cognitive functioning. None of these children could be characterized as Rourke G1 or G2 types; however, a large number (46%) were considered arithmetic-disabled with the Rourke G3 classification criteria. Most of the Group 4 children (82%) were considered normal academic achievers on the basis of their WRAT performances. Approximately 25% of these children were designated as learning disabled on the basis of IQ-Achievement discrepancy criteria regardless of WISC or PPVT cutoff IQ score.

Exactly 50% of the children in Group 4 were considered emotionally disturbed. Only 9% of the children in Group 4 exhibited impairment on the Sweep Hearing Test. None of the other categories of children usually excluded from traditional learning disabled studies were overly represented in this subtype.

Group 4 appeared to consist of both 'normal' academic achievers, arithmetic-disabled, and emotionally disturbed children in relatively large frequencies compared with the other subtypes. Thus, Group 4 was the most heterogeneous with respect to the types of children it contained. The mean performances of these children on the neuropsychological variables were most often better than (but not necessarily significantly different from) those obtained by children in the other subtypes. Some of the arithmetic disabled children in Group 4 were most likely emotionally disturbed (Rourke & Strang, 1985); however, this may have been the case with children in this subtype considered to be "normal" academic achievers. Since this possible overlap in categorization was not addressed in the present study, Group 4 was difficult to label with any degree of certainty.

<u>Phase I WRAT Outliers.</u> The children categorized as outliers were interesting for several reasons. There was a higher percentage of below-average performances apparent on visual-spatial skills (i.e., 18%) compared with the WRAT subtypes. There were some Rourke G3 arithmetic-disabled children (i.e., 15%) in this category, but no Rourke G2 types and few Rourke G1 (4%) types. Many children in this outlier classification (i.e., 56%) were at least low-average achievers in terms of their WRAT scores. Only 10% of these children exhibited PPVT IQs less than 90. In these respects

the outliers were similar to WRAT Group 4; however, the percentage of children thought to be emotionally disturbed was most similar to that found in WRAT Group 1. The frequency of low-IQ children as determined by WISC IQ cutoff scores most similar to Group 3, as was the frequency of occurence of children designated learning disabled with IQ-Achievement discrepancy criteria. The outlier category contained a percentage of children with impairment on the Sweep Hearing Test that was similar to all WRAT subtypes except Group 4. In these respects, the outliers were the most heterogeneous classification of children to emerge from the cluster analysis of Sample A.

Phase II

In Phase II the Sample A children were clustered on the 12 neuropsychological variables (following T-score conversion) in two distinct procedures. First, in Part A of Phase II, this sample was subjected to the four agglomerative hierarchical clustering methods with Lorr's (1983) procedure to emphasize profile shape. Three profile shapes emerged and were successfully replicated with the internal validation samples N=800 and N=600. In Part B of Phase II, each of these profile shapes was again subjected to the four cluster-analytic techniques. However, neither profile shape nor profile elevation were emphasized.

Three subtypes emerged from the analyses of each profile shape. These three-cluster solutions were replicated with split-samples to demonstrate their internal validity. The concurrent (external) validity of these solutions was not demonstrated since no variables external to the cluster analyses were selected for this purpose. Nine NEURO Groups resulted from these analyses. These subgroups were examined to determine the frequency of occurence of 'low-IQ' and other 'types' of children as was done in Phase I. A description of the nine subtypes and the types of children within them is presented below.

Description of the Phase II NEURO Subtypes

NEURO Group 1. Group 1 (n=230) was the largest subtype to emerge from the Phase II cluster analyses of Sample A. It contained approximately 5 males to 1 female and 5 right-handed children for every 1 left-handed child. These proportions were very similar to the sex and handedness ratios of the whole sample. The average age of these children was 11.69 years. WRAT Reading (i.e., word recognition), Spelling, and Arithmetic skills were within the low-average range. However, the obtained mean Spelling score was at the lower limits of the low-average range, and Reading skills were somewhat better developed than were Spelling or Arithmetic. Although WISC Full Scale, Verbal, and Performance IQs were well within the average range, NEURO Group 1 evidenced a 15-point Verbal-Performance IQ discrepancy in favour of the latter.

Twenty-one percent of the NEURO Group 1 children exhibited below-average performances in simple language skills. A majority of these children (75%) evidenced below-average performances in complex language skills. Relatively few of these Group 1 children evidenced below-average performances on complex-motor, visual-spatial, and 'higher-order' skills.

NEURO Group 1 contained the largest numbers of Rourke G1 (i.e., 71, or 31%) and G2 (i.e., 22, or 10%) types of children. Only 4% could be classified as Rourke G3 types. Twenty percent exhibited at least low-average performances on all WRAT subtests (i.e., normal academic achievers). However, depending on the measure of psychometric intelligence chosen (i.e., WISC or PPVT) and IQ cutoff point, a large majority of these children (66% to 91%) were considered learning disabled on the basis of IQ-Achievement discrepancy criteria. Relatively few low-IQ children were identified within NEURO Group 1. Compared with the other NEURO subtypes, none of the categories of children (e.g., hearing anomalies present) usually excluded from learning disability studies appeared to be overly represented in this subtype.

The test performances of NEURO Group 1 could be characterized as follows: (a) very well-developed visual-spatial skills; (b) well-developed eye-hand coordination, non-verbal problem-solving, and abstract reasoning abilities; (c) average performance on word definitions, and low-average performance on a test involving store of general information; and (d) mildly impaired performances on verbal fluency and memory for sentences.

NEURO Group 2. Group 2 (n=185) was the second largest subtype to emerge from the Phase II cluster analyses. There were approximately 7 males to 1 female and six right-handed children for every left-handed child in this subtype. The average age of these children was 10.94 years. WRAT Reading skills were average, while Spelling and Arithmetic skills were within the low-average range. WISC Full Scale and Verbal IQs were within the average range while the obtained Performance IQ was high-average. There was a Verbal-Performance IQ discrepancy of 14 points in favour of the latter.

Only 18% of the NEURO Group 2 children could be be classified as Rourke G1 types and relatively few were considered to be Rourke G2 or G3 types. Although 42% of the Group 2 children were at least low-average achievers with respect to WRAT standard scores, more than 70% could be categorized as learning disabled according to the various

IQ-Achievement discrepancy criteria. None of the Group 2 children could be characterized as 'low-IQ' with WISC FSIQ cutoff points. Twenty-seven percent were thought to be emotionally disturbed and only 10% evidenced impairment on the Sweep Hearing Test. None of the other exclusionary categories appeared to be overly represented in this subtype.

Some of these Group 2 children (i.e., 41%) exhibited below-average performances on complex language skills. However, relatively few exhibited below-average performances within any other neuropsychological skill area. Test performances were characterized by: (a) above-average visual-spatial skills; (b) well-developed speeded eye-hand coordination and simple motor skills, non-verbal problem-solving, abstract reasoning, and word definition abilities; (c) average ability to access stored general verbal information and (d) low-average performances on verbal fluency and sentence memory.

<u>NEURO Group 3.</u> Group 3 (n=89) contained approximately 3 males to 1 female and 4 right-handed children for every 1 left-handed child. These proportions were very similar to the sex and handedness ratios occuring within Sample A. The average age of these Group 3 children was 11.65 years. WRAT Reading, Spelling, and Arithmetic skills were all close to the lower limits of the low-average range. WISC Full Scale

IQ was within the low-average range while Verbal IQ was below-average. Performance IQ was well within the average range. Group 3 exhibited a Verbal IQ-Performance IQ discrepancy of 14 points in favour of the latter. Peabody Picture Vocabulary IQ was within the low-average range.

Approximately 30% of the NEURO Group 3 children were classified as Rourke G1 types while the Rourke G2 and G3 types were almost absent. Only 13% of the Group 3 children were considered to be at least low-average academic achievers. Depending on the IQ cutoff score, 38% to 80% were learning disabled on the basis of IQ-Achievement discrepancy criteria, and 20% to 60% would be considered low-IQ children. It was considered noteworthy that, if a WISC FSIQ cutoff of 80 were employed, then 80% of the Group 3 children would be considered learning disabled with the discrepancy criteria and the remaining 20% would be categorized as low-IQ children. Only 16% of the NEURO Group 3 children were thought to be emotionally disturbed. None of the other exclusionary categories were overly represented in this subtype.

A majority of the NEURO Group 3 children exhibited below-average performances in simple and complex language skills (i.e., 55% and 81%, respectively). Relatively few of these children evidenced poor performances in visual-spatial skills. Test performances were characterized by: (a) severely impaired sentence memory abilties, poorly developed store of general information, word definitional and verbal fluency skills; (b) low-average abilities with respect to simple motor and speeded eye-hand coordination tasks; and (c) low-average abilities on tasks designed to assess abstract reasoning and non-verbal problem-solving skills within the context of relatively well-developed visual-spatial skills.

NEURO Group 4. Group 4 (n=111) contained approximately 4 males to 1 female and 7 right-handed children for every 1 left-handed child. The average age of these children was 11.08 years. WRAT Reading, Spelling and Arithmetic skills were within the low-average range; however, Reading skills were relatively better developed. WISC Full Scale, Verbal and Performance IQs were within average limits and there was a small Verbal IQ-Performance IQ split of five points in favour of the latter.

Relatively few of the Group 4 children could be classified as Rourke G2 or G3 types; however, 25% were designated as Rourke G1 types. Twenty-four percent were considered 'normal' academic achievers, while 54% to 85% could be classified as learning disabled with the various IQ-Achievement discrepancy definitions. Although 37% of the Group 4 children would be considered to be 'low-IQ' on the basis of obtained PPVT scores, relatively few were considered as such when a WISC Full Scale IQ cutoff of 85 was chosen. Although 20% of the Group 4 children were thought to be emotionally disturbed, none of the other exclusionary categories were (considered to be) overly represented within this subtype.

Twenty-two percent of the NEURO Group 4 children exhibited below-average performances on simple language skills and many (71%) of these children evidenced below-average performances on complex language skills. Some of the Group 4 children exhibited below-average performances on visual-spatial and 'higher-order' skills (i.e., 11% and 18%, respectively). Relatively few experienced severe difficulty with simple or complex motor skills. Test performances were characterized by: (a)severely impaired ability to recall orally-presented sentences and poor verbal fluency skills; (b) low-average abilities to define words and a rather poorly developed store of general verbal information; (c) adequately developed non-verbal problem-solving and abstract reasoning skills within the context of well-developed simple motor and speeded eye-hand coordination abilities.

<u>NEURO Group 5.</u> Group 5 (n=51) contained approximately 6 males to 1 female and 5 right-handed children for every left-handed child. The average age of these children was 10.88 years. WRAT Reading skills were at the lower limits

of the average range, while Spelling and Arithmetic skills were within the low-average range. Although WISC Full Scale, Verbal and Performance IQs were well within the average range, NEURO Group 5 evidenced a 12 point Verbal IQ-Performance IQ split in favour of the latter.

Very few of the Group 5 children could be designated as Rourke G2 or G3 types, although 29% were categorized as Rourke G1 types. Although 45% of these children were considered to be 'normal' academic achievers, between 65% and 78% were classified as learning disabled with the various IQ-Achievement discrepancy criteria. Twenty percent were considered low-IQ with the PPVT cutoff but next to none were designated as such on the basis of WISC FSIQ cutoff points. This subtype contained the largest group proportion of emotionally disturbed children (45%). Only 8% of the Group 5 children exhibited impairment on the Sweep Hearing Test. None of the other exclusionary categories were overly represented within this subtype.

Relatively few of the NEURO Group 5 children evidenced below-average performances on simple language and 'higher-order' skills. However, 45% of these children exhibited below-average performances in complex language skills. All children in Group 5 evidenced at least low-average levels of performance in the simple and complex motor, and visual-spatial skill domains. Test performances were characterized by: (a) high-average to above-average simple motor abilities and speeded eye-hand coordination; (b) average to high-average non-verbal problem-solving and abstract reasoning skills; (c) average abilities on tasks involving word definitions, general store of information, and verbal fluency within the context of mildly impaired abilities on a sentence memory task.

NEURO Group 6. Group 6 (n=95) contained approximately 3 males to 1 female and 5 right-handed children for every 1 left-handed child. The average age of these children was 11.83 years. WRAT Reading skills were at the lower limits of the average range, while Spelling and Arithmetic skills were within the low-average range. WRAT Reading and Spelling skills were somewhat better developed than Arithmetic skills. WISC Full Scale, Verbal and Performance IQs were all well within normal limits. There was no VIQ-PIQ discrepancy. Peabody Picture Vocabulary IQ was within the average range.

Sixteen percent of the NEURO Group 6 children could be classified as Rourke G1 types and 9% were designated as Rourke G3 types. Only one Rourke G2 type was found within Group 6. Twenty-five percent of the children in NEURO Group 6 were at least low-average academic achievers on the basis of their obtained WRAT scores. Depending on the IQ measure and cutoff score selected, 34% to 71% were considered learning disabled with respect to the IQ-Achievement discrepancy criteria. The proportion of low-IQ children in Group 6 varied between 20% and 59% according to the various IQ cutoff points. Although 31% of the children in Group 6 were thought to be emotionally disturbed, none of the other exclusionary categories were overly represented within this subtype.

Although only 15% of the NEURO Group 6 children exhibited below-average performances on simple motor skills, at least 25% evidenced below-average performances in all other skill areas. Complex language skills and 'higher-order' skills were below-average for 63% and 45% of these children, respectively. Test performances could be characterized as follows: (a) well below-average on one task requiring the recall of spoken sentences, below-average skills on verbal fluency, low-average skills on tasks designed to assess general store of verbal information and ability to define words; (b) low-average to average abilities on tasks requiring visual-spatial and simple motor skills; (c) below-average on one non-verbal problem-solving task which involved psychomotor output; and (d) well below-average on a task of speeded eye-hand coordination. Somewhat inconsistent with this depiction was the average level of performance obtained on another complex motor task (i.e., Maze Test) and a low-average performance evident on a non-verbal task requiring abstract reasoning ability (i.e, Category Test).

<u>NEURO Group 7.</u> Group 7 (n=107) contained 7 males to 1 female and 5 right-handed children to 1 left-handed child. The average age of these children was 10.95 years. WRAT Reading skills were at the lower limits of the average range; Spelling and Arithmetic skills were within the low-average range. WRAT Reading skills were somewhat better developed than Spelling skills. WISC Full Scale, Verbal and Performance IQs were all well within normal limits. WISC Performance IQ was approximately four points higher than Verbal IQ. Peabody Picture Vocabulary IQ was within the average range.

Relatively few of the Group 7 children were categorized as Rourke G2 or G3 types, while 26% were considered Rourke G1 types. Approximately 30% of these children were considered to be 'normal' academic achievers; however, on the basis of various IQ-Achievement definitions, 74% to 85% of the Group 7 children were classified as learning disabled. Group 7 contained a very small number of low-IQ children regardless of the psychometric measure or IQ cutoff score employed. Although 32% of the Group 7 children were thought to be emotionally disturbed, none of the other exclusionary categories were overly represented within this subtype.

More Group 7 children (48%) exhibited below-average performances on the complex motor skills than in any other skill domain. Thirty-nine percent of the Group 7 children evidenced below-average performances on complex language skills. Relatively few of the Group 7 children exhibited below-average performances within any of the other neuropsychological skill areas. The neuropsychological test performances of the Group 7 children could be characterized as follows: (a) well-developed abilities on tasks requiring visual-spatial skills, non-verbal problem-solving, abstract reasoning, and simple motor skills; (b) average to low-average skills on tasks requiring access of stored verbal information, ability to define words, verbal fluency, and recall of spoken sentences; and (c) low-average to below-average skills on tasks designed to assess speeded eye-hand coordination.

NEURO Group 8. Group 8 (n=170) contained approximately 4 males to 1 female and 3 right-handed children for every left-handed child. These proportions were very similar to the sex and handedness ratios of the entire sample. The average age of these children was 11.15 years. WRAT Reading, Spelling and Arithmetic skills were in the low-average to below-average range. WISC Full Scale, Verbal and

Performance IQs were within normal limits. There was a VIQ-PIQ discrepancy of approximately 4 points in favour of the latter. Peabody Picture Vocabulary IQ was well within the average range.

Although a small number of Rourke G2 and G3 types were present, 20% percent of the Group 8 children were classified as Rourke G1 types. Only 18% of the children in NEURO Group 8 were considered 'normal' academic achievers on the basis of their WRAT subtest scores. At the same time, a large number of these children (42% to 72%) were classified as learning disabled according to various IQ-Achievement discrepancy criteria. A relatively large number (i.e., 51% to 21%) of the children in Group 8 were categorized as low-IQ. Higher percentages of children with hearing (16%) and visual (15%) anomalies occured within Group 8 than in any other subtype. Twenty-six percent of the Group 8 children were considered emotionally disturbed and 27% of these children evidenced impairment on the Sweep Hearing Test.

A large majority of the Group 8 children exhibited below-average performances on complex language skills (75%) and complex motor skills (86%). Approximately 20% to 30% of these Group 8 children were below-average in all other skill areas. The neuropsychological test performances of this subtype were characterized by: (a) low-average to average abilities on tasks requiring visual-spatial skills, nonverbal problem-solving, abstract reasoning, and simple motor skills; (b) low-average skills on tasks requiring access of stored verbal information and ability to define words; (c) below-average to mildly impaired abilities with respect to verbal fluency and short-term memory for spoken sentences and (d) mildly impaired to impaired abilities on tasks requiring speeded eye-hand coordination.

NEURO Group 9. Group 9 (n=28) was the smallest subtype to emerge from the Phase II cluster analyses of Sample A. This subgroup contained approximately equal numbers of males and females, and 6 right-handed children for every left-handed child. The average age of these children was 11.36 years. WRAT Reading, Spelling and Arithmetic skills were within the low-average range, although Arithmetic skills were somewhat less well developed. WISC Full Scale and Performance IQs were well below-average and Verbal IQ was at the low end of the average range. There was a Verbal IQ-Performance IQ discrepancy of 15 points in favour of the former. Group 9 was the only subtype to evidence this type of VIQ-PIQ split.

Only one Group 9 child could be categorized as a Rourke G3 type while none of the Rourke G1 or G2 types were found in this subtype. Twenty-one percent of the children in Group 9 were considered 'normal' academic achievers. With respect to the IQ-Achievement discrepancy criteria, 46%

were classified as learning disabled when the PPVT IQ cutoff score was employed. However, relatively few of these children (4% to 25%) were categorized as learning disabled with the WISC FSIQ cutoff points. Fifty percent of the Group 9 children were considered low-IQ with the PPVT IQ cutoff score; however, most of these Group 9 children (71% to 93%) were designated 'low-IQ' with several WISC FSIQ cutoff points. Only 11% of the children (i.e., 31) in this subtype were thought to be emotionally disturbed; however, 21% of these Group 9 children were suspected of having some form of brain pathology and 25% were impaired on the Sweep Hearing Test. None of the remaining exclusionary categories were thought to be overly represented within this subtype.

All children in Group 9 exhibited below-average performances in complex motor skills. A majority of the children (63% to 77%) evidenced below-average performances in all other skill areas with the exception of simple language skills. In this neuropsychological skill area 34% of the Group 9 children exhibited below-average performances. The neuropsycholgical test performances of this subtype were characterized by: (a) outstanding impairment on tasks designed to assess speeded eye-hand coordination; (b) mild impairment on a finger tapping task; (c) impairment on one task requiring psychomotor and nonverbal problem-solving skills; (d) below average to mildly impaired abstract reasoning and visual-spatial skills; (e) low-average to below-average abilities on tasks designed to assess store of general verbal information, ability to define words and verbal fluency; and (f) mildly impaired ability to recall spoken sentences. On one simple motor task (Grip Strength) a low-average performance was obtained.

Phase III

In Phase III four subsamples were selected from Sample B on the basis of WISC FSIQ level. Except for low-IQ children, all other 'types' were excluded according to criteria traditionally employed in learning-disability research. The intent of this set of analyses was to determine if similar profile shapes would emerge regardless of the subsample IQ range, and whether the lowest IQ subsample would yield fewer and distinct subtypes. For these purposes, the 12 measures of neuropsychological ability were subjected to four different agglomerative hierarchical cluster methods. Squared Euclidean distance was employed as the similarity measure; however, Lorr's (1983) prosedure was used to emphasize profile shape rather than elevation.

Four subtypes emerged from each of the WISC FSIQ subsamples. Thus there was a total of 16 subtypes which were replicated with split-samples of the original data. Eight of these subtypes were found that were thought to represent two basic profile shapes (Shape A and Shape B). A subtype emerged from every WISC FSIQ level that was thought to be similar to Shape A and Shape B. Two other subtypes shared some characteristics with Shape A, and another subtype was somewhat similar to Shape B. However, there were notable differences between these subsample profiles and the two basic shape profiles. The six remaining subtypes were considered to be distinct from each other and different from all other subgroup profiles.

Although profile elevation is considered important in determining subtype structure (Fletcher & Satz, 1985) other authors (e.g., Rourke, 1978; Rourke & Adams, 1984) have suggested that profile similarity (i.e., shape) is particularly relevant for clinical and taxonomic purposes. Therefore, an attempt was made to interpret the patterns of neuropsychological performance identified with Shape A and Shape B even though the levels of performance on these variables obviously vary with WISC FSIQ levels.

Shape A. This profile was characterized by: (a) less well-developed skills on tasks requiring word definitions and ability to access stores of long-term verbal information; and (b) poorly developed verbal fluency and short-term memory for spoken sentences. These performances were in contrast to better developed simple and complex motor skills, visual-spatial skills, and abilities for nonverbal problem-solving and abstract reasoning. This profile was considered to represent a 'language-disordered' subtype which occured within all WISC FSIQ levels.

Shape B. This profile was characterized by: (a) poorly developed abilities on tasks requiring speeded eye-hand coordination; (b) some difficulty on verbal expressive tasks; and (c) relatively better performances on tasks designed to assess store of verbal information, ability to define words, simple motor and visual-spatial skills, nonverbal problem-solving and abstract reasoning abilities. This profile was thought similar to the articulatory and graphomotor disability group identified by Mattis et al. (1975) and to the 'ACID' pattern subtype reported by Petrauskas and Rourke (1979).

Evaluation of Expectations

Six distinct subgroups were expected to emerge from the cluster analysis of the WRAT scores in Sample A. Only four subtypes were found and although the external validity of these subgroups was demonstrated, they differed on the neuropsychological measures primarily in terms of profile elevation. Since this was the case, it was difficult to evaluate these WRAT groups with respect to the hypotheses outlined for the Phase I analysis. However, it was apparent that Hypotheses #1, #2, and #2A were not supported. None of the WRAT subtypes could be considered 'normal' academic achievers with any degree of assurance. There was some support for Hypothesis #2B. Group 2 exhibited the most impaired WRAT scores and obtained the greatest proportion of low-IQ children. Group 2 also evidenced a higher percentage of children with below-average performances in more neuropsychological skill areas than any other subtype. However, contrary to expectations, Group 2 also contained more children categorized as Rourke G1 types than was predicted by Hypothesis #2A. This finding was more supportive of Hypothesis #2C. Indeed, the pattern of neuropsychological abilities of Group 2 was most similar to that predicted by Hypotheses #2C and #2D. Since the obtained mean Arithmetic score was somewhat better developed than Reading and Spelling, Group 2 was supportive of Hypothesis #2D. This subtype also contained more Rourke G2 type children than did any other subgroup as expected from the Hypothesis #2D prediction.

WRAT Group 4 was similar to a subtype predicted by

Hypothesis #2E. Although arithmetic performance was not impaired, it was well below spelling and reading skills for this group. Many children in this subtype could be classified as Rourke G3 types and were considered emotionally disturbed as predicted by Hypothesis #2E. However, the neuropsychological performances of these children did not support this hypothesis. For example, average performances were obtained on visual-spatial and nonverbal problem-solving tasks. These performances were in sharp contrast to those predicted for Rourke's G3 type children. The patterns of neuropsychological abilities of WRAT Group 3 were somewhat suppotive of Hypothesis #2F. WISC Verbal, Performance, and Full Scale IQs were within the average range, however, the obtained VIQ-PIQ discrepancy was much less than predicted.

At any rate, the majority of the expectations for the Phase I analyses were unsupported. It was not immediately obvious why this was the case. However, WRAT Groups 1, 2, and 4 appeared to be very heterogeneous with respect to the 'types' of children they contained. In addition, there were rather large ranges associated with these groups for the both academic and neuropsychological measures.

With respect to the Phase II expectations, it was clear that Hypotheses #3 and #4 received no support. Nine subgroups emerged from these analyses and at least one (i.e., NEURO Group 2) could be considered 'normal' with respect to patterns of neuropsychological functioning and academic performance (i.e., average WRAT Reading skills). Hypothesis #5 received some (equivocal) support. NEURO Groups 4 and 5 evidenced minimal neuropsychological impairment relative to the other subtypes, however, neither of these subgroups evidenced relatively poor performances on the WRAT Reading subtest as predicted by Hypothesis #5.

Hypothesis #6: It was hypothesized that one subtype of children would exhibit impaired performances on most of the neuropsychological measures; contain a large group percentage of low-IQ children; exhibit WISC and PPVT IQ levels well belo-average; and, evidence severely impaired performances on the WRAT subtests. It appeared that NEURO Group 9 was quite similar to this proposed subtype. However, the obtained PPVT IQ and WRAT scores were not as depressed as predicted.

Hypothesis 7: It was predicted that a subtype would emerge which exhibited relatively poor language-related abilities in the context of well developed motor, visual-spatial, and nonverbal problem-solving skills. It appears that NEURO Group 1 is very similar to this proposed subtype in every respect except that WRAT reading was not below arithmetic. However, the obtained WRAT spelling score was lower than arithmetic as predicted.

Hypothesis 8: It was hypothesized that a 'mixed deficit' subtype would emerge with below-average performances on many of the neuropsychological measures, but not nearly as depressed as found with NEURO Group 9. It appears that NEURO Group 6 is very similar to this proposed subtype. It contains a large frequency of low-IQ children as predicted and exhibits below-average levels of performance in three of the six neuropsychological skill areas.

Directions for Future Research

The effect of the IQ variable on the types (i.e., structure) and number of subtypes emerging from cluster analyses of neuropsychological data can be investigated futher by selecting other samples of this data according to different IQ ranges. For example, it would be useful to compare the subtypes that emerge from analyses of IQ ranges commonly employed in LD studies (i.e., WISC FSIQ $\geq$ 80 and WISC FSIQ $\geq$ 85) with those that result from analyses of the data below these cutoff points (i.e., WISC FSIQ $\leq$ 80 and WISC FSIQ $\leq$ 85). Such analyses may provide additional information regarding differences in subtype structure that occurs in 'low-IQ' children. In particular, the Phase III results yielded evidence of 16 subtypes from a WISC FSIQ range of 70 to 110 points while the Phase II analyses revealed 9 subtypes within the WISC FSIQ range of 60 to 120. It is quite possible that some of the Phase III subtypes represent 'outlier' categories that were not readily apparent in the Phase II analyses. The validity of the subtypes from the low IQ (e.g., WISC FSIQ 70-80) ranges selected from Sample B could be demonstrated by clustering the Sample A subjects that occur at this IQ level.

Cluster analyses of the entire Sample B (n=882) would yield more information regarding the effect that including children typically not considered in these types of research efforts (i.e., brain damaged, emotionally disturbed) had on the results which emerged from Phase II. In this manner, application of cluster-analytic methodology to Sample B as a whole could serve as a control for the presence of these unusual children within Sample A. Although only the emotionally disturbed children appeared to emerge in varying quantities across the Phase II subtypes, indicating that they may indeed be best considered distinct from LD children, the design of the present study did not directly control for this possibility. It may also be useful to apply the chi-square statistic to the categories of children within each of the Phase II subtypes to determine if indeed there were types of children which occured with greater than expected frequency in any particular cluster group.

Another method of comparing the Phase II and Phase III subtypes more directly would be to employ a similarity analysis of the cluster profiles. This method involves determining the degree to which two (or more) profiles can be considered to be "parallel" (Lorr, 1983). Appliction of this method yields a statistical indice of the similarity in profile shape. It would, therefore, be most useful in determining which subtypes were adequately reproduced from subsets of the original data (internal validity). In the present study these comparisons between the original cluster results and the split-samples were demonstrated visually by overlapping the cluster profiles. Although these visual comparisons were most useful a more sophisticated statistical technique such as profile similarity analysis is certainly desirable. In addition, with the application of this technique, it would also be possible to make direct comparisons between the 16 subtypes that emerged from the analyses in Phase III. Although an attempt was made to search for subtype similarities across the four IQ ranges selected from Sample B, the method employed in this comparison summarized data within each skill area and may have obscured relevant distinctions between cluster groups. (Descriptions of all subtypes which emerged from the Phase II and Phase III analyses are listed in Appendix A for easy reference.)

The Phase I analyses yielded four rather heterogeneous clusters. It was expected that the cluster analyses of Sample A with respect to the WRAT variables would reveal a subtype of relatively 'normal' academic achievers who could be excluded from further data manipulation since they were not LD. Although some normal children were thought to be included in this sample they were not identified as such by the various cluster techniques. This was probably due to the fact that there were relatively few of these children within this sample. However, it is suggested that this could be explored further by application of the two-level cluster methodology (first cluster for shape, then elevation) as was successfully demonstrated in Phase II. Lorr's (1983) clustering strategy as applied in the Phase II analyses should be carried out on the Sample A data with respect to the WRAT variables. Such an analysis would reveal the subtype structure of Sample A in terms of the academic variables in greater detail.

Finally, it should be noted that this study is limited with regard to the similairty coefficient and cluster methods chosen, and the types of variables selected for the analyses. It may well be the case that different methods such as Q-factor analysis and other variables (e.g., use of left- and right-hand scores rather than composite measures) would yield different subtypes than those which emerged here.

Reference Notes

1. There were two data transformations utilized in this study. The first was a T-score transformation of all variables (i.e., WRAT scores; tweleve measures of neuropsychological abilities) employed in the cluster analyses and the external validation of the Phase I subtypes. This initial T-score transformation was separate from and independent of the second Z-score transformation discussed on page 110 of the METHOD section. The Z-score transformation was employed in the Phase II and Phase III cluster analyses. As described by Lorr (1983) and Skinner (1978) this type of transformation occurs across all relevant variables <u>within</u> each subject. This transformation serves to remove information regarding elevation and scatter from each individual subject's profile of test scores previous to the cluster analysis.

The Z-score transformation $z=X-x/SD$ employed in the present study, applied across each subject's profile row vector, can be explained as follows where:

x is the subject's raw score on the variables in it's profile row vector;

X is the mean of the subject's profile scores and can be shown to represent the elevation of this profile (Cronbach & Glesser, 1953).

SD is the subject's standard deviation associated with the scores in it's profile vector.

Then $X-x$ eliminates information in the subject's profile with respect to elevation since X (the profile mean) is being removed from each raw score x. The resultant profile deviation scores (i.e., all $X-x$) are then standardized within each subject by division with SD. This serves to equate all profiles within the data matrix with respect to scatter (Lorr, 1983; Skinner, 1978). According to Lorr (1983) any type of profile score (raw, standardized) may be treated in this manner. In the present study the profile scores were T-score transformations of the raw data.

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APPENDIX A

SUMMARY DESCRIPTIONS OF ALL SUBTYPES THAT EMERGED FROM THE PHASE II AND PHASE III CLUSTER ANALYSES

Table

Summary of all Subtypes that Emerged from the Phase II Cluster Analyses

Phase II Subtypes

Neuro Group 1. (n=230)	(a) well developed visual-spatial skills, nonverbal problem-solving, abstract reasoning, and eye-hand coordination.
	(b) average to low-average abilities when required to define words and access verbal information.
	(c) mildly impaired performances on complex language tasks (i.e., VFLU and SENMEM).
Neuro Group 2. (n=185)	(a) above-average visual-spatial skills
	(b) simple and complex motor skills, nonverbal problem-solving, abstract reasoning, and word definitional abilities were all well developed.
	(c) low-average performances on complex language tasks.
Neuro Group 3. (n=89)	(a) relatively well developed visual-spatial abilities.
	(b) low-average performances on tasks designed to assess abstract reasoning, nonverbal problem-solving, simple and complex motor abilities.
	(c) poor performances on simple and complex language tasks, with severely impaired abilities to recall spoken sentences.

Neuro Group 4. (n=111)	(a) well developed simple and complex motor skills.
	(b) adequately developed abstract reasoning, nonverbal problem-solving and visual-spatial skills.
	(c) more poorly developed abilities with simple language tasks, and severely impaired recall of spoken sentences.
Neuro Group 5. (n=51)	(a) very well-developed simple and complex motor skills.
	(b) well developed nonverbal problem-solving, abstract reasoning, and visual-spatial skills.
	(c) adequately developed simple language skills in the context of impaired recall for spoken sentences.
Neuro Group 6. (n=95)	(a) well developed simple motor skills.
	(b) poorly developed to severely impaired performances on simple and complex language tasks.
	(c) impaired performances on some tasks requiring complex motor and psychomotor output.
	(d) poorly developed visual-spatial and nonverbal problem-solving skills.
Neuro Group 7. (n=107)	(a) all skill areas adequately developed (or better) except for complex language and complex motor functioning.

Neuro Group 8. (n=170)	(a) poorly developed simple and complex language skills. (b) impaired complex motor functioning. (c) adequately developed visual-spatial and nonverbal problem-solving skills.
Neuro Group 9. (n=28)	(a) outstanding impairment on complex motor tasks, and difficulty with simple motor functioning. (b) impaired performances on all nonverbal problem-solving and visual-spatial tasks. (c) relatively better developed simple language skills and poor performances on tasks of complex language functioning.

Table (continued)

Summary of all Subtypes that Emerged from the Phase III Cluster Analyses

WISC FSIQ (70-80)

Subtype #1-1 (n=26)	(a) outstanding impairment on complex motor tasks. (b) severely impaired abilities for the recall of spoken sentences. (c) impaired performances noted within all six skill areas but some relatively better performances noted for simple motor and visual-spatial tasks.
Subtype #1-2 (n=31)	(a) adequate to below average performances in evidence for all skill areas. (b) below average to impaired abilities for simple and complex language functioning.
Subtype #1-3 (n=7)	(a) adequately developed simple motor skills. (b) impaired abilities with respect to simple and complex language functioning. (c) some severe difficulties noted on tasks designed to assess complex motor and nonverbal problem-solving.
Subtype #1-4 (n=4)	(a) difficulties with simple motor tasks, and one outstandingly impaired performance on a task requiring complex motor abilities. (b) low-average performances on tasks involving simple and complex language functioning. (c) somewhat below-average skills with respect to visual-spatial and abstract reasoning abilities. (d) an average performance on one task that requires nonverbal problem-solving and psychomotor output.

WISC FSIQ (81-90)

Subtype #2-1 (n=35)	(a) mild difficulty with simple language tasks and impaired functioning on complex language tasks. (b) all other areas of neuropsychological functioning appeared to be adequately or well developed.
Subtype #2-2 (n=15)	(a) low-average performances on tasks designed to assess simple language skills with impaired performances on tasks of complex language functioning. (b) all other skill areas were adequately developed although one complex motor task was performed in a below-average fashion.
Subtype #2-3 (n=12)	(a) adequate to low-average performances on all tasks with the exception of severe impairment noted on complex motor tasks.
Subtype #2-4 (n=6)	(a) low-average performances on simple and complex language tasks. (b) low-average to below-average performances on tasks designed to assess visual-spatial and nonverbal problem-solving. (c) well developed simple and complex motor skills.

WISC FSIQ (91-100)

Subtype #3-1 (n=24)	(a) all neuropsychological skill areas were well developed except for some mild difficulty noted with simple language skills. (b) difficulty with the recall of spoken sentences.

Subtype #3-2 (n=18)	(a) mild diffculties with complex language abilities and severe impairment noted on tasks requiring complex motor skill. (b) all other skill areas were adequately developed.
Subtype #3-3 (n=17)	(a) adequately to well-developed abilities in all skill areas with the exception of impaired performances in complex language and difficulty with one complex motor task that requires speeded eye-hand coordination.
Subtype #3-4 (n=7)	(a) some mild problems with simple and complex language tasks. (b) adequately developed abilities in all other areas and very well developed complex motor functioning.

WISC FSIQ (101-110)

Subtype #4-1 (n=37)	(a) below-average performances were evident on complex language tasks, all other areas of neuropsychological functioning were adequately to well developed.
Subtype #4-2 (n=9)	(a) difficulty with finger tapping and severe problems with verbal fluency, all other tasks were performed in a low-average fashion or better. (b) well developed visual-spatial abilities were readily apparent.
Subtype #4-3 (n=15)	(a) some (relatively) mild difficulty with complex language tasks, and severe problems with complex motor tasks were evident. (b) all other areas of neuropsychological functioning were well developed.

Subtype #4-4 (n=5)	(a) some difficulty with verbal fluency and nonverbal problem-solving in the context of psychomotor output was evident. (b) all other areas of neuropsychological were well developed.

VITA AUCTORIS

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