Modal Profiles for the Halstead-Reitan Neuropsychological Battery for Children

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Modal Profile Analysis was used to cluster students (aged 9 to 14 years) on 16 subtest scores from the Halstead-Reitan Neuropsychological Battery for Children (HRNB-C). This analysis produced eight modal profile types, all of which were replicated in multiple samples. An initial attempt to establish external validity indicated that the modal groups display dissimilar patterns of performance on independent variables. The present typology is compared to similar typologies developed with adult neuropsychological data. In sum, the current classification system provided less coverage than the adult typologies, but produced more unique or homogeneous modal groups. Discussion focuses on potential clinical and research uses of the modal HRNB-C profiles. © 1997 National Academy of Neuropsychology. Published by Elsevier Science Ltd

INTRODUCTION

The identification of commonly occurring patterns of performance on neuropsychological batteries (i.e., profile types) may provide substantial theoretical and practical benefits to the
field of clinical neuropsychology (Moses, Pritchard, & Faustman, 1994). First, the identification of profile types may lead to the detection of distinct subgroups of patients that are responsive to similar interventions. Second, knowledge of profile types may help identify patients with atypical patterns of performance who require further assessment. Finally, the discovery of profile types may promote research efforts by identifying homogeneous groups of patients that are comparable from study to study (Moses et al., 1994).

To date, most efforts to identify profile types have utilized adult populations. Early research with adults using both the Luria-Nebraska Neuropsychological Battery (LNNB; e.g., Silverstein, Strauss, & Fogg, 1990; Strauss & Silverstein, 1986) and the Halstead-Reitan Neuropsychological Battery (HRNB; e.g., Goldstein, 1990; Goldstein & Shelly, 1987; Silverstein, Strauss, & Fogg, 1990) generally found that the major difference among the identified profile types was in overall level of performance and not in profile shape or pattern. With these profile types, patients could be distinguished according to their overall level of performance, but they could not be distinguished by patterns of strengths and deficits. While neuropsychological tests do provide valuable information regarding relative strengths and weaknesses (e.g., Reitan & Wolfson, 1992), the results of these early studies reflect the tendency of large differences in profile level to obscure relatively smaller differences in profile pattern when applying clustering procedures to neuropsychological data.

Two principal techniques have been proposed to circumvent this problem. First, to eliminate differences due to profile level, a similarity measure can be selected that is sensitive only to profile pattern (e.g., correlation coefficient; Skinner, 1978). An alternative is to adjust the data so that differences resulting from profile elevation are removed. In this latter technique, once profile types have been identified on the basis of patterns of performance, information on elevation may then be restored. A clustering algorithm to accomplish this task was developed by Skinner (Skinner, 1977, 1978, 1979; Skinner & Jackson, 1978; Skinner & Lei, 1980) and is commonly referred to as Modal Profile Analysis (MPA). Moses et al. (1994) submitted T scores for the 11 LNNB clinical scales to a modified MPA. The analysis identified 22 modal profile types (seven of which were replicated in multiple samples), with 82% of the subjects assigned empirically to a modal profile group. In a subsequent study (Moses, Pritchard, & Adams, 1996), MPA was used to identify modal profile types on 11 scores from the HRNB. The analysis identified 18 modal types (12 of which were replicated in multiple samples of subjects), with 54% of the subjects assigned to a modal profile group.

The research of Moses et al. (1994, 1996) resulted in the identification of manageable sets of profile types that represent the most frequently occurring profile patterns on the adult LNNB and HRNB. However, a review of the literature did not reveal any studies that applied MPA to neuropsychological batteries for children and/or adolescents. Although there is an extensive literature involving the application of clustering techniques to samples of children with learning disabilities (e.g., Rourke, 1985), these studies usually attempt to discover subtypes of learning disabled subjects, and have not tried to identify profile types associated with specific neuropsychological batteries. While there is considerable overlap in terms of technique (i.e., clustering algorithms), there are differences between studies that attempt to identify profile types specific to standard test batteries and studies that focus on classification of psychopathology. The distinction is primarily one of scope or focus. Profile types are intricately related to a specific battery of tests (e.g., HRNB) and are of primary benefit to researchers and clinicians utilizing that specific battery. In contrast, classification research is typically independent of assessment technique and applies to the population of individuals with the spectrum of disabilities addressed. Nevertheless, these paradigms are conceptually related and should be viewed as complementary.

There are two sample characteristics that promote the successful detection of profile types in neuropsychological data. First, it is desirable to have relatively large samples that facilitate
the detection of infrequent, but recurrent patterns of performance. Second, the subjects should represent the types of patients to whom the tests are generally administered. For example, Snow and Desch (1989) noted that when studying learning disabled children, it is advantageous to include the broader population of subjects experiencing difficulties in the learning environment (e.g., emotional disturbance, Attention Deficit Hyperactivity Disorder) and not limit the study to “pure” populations of learning disabled subjects.

The goal of the present study is to develop a typology of patterned differences on the Halstead-Reitan Neuropsychological Battery for Children (HRNB-C; Reitan, 1969; Reitan & Wolfson, 1992). Once frequently occurring profiles are identified and subjects are classified into the most similar modal profile, the typology will be evaluated in terms of coverage, replicability, and uniqueness or homogeneity. With regard to clinical applications, the identification of profile types may lead to the identification of groups of children that are differentially responsive to specific forms of instruction and intervention (Selz & Wilson, 1989). While research assessing the match between specific remediation strategies and subgroups based on neuropsychological deficits and abilities is at an early stage (e.g., D’Amato, 1990; Hooper, Willis, & Stone, 1996; Reitan & Wolfson, 1992; Rourke, 1985; Rourke, Bakker, Fisk, & Strang, 1983; Teeter, 1989; Telzrow, 1985), it is felt that the current line of study will contribute to the development of empirically based neuropsychological treatment models.
METHOD

Subjects

This research was based on a sample of 513 subjects (9–14 years) referred to a special services cooperative by parents and/or school personnel due to academic and/or behavioral concerns. The purposes of this referral were to determine if the student qualified for special education services in the schools (i.e., initial referrals) or to facilitate a match between students’ needs and services (e.g., help develop educational modifications). The subjects attended schools located in suburban and rural areas of central Texas serviced by a special services organization. Seventy-three percent of the subjects were boys (n = 375) and 27% were girls (n = 138). The mean age was 142.4 months (SD = 21.1) and mean grade in school was 5.5 (SD = 1.8). Eighty-seven percent of the subjects (n = 447) were right-handed and 13% were left handed (n = 66). This sample was comprised predominantly of the children from middle-class families and included 456 White students (89%), 32 Hispanic students (6.2%), 24 African American students (4.7%), and one Asian American student. Table 1 presents the distribution of age, grade in school, and diagnostic classification for the sample. As noted in the procedure section, the total sample of 513 subjects was randomly divided into three separate samples prior to analysis.

Instruments

As part of a comprehensive psychoeducational assessment, an individually administered intelligence test, an achievement test, and the Halstead-Reitan Neuropsychological Battery for Children (HRNB-C) were administered to all subjects. Intellectual and achievement data were collected by certified psychological associates with specific academic and experiential training in the assessment and diagnosis of childhood learning/emotional disorders. All neuropsychological assessments were administered by a technician with extensive training in the administration of the HRNB-C. In the present study, HRNB-C variables were submitted to MPA, while intelligence and achievement data were reserved for examination of external validity.

The following HRNB-C subtests were administered: Category Test, Tactual Performance Test (TPT), Seashore Rhythm Test, Speech Sounds Perception Test, Trail Making A and B, Finger Oscillation Test, Aphasia Screening Test, and Sensory Perceptual Examination. Detailed descriptions of this battery are available in the literature (e.g., Boll & Barth, 1981; Reitan & Wolfson, 1986, 1992; Robbins, 1989; Teeter, 1986). In addition to the standard HRNB-C subtests, raw data were available for “Name Writing Dominant and Nondominant” (Selz & Reitan, 1979). All tests were administered in the standard manner with the exception of the Speech Sounds Perception Test (SSPT). Approximately half of the subjects received the full SSPT while others received an abbreviated form of the SSPT (i.e., half-test; Golden & Anderson, 1977). Administrations of both the original projection version of the Intermediate Category Test and the booklet version were included. Research supports the comparability of projector- and booklet-administered forms of the Category Test (e.g., Holtz, Gearhart, & Watson, 1996).

Procedure

Raw data for 14 HRNB-C variables and two Name Writing time scores (i.e., Dominant and Nondominant) were submitted to Modal Profile Analysis (Skinner, 1977, 1978). Raw

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1The Aphasia screening test was scored with a procedure developed by one of the authors. This procedure produced two scores, Aphasia and Praxis. For a full description of this scoring protocol, contact the first author.
data for Trail Making A and TPT-Both Hand were excluded from the final analysis because there was relatively little variation in raw scores. In addition, the individual items of the Sensory Perceptual Examination were excluded because of the relative unreliability of individual items (Nunnally, 1978).

Since some of the raw scores were error scores, some items correct, some time scores, and some performance scores, it was necessary to reflect (i.e., invert) some raw scores so that higher scores on each variable indicate “better” performance and lower scores on each variable reflect “poorer” performance. The reflected variables were: TPT-Dominant, TPT-Nondominant, SSPT, Trail Making B, Category, and Name Writing Dominant and Nondominant. Reflection occurred by subtracting each subject’s raw score from the maximum score obtained in the sample.

Two data transformations were performed on the reflected raw scores prior to submission to the Modal Profile Analysis program. First, each subject’s raw scores on each variable were converted to age-dependent z scores. This was accomplished by initially computing means and standard deviations for each variable within each age category (i.e., 9–14 in yearly increments). After age-dependent means and standard deviations were calculated, each subject’s raw scores were converted to z scores based on their age. This transformation had the effect of eliminating between-subject differences due to age. As a result, the final modal profiles are appropriate for use with any child between the ages of 9 and 14 years. The limitation with this approach is that any age-specific patterns in HRNB-C scores are not detected. The only way to overcome this limitation is to collect large sets of data on each age group and perform MPA on each age group separately. The current sample size does not permit such an approach.

After each subject’s raw scores were transformed to age-dependent z scores, each variable was then standardized across the entire sample. That is, each subject’s age-dependent z scores were transformed to sample-dependent z scores, where the average score on each variable for the entire sample was 0.0 and the sample SD was 1.0. This transformation had the effect of putting each variable on the same scale and, therefore, making them comparable to one another. These “doubly” standardized scores were then input into the MPA program.

In Stage 1 of MPA, each subject’s scores are transformed to ipsative z-scores (i.e., in calculating ipsative z scores, each subject’s mean score across the variables in the profile is computed (Profile Level); each subject’s standardized deviation of scores around this average is computed (Profile Scatter); and each subject’s score on each variable is transformed to an ipsative z score using Profile Level and Profile Scatter to compute the new scores). The Profile Level and Profile Scatter parameters are set aside and each subject’s vector of ipsative z scores is correlated with every other subject’s vector of ipsative z scores. The resulting profile-by-profile intercorrelation matrix is subjected to a principal components analysis and rotated using a varimax criterion. Based on the pattern of subject loadings on each retained factor (Criterion: Eigenvalue > 1.0), an ideal factor loading matrix is hypothesized. The principal components are rotated to conform as closely as possible to the hypothesized matrix. The weighted average profile associated with each retained factor is then computed as a “modal profile.” This process is repeated separately for each sample input to the MPA program. In the current study, the total sample of 513 subjects was divided into three separate samples that were submitted separately to the above process.

Stage 2 of MPA performs a principal components analysis of the profile-by-profile intercorrelation matrix, using the modal profiles generated in stage one. The procedure is exactly the same as in stage one: principal component analysis of the profile-by-profile intercorrelation matrix with varimax rotation; construction of a hypothesized transformation matrix; confirmatory rotation to the hypothesized matrix; retention of factors with eigenval-
ues greater than 1.0; and computation of the weighted average profiles associated with each retained factor. These weighted average profiles represent the final modal profiles.

Stage 3 of MPA classifies each individual subject into one of the final modal profiles according to its product-moment correlation with the associated modal profile. In order to facilitate comparison of results with those obtained by Moses et al. (1994, 1996), the same similarity rule was initially used to classify subjects into modal profiles. That is, each subject’s profile was correlated with each of the final modal profiles and was assigned to a modal profile type if its correlation was maximal and greater than or equal to 0.65 (MAXR rule). If a subject’s profile correlated less that 0.65 with each of the final modal profiles, that subject remained unclassified. After the initial classification, the MAXR criterion was reduced from 0.65 to 0.60 to enhance coverage and evaluate its impact on typal uniqueness.

Once subjects were assigned to modal profiles, the groups were evaluated for coverage by determining the total percentage of subjects assigned to modal profile types (utilizing both the 0.65 and 0.60 criteria). Typal uniqueness was assessed with the simple distance probability statistic (SDP; Overall & Klett, 1972). SDP indexes the relative probability that the subject belongs to the assigned modal type and not to another modal profile type. If a subject’s profile is highly similar to only one type the SDP will be large (maximum = 1.0). However, if a subject’s profile is also similar in shape to modal types other than the one assigned by the MAXR rule, then SDP will be smaller.

Two final statistical analyses were conducted to address separate questions. First, canonical correlation analyses were conducted to estimate the proportions of variance accounted for by differences in profile level, profile scatter, and profile pattern. Second, to address external validity, profile analysis was used to compare the modal clusters on cognitive variables that were not included in the clustering procedures. Profile analysis assesses group differences in profile shape (i.e., are the profiles parallel?) and level (i.e., are the profiles coincident?). It also provides a test of the flatness of the combined or pooled profile for the groups (Harris, 1985; Stevens, 1986). A nontechnical and readable discussion of this technique is provided by Francis, Epsy, Rourke, and Fletcher (1991).

RESULTS

In Stage 1 of MPA, each of the subsamples produced seven clusters of subjects (each characterized by a distinct modal profile). These 21 modal profiles were reduced to 8 modal profiles in Stage 2. Of these, six modal profiles were replicated in all three samples, and two were replicated in two of the three samples. In Stage 3 of MPA, subjects were classified into modal clusters if their absolute correlation with that cluster’s modal profile was maximal and at least 0.65.

Using this criterion, 28% of the 513 subjects were assigned to one of the eight final modal profiles (with 72% remaining unclassified). Examination of the correlation coefficients of classified subjects revealed that four of the eight modal profiles had both positive and negative clusters of subjects (i.e., some subjects correlated ≥ +0.65 and some subjects correlated ≥ −0.65 with the respective modal profiles). Therefore, four of the eight modal groups were split into two, mirror image groups. As a result, the final set of modal profiles consisted of 12 profiles: 4 distinct profiles and 4 profiles with associated mirror-image profiles.

To determine the coverage and typal uniqueness of the final modal types, the MAXR criterion was reduced from 0.65 to 0.60. Decreasing the minimal correlation needed for classification to 0.60 increased the coverage of the typology from 28% to 42%. The cost of using a less stringent criterion for classifying profiles is that subjects may be classified into
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Note. Gr-D = Grip Strength-Dominant; Gr-N = Grip Strength-Nondominant; Ta-D = Finger Tapping-Dominant; Ta-N = Finger Tapping-Nondominant; Nw-D = Name Writing-Dominant; Nw-N = Name Writing-Nondominant; Tpt-D = TPT-Dominant Hand Time; Tpt-N = TPT-Nondominant Hand Time; Tpt-M = TPT-Memory; Tpt-L = TPT-Location; SRT = Seashore Rhythm Test; SSPT = Speech Sounds Perception Test; Prx = Praxis Score; Tr-B = Trail Making, Part B; Aph = Aphasia Score; Cat = Category Test.

*aReplicated in all three samples.
*bReplicated in two of three samples.

describes a specific modal group when they have substantial correlations with other modal groups. As noted, the simple distance probability statistic (SDP) is an index of the relative probability that a subject belongs to a particular modal group compared to all other groups. The average SDP for subjects classified with the MAXR ≥ 0.65 was 0.939, while the average SDP for subject’s classified with the MAXR ≥ 0.60 was 0.872. This indicates that reducing MAXR criterion to 0.60 increases the coverage from 28% to 42% without unduly sacrificing the uniqueness of the subject’s classification.

Table 2 presents the modal profiles for the 12 clusters of subjects. The first column of the table lists the labels for the modal profiles while the body presents the vector of weighted average z scores. Each value in the body of the table is the number of ipsative SDs above (positive) or below (negative) the profile elevation for that particular subtest. For example, for Modal Profile 1a the Grip Strength — Dominant score is 0.61 ipsative standard deviations above the profile mean, the Grip Strength — Nondominant score is 0.63 ipsative standard deviations above the profile mean, etc. These values represent the weighted average profiles of the modal profiles obtained in Stage 1 of MPA, not the average profile of subjects assigned to each Modal Profile by the MAXR rule in Stage 3 (Modal Profiles are displayed graphically in Figures 1–8). Descriptions of the 12 modal profiles are provided in the Appendix, where each modal type is described both in terms of the HRNB-C variables used in the actual clustering process and intellectual, achievement, and demographic variables not included in the clustering procedure.

To assess differences among the 12 modal clusters in profile elevation and scatter, analyses of variance were computed with each modal group forming one level of a factor. Here, unclassified subjects were excluded and the analysis was performed only on classified subjects (MAXR ≥ 0.60). Results indicated a significant effect for both profile elevation

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2In addition to a minimal reduction in SDP when reducing MAXR criterion to 0.60, the two indices (MAXR and SDP) produced identical classifications at both MAXR levels. That is, MAXR ≥ 0.65 and maximal SDP classified 100% of the students into the same modal groups. When the classification rule was reduced to MAXR ≥ 0.60, maximal SDP continued to classify 100% of the students into the same modal groups.
(F(11, 201) = 3.53, p < 0.01) and scatter (F(11, 201) = 8.27, p < 0.01). Since the typology was constructed by decomposing original raw scores into components of profile level, scatter, and shape, it was possible to establish the relative contribution of these components to overall variance in HRNB-C profiles. Canonical correlation analyses revealed that profile level accounted for 20.4% and profile scatter accounted for 2% of the variance in HRNB-C profiles (in doubly-standardized HRNB-C profiles, not raw-score profiles). The residual variance (i.e., 77.6%) was due to difference in profile shape plus measurement error. There is no direct
FIGURE 3. Gr-D = Grip Strength-Dominant; Gr-N = Grip Strength-Nondominant; Ta-D = Finger Tapping-Dominant; Ta-N = Finger Tapping-Nondominant; Nw-D = Name Writing-Dominant; Nw-N = Name Writing-Nondominant; Tpt-D = TPT-Dominant Hand Time; Tpt-N = TPT-Nondominant Hand Time; Tpt-M = TPT-Memory; Tpt-L = TPT-Location; SRT = Seashore Rhythm Test; SSPT = Speech Sounds Perception Test; Prx = Praxis Score; Tr-B = Trail Making, Part B; Aph = Aphasia Score; Cat = Category Test.

A method of estimating the proportion of profile variance due to shape independent of measurement error. However, consideration of the reliabilities of the individual scores in the profile may provide useful information.

FIGURE 4. Gr-D = Grip Strength-Dominant; Gr-N = Grip Strength-Nondominant; Ta-D = Finger Tapping-Dominant; Ta-N = Finger Tapping-Nondominant; Nw-D = Name Writing-Dominant; Nw-N = Name Writing-Nondominant; Tpt-D = TPT-Dominant Hand Time; Tpt-N = TPT-Nondominant Hand Time; Tpt-M = TPT-Memory; Tpt-L = TPT-Location; SRT = Seashore Rhythm Test; SSPT = Speech Sounds Perception Test; Prx = Praxis Score; Tr-B = Trail Making, Part B; Aph = Aphasia Score; Cat = Category Test.
DISCUSSION

The current results present the most frequently occurring HRNB-C profiles among subjects between the ages of 9 and 14 years referred for academic and behavioral problems in a public school setting. The range of diagnoses contained in the current study is probably representative of similar school populations. As a result, the modal profiles discovered in this sample are likely to characterize a considerable proportion of patients in similar settings. However, it is likely that additional modal groups exist that characterize subjects evaluated in other settings (e.g., hospital and rehabilitation facilities).

Construct validation of the modal profiles involves examining the internal characteristics of the classification system, the external validity of the modal profiles, and the degree to which the system generalizes (Moses et al., 1994). Internal characteristics of the classification system include its reliability, coverage, homogeneity, and robustness (Skinner, 1981). The reliability with which individual profiles are assigned to modal profiles depends on the reliability of the component scores (Moses et al., 1994). As a result, the reliability of the current system is dependent on the reliability of the component subtests of the HRNB-C. While the psychometric properties of neuropsychological tests for children have come under increasing scrutiny in recent years, the focus has been on establishing the validity of these tests (for review, see Reitan & Wolfson, 1992), and reliability has received less attention (Francis, Fletcher, Rourke, & York, 1992). The available research addressing reliability of the adult Halstead-Reitan battery suggests adequate reliability (e.g., Goldstein & Watson, 1989; O’Donnell, De Soto, & De Soto, 1993; Moses, 1985; Russell, 1992). While there is less research examining the reliability of HRNB subtests with children and adolescents, the existing psychometric studies are positive and suggest adequate reliability (e.g., Brown, Rourke, & Cicchetti, 1989; Byrd & Ingram, 1988). Nevertheless, further efforts to establish the reliability of HRNB-C subtest scores in pediatric populations are clearly indicated.

Coverage refers to the percentage of subjects classified in one of the modal types. In the current study, two threshold criteria were used for assigning subjects to modal types. Using the more stringent 0.65 criterion, 28% of the 513 subjects were assigned to a modal group.
Decreasing the minimal correlation needed for classification to 0.60 increased the coverage of the typology from 28% to 42%. By way of comparison, previous research using MPA with adult populations (MAXR \( \geq 0.65 \)) reported coverage rates of 82% for the Luria-Nebraska Neuropsychological Battery (Moses et al., 1994) and 54% for the Halstead-Reitan Neuropsychological Battery (Moses et al., 1996). It is apparent that the current system provides less coverage than the systems derived for neuropsychological batteries with adult populations.

In essence, the lower coverage of this typology indicates that the majority of subjects displayed unique patterns of performance. While the basis for this is unclear, several hypotheses may be proposed. For example, it is possible that replicable patterning within each age group (i.e., 9–14 in yearly increments) was averaged out of the current analysis by age-standardizing all the component variables. It is also possible that the reduced coverage could be due to relative unreliability on specific component scales with these younger subjects. Such unreliability might be the result of rapid developmental neurological changes occurring with this population. Finally, many of these children may have complex and highly individualistic neuropsychological profiles that evade subtyping (for a related discussion, see Reitan & Wolfson, 1992). Continued research is clearly indicated to assess these (and possibly other) hypotheses.

Homogeneity of profile types refers to the similarity of subjects assigned to a particular profile group in relation to other clusters. In other words, homogeneity reflects the “distinctness” or “uniqueness” of the modal profiles. In the present study, the homogeneity of the 12 HRNB-C types was assessed by calculating the average SDP. As noted, the average SDP for subjects classified with the MAXR \( \geq 0.65 \) was 0.939 and the average SDP for subject’s classified with the MAXR \( \geq 0.60 \) was 0.872. In relation to the earlier research by Moses et al. (1994, 1996), these profiles are more unique than those obtained with either the LNNB-Adult (SDP = 0.59) or the HRNB-Adult (SDP = 0.77). Therefore, while greater classification coverage was obtained with the LNNB-Adult and HRNB-Adult (Moses et al., 1994, 1996), the modal groups were less unique or homogeneous in the adult batteries. It would be possible to increase the coverage of the present HRNB-C typology by reducing the classi-
classification criterion (at the expense of reduced homogeneity). As noted by Blashfield and Draguns (1976), there tends to be an inverse relationship between reliability and coverage in classification systems. Diagnostic categories high in specificity (i.e., unique) tend to be reliable, but provide low coverage. In contrast, categories that are less clearly defined generally provide good coverage, but at the expense of reliability.

Robustness refers to the replicability of profile types in new subject samples. In the current sample, six profiles were replicated in three separate subsamples while two profiles were replicated in two of the three subsamples. However, these three samples were simply subsets of the overall sample, which underrepresented females and was relatively homogeneous in terms of race and socioeconomic status. Whether these results will generalize to other samples requires additional research. Studies using other populations can test the replicability of the profile types and possibly lead to the discovery of additional modal profiles.

The external validity of profile types refers to their descriptive, predictive, and clinical validity. Descriptive validity is demonstrated when relationships exist between profile types on independent variables (i.e., variables not included in the initial analyses). For example, the HRNB-C modal profiles should be distinguishable from each other on various intellectual, achievement, and behavioral measures. To illustrate this line of study, profile analysis was performed to assess profile differences between MP 1a and MP 1b on Wechsler factor scores (i.e., Verbal Comprehension, Perceptual Organization, and Freedom From Distractability). When establishing external validity, Morris and Fletcher (1988) highlighted the importance of using independent variables that were not included as variables in the clustering procedure. While it is established that IQ influences performance on the HRNB-C, it is also documented that these tests reflect different sets of abilities (D'Amato, Gray, & Dean, 1988; Klonoff, 1971; Seidenberg, Giordani, Berent, & Boll, 1983). As a result, the use of Wechsler factor scores appears warranted when assessing the external validity of this solution.

The analysis revealed that the two modal groups were not parallel ($F(2, 37) = 6.64, p < 0.01$). In other words, the two groups did not display similar patterns of strengths and

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4The profiles were also not coincident or level, but these tests are of little meaning in light of the finding of nonparallelism (Stevens, 1986).
weaknesses on the Wechsler factor scores. This demonstrates a discriminative relationship between these HRNB-C groups on the Wechsler factor scores and provides preliminary evidence of descriptive validity.

Predictive and clinical validation requires an ongoing series of studies aimed at establishing the external validity of the typology (Skinner, 1981). The predictive validity of the modal profiles can be evaluated through test-retest designs assessing temporal stability of profile type (e.g., do subjects remain in the same subtype when retested). Temporal stability could also be demonstrated if subjects exhibiting either a positive or negative change in level of performance (e.g., as the result of a progressive disease or treatment effect) remain in the same modal profile subtype.

Since the modal profile represents patterns of neuropsychological strengths and weaknesses, it might be expected that subjects assigned to different subtypes would respond differently to interventions. As a result, clinical utility would be demonstrated when knowledge about modal profile assignment facilitates assignment to different interventions or treatment programs. For example, MP 6 is characterized by poor phonological coding and deficits in attention/concentration. Research (e.g., Cohen, Krawiecki, & DuRant, 1987; Lyon, 1985; Telzrow, 1985) suggests that subjects with this pattern of deficits often benefit from an instructional program emphasizing whole word and analytic phonics principles. In contrast, subjects with intact auditory and phonological skills, but deficits in abstract reasoning abilities (e.g., MP 1a) may benefit more from a synthetic phonetics approach. Research demonstrating differential intervention effects would support the clinical validity and utility of the typology.

Assignment to a modal profile using the described procedures is based on the subject’s pattern of relative strengths and weaknesses on the HRNB-C. As Moses et al. (1994) noted, it is also important to consider differences in profile elevation, which reflects the severity or level of global impairment across all scales. For example, two subjects may be widely different in elevation, but display a high degree of similarity to the same modal profile. As a result, the clinical significance of a modal profile will probably vary as a function of profile...
elevation. The detection of differences within modal clusters related to elevation is an important factor to be examined in establishing external validity.

Research with independent samples is clearly needed to assess the external validity of this typology. For example, it is important to evaluate the coverage of this typology in independent samples. Moses et al. (1994) reported shrinkage of approximately 5% in the coverage of their LNNB typology when the modal profiles were applied to a new sample of patients. Additionally, research with independent samples may facilitate the identification of additional modal profiles. That is, there may be unique modal profiles that characterize subjects evaluated in other settings (e.g., neurological clinics, private practice, rehabilitation centers). In sum, research with independent samples is indicated to verify the present typology and promote the development of a more comprehensive HRNB-C typology.

As noted, this line of research may help practitioners to translate neuropsychological research into educational and rehabilitation applications. Selz (1981) noted that the most extensive application of pediatric neuropsychology involves the assessment and remediation of learning disabilities. Research in this area has consistently shown that learning disabled subjects are not a homogeneous population (Lyon, 1985; Rourke & Finlayson, 1978; Rourke & Strang, 1978; Selz, 1981). Learning disabled subjects display diverse patterns of cognitive strengths and deficits, and as a result, they do not respond equally well to a single approach to remediation. Ideally, effective programming should be based on an understanding of the subject’s unique neuropsychological pattern. It is anticipated that the identification and validation of HRNB-C modal profiles will have prognostic value and can enhance the design of remediation programs.

SUMMARY

The present study presents a typology for classifying HRNB-C profiles according to profile shape. While the current system provides limited coverage (i.e., 28%-42%), other internal and external characteristics are encouraging and justify further research efforts. Future studies in this series will focus on examining the external validity of the 12 HRNB-C modal profiles and refining the typology. The relative importance of profile elevation versus profile shape will also be addressed.

The ultimate goal of this program of research is to establish a set of empirically based decision rules for classifying subjects according to their pattern of functional strengths and weaknesses. As the characteristics of the modal groups are further delineated, research on neuropsychological treatment models can be utilized to propose instruction and intervention strategies that are most appropriate for specific groups.

REFERENCES


**APPENDIX: COMPENDIUM OF MODAL PROFILES**

These descriptions of the Modal Profiles are based on two principal processes. First, the profiles types are examined relative to the HRNB-C variables that were used in the actual clustering process. Second, the group profiles of students assigned to Modal Profile Types are examined on variables not included in the initial clustering procedure. For this sample, measures of intellectual ability (i.e., FSIQ, VIQ, PIQ) and academic achievement (i.e., Basic Reading, Spelling, and Math Calculation) were available. Additionally, demographic information regarding the student’s age, sex, and diagnostic classification were available and examined.

**Modal Profile 1a (n = 19):** On the HRNB-C variables, this modal type is characterized by moderate deficits in abstract concept formation, tactual performance, and spatial memory. In contrast, there are relative strengths in psychomotor abilities, particularly motor speed. Students assigned to this modal type were characterized by intelligence in the Low-Average range, with comparable Verbal and Performance IQs. Consistent with IQ scores, achievement scores were in the Low-Average range, with Math scores lower than language-based scores. Relative to the overall sample, students in this group displayed lower intellectual abilities.

**Modal Profile 1b (n = 33):** This modal type is the mirror image of MP 1a. On the HRNB-C variables, this modal type is designated by weak psychomotor skills, particularly
motor speed. There are relative strengths in abstract reasoning, tactual performance, and spatial memory. Students assigned to this modal group were characterized by intelligence in the Average range, with Performance IQ higher than Verbal IQ. Achievement scores were generally at the low-end of the Average range. Relative to the overall sample, these students displayed good performance on intellectual measures, particularly the Performance scale.

Modal Profile 2a (n = 25): On the HRNB-C variables, this modal type is characterized by deficient motor strength and mild deficits in spatial memory, with most other abilities spared. Motor speed, nonverbal auditory discrimination, abstract concept formation, and tactual performance are relative strengths. Students assigned to this modal group were characterized by intelligence in the Average range, with comparable Performance and Verbal IQs. Achievement scores were generally consistent with IQ scores. There was a slight over-representation of emotionally disturbed (ED) students assigned to this modal group. This appears to be one of the least impaired modal groups, with members displaying relatively good intellectual and academic abilities.

Modal Profile 2b (n = 12): On the HRNB-C variables, this modal type is designated by a pattern of mild to moderate deficits involving motor speed, tactual performance, nonverbal auditory perception, and abstract concept formation. In contrast, motor strength and spatial memory are relative strengths. Students assigned to this modal group were characterized by intelligence scores at the low-end of the Average range, with similar Performance and Verbal IQs. Achievement scores were relatively low, particularly spelling scores. There was an over-representation of students with speech handicaps assigned to this modal group. Relative to the overall sample, students assigned to this group displayed poor academic achievement scores.

Modal Profile 3a (n = 17): On the HRNB-C variables, this modal type is characterized by an array of mild to moderate deficits in spatial memory, verbal auditory perception, and abstract reasoning. In contrast, tactual performance and motor strength are well developed. Students assigned to this modal group were characterized by intelligence in the Average range, with Performance IQ superior to Verbal IQ. Achievement scores were in the Low-Average range, with spelling scores being the lowest. There was an over-representation of students with Attention Deficit Hyperactivity Disorder (ADHD) assigned to this modal group.

Modal Profile 3b (n = 16): On the HRNB-C variables, this modal type is characterized by moderate deficits in tactual performance and motor strength. In contrast, spatial memory, verbal auditory perception, and abstract reasoning are relative strengths. Students assigned to this modal group were characterized by intelligence in the Average range, with comparable Performance and Verbal IQs. Language-based achievement scores (i.e., reading and spelling) were also in the Average range. This appears to be one of the least impaired modal groups, with members displaying relatively good intellectual and academic abilities.

Modal Profile 4a (n = 18): On the HRNB-C variables, this modal type is designated by mild to moderate deficits in abstract reasoning and nonverbal auditory discrimination. In contrast, there are relative strengths in motor speed and spatial memory. Students assigned to this modal group were characterized by intelligence quotients at the low-end of the Average range, with similar Performance and Verbal IQs. Achievement scores were generally in the Low-Average range. There was an over-representation of male students assigned to this modal group.

Modal Profile 4b (n = 12): On the HRNB-C variables, this modal type is designated by moderate deficits in motor speed and spatial memory. In contrast, there are relative strengths in abstract reasoning and nonverbal auditory discrimination. Students assigned to this modal group were characterized by intelligence in the Average range, with similar Verbal and Performance IQs. While Verbal and Performance IQ were similar, this was the only modal
type with VIQ several points higher than PIQ (i.e., approximately 4 points). Achievement scores were in the Low-Average range, with math skills less well developed than language-based skills. There was an over-representation of female students assigned to this modal group.

**Modal Profile 5 (n = 23):** On HRNB-C variables, this modal type is characterized by substantial deficits in abstract reasoning and concept formation. Secondary deficits of a more subtle nature are evident on nonverbal auditory perception, and possibly attention and concentration. In contrast, there are relative strengths on tasks emphasizing tactual performance. Students assigned to this modal group were characterized by intelligence scores at the low-end of the Average range, with similar Performance and Verbal IQs. Achievement scores were in the Low-Average range, with spelling skills the most deficient. There was an over-representation of female students assigned to this profile group.

**Modal Profile 6 (n = 16):** On HRNB-C variables, this profile type is characterized by moderate to severe deficits across a variety of language and auditory based measures (e.g., verbal auditory discrimination, sound-symbol matching). There is also the suggestion of deficits in attention and concentration. The primary area of strength is abstract reasoning abilities. Students assigned to this modal group were characterized by intelligence in the Low-Average range, with Performance IQ superior to Verbal IQ. All achievement scores were low, with reading and spelling skills particularly deficient. There was an over-representation of students with speech handicaps assigned to this profile type. Relative to the overall sample, these students displayed lower intellectual abilities. Relative to other modal groups, students in this group displayed the most deficient academic skills.

**Modal Profile 7 (n = 15):** On HRNB-C variables, this profile type is designated by poor performance on measures of constructional praxis and basic language abilities. Relative strengths are evident in tactual performance and verbal auditory perception. Students assigned to this modal group were characterized by intelligence quotients at the low-end of the Average range, with Performance IQ superior to Verbal IQ. Achievement scores were in the Low-Average range.

**Modal Profile 8 (n = 7):** On HRNB-C variables, this profile type is characterized by moderate deficits in abstract reasoning and language-based abilities. In contrast, there are relative strengths in nonverbal auditory perception and spatial memory. Students assigned to this modal group were characterized by intelligence scores in the Low-Average range, with Performance IQ superior to Verbal IQ. All achievement scores were low, with reading and spelling skills particularly deficient. Relative to the overall sample, students in this group displayed poor performance on measures of intellectual abilities.