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ABSTRACT

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The Relationship Between Reading Achievement and Information Processing in Subtypes of Learning Disabled Children

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Abstract

The purposes of this study were to use empirical, multivariate classification techniques to form subtypes of learning disabled readers (n=59) on a select sample of information processing skills and to validate the subytpes on reading achievement subskills. Hierarchial cluster analysis techniques resulted in a 6 cluster solution which demonstrated good internal validity. Each of the 6 subtypes displayed a deficit in speed of recoding but differed from each other on sustained attention, phonetic and semantic encoding, short term memory capacity, and long term memory organization. The subtypes were marginally differentiated by the 5 reading subtests of the <u>Woodcock Reading Mastery Test</u>. These results indicated support for the heterogeneity of strengths and weaknesses in cognitive processing for this group of learning disabled readers but suggested caution regarding the role of specific processes in reading failure.

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Summary

Information Processing and Reading in Subtypes of Learning Disabled Readers

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A fundamental issue in the field of learning disabilities is the great diversity of skills in children who are classified as learning disabled. That is, these children tend to be quite different from each other in terms of strengths and weaknesses in a wide variety of domains. This heterogenity of skills has frustrated efforts to correctly classify and teach children with specific learning disabilities.

One area that is particularly problematic for learning disabled children with reading difficulties is the processing of information. Although past research has demonstrated that learning disabled readers are less proficient than normally achieving readers on a variety of information processing tasks, it is not clear which processes are most important for skilled reading.

Also, because LD children have a variety of processing strengths and weaknesses, it is not appropriate to conclude that all LD readers have the same problems. From this perspective, two research goals were established: (1) to form homogeneous subgroups of LD readers such that children in each subgroup would have the same information processing strengths and weaknesses; and (2) to determine if the subgroups of LD readers exhibited different strengths and weaknesses in reading subskills performance.

Several information processing tasks were given to 59 learning disabled readers and average achieving readers in the third and fourth grades. The tasks measured (1) sustained attention - the ability to attend to a long task; (2) encoding - the ability to transform words into phonetic and semantic

(meaning) codes; (3) short term memory capacity - the ability to remember information for a brief period; (4) memory organization - the ability to strategically store information for correct recall; and (5) speed of recoding - the ability to quickly read aloud common words and digits. The processes measured by these tasks have been shown to be important in distinguishing between learning disabled and normally achieving readers.

Analysis of the data resulted in 6 subtypes of learning disabled readers. All subtypes demonstrated a specific weakness in at least two cognitive processes when compared with average achieving readers and none of the subtypes showed a normal pattern of performance. This finding underlined the importance of cognitive processes in differentiating learning disabled and normally achieving children (see attached Figure). One of the most interesting aspects of the subtype patterns was that each profile demonstrated a specific problem in quickly recoding digits and words (speed of recoding tasks). This finding indicated that a majority of the learning disabled readers had difficulty retreiving names of digits and common words. This result agreed with past research which indicated that children with reading problems have to exert a great deal of processing capacity for word identification resulting in limited cognitive capacity for comprehension activities.

Although the 6 subtypes were quite different on the information processing measures, the LD children did not show different strengths and weaknesses in reading performance. It appeared that the processes measured were too different from actual reading performance to be able to differentiate on reading skills.

Thus, although definitions of learning disabilities emphasize the importance of basic cognitive processes, this study demonstrated that these basic processes may not provide insights on teaching interventions. On the other hand, it is important to search for more homogeneous groups of learners in order to more specifically test the effectiveness of teaching strategies with different subgroups of leaning disabled readers. In future studies it would be appropriate to measure more task-specific processes and to relate these processes to reading skill.

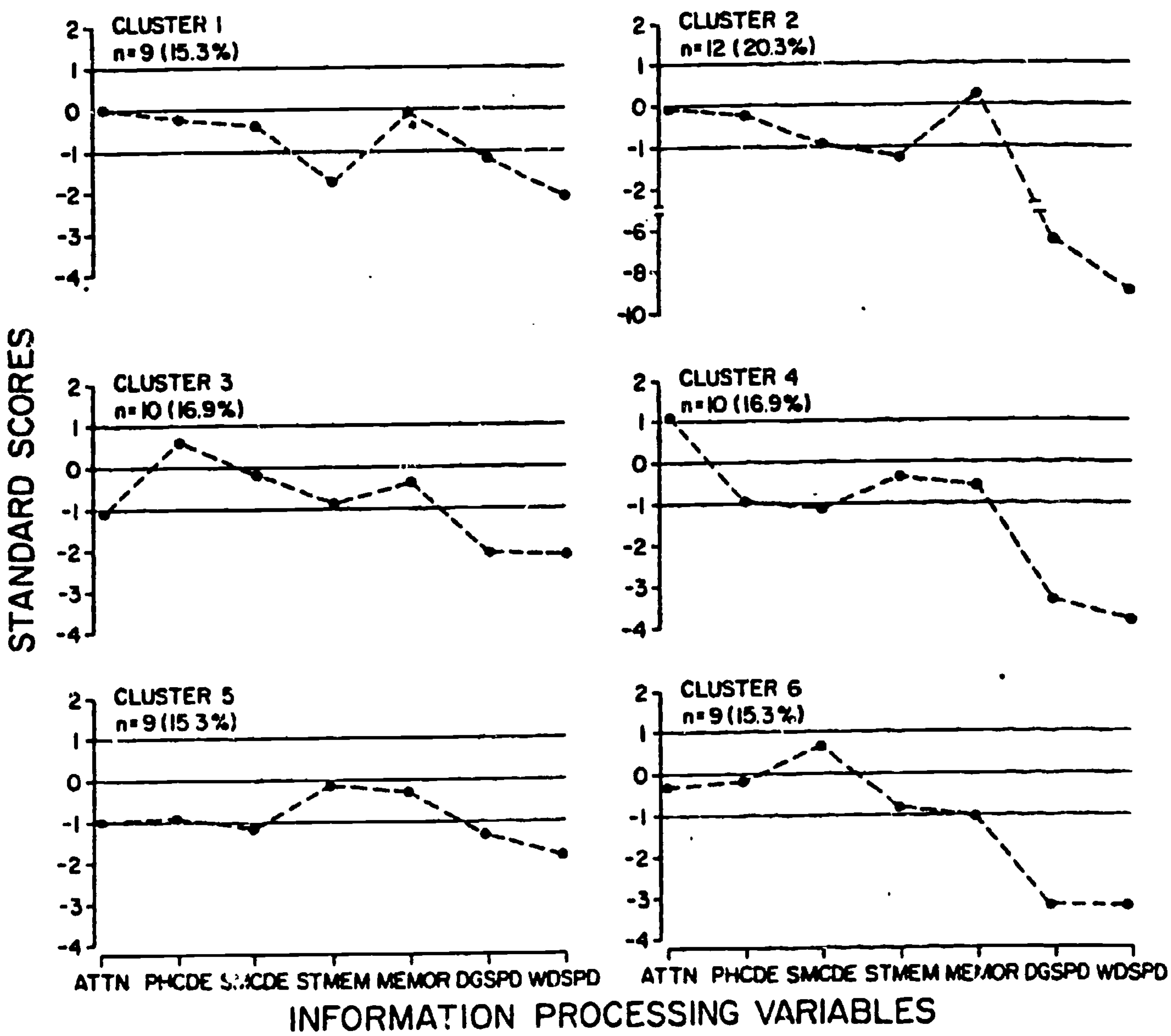

Figure 2. Mean profiles of LD clusters based on information processing variables standardized relative to the normal comparison group (ATTN = Sustained Attention, PHCDE = Phonetic Encoding, SMCDE = Semantic Encoding, STMEM = Short Term Memory Capacity, DGSPD = Speed of Recoding Digits, WDSPD = Speed of Recoding Words).

The Relationship Between Reading Achievement and Information Processing in Subtypes of Learning Disabled Children

The purposes of this research were (1) to identify subgroups of learning disabled readers according to their performance on a select sample of information processing tasks and (2) to determine whether different types of specific learning disability, as defined by subgroup membership, impair reading performance selectively. This study was based on the assumption that reading is a complex information processing activity that requires proficiency in each of a number of different component skills. The previous literature has indicated that learning disabled readers differ from normally achieving peers on a variety of information processing measures. While this work is valuable in laying the groundwork for the importance of certain cognitive processes, the relationship between many of these processes and specific reading disabilities is not clear. If different subtypes of learning disabled children are impaired in one or more of these cognitive processes, then it is possible that various subgroups of children would exhibit different types of reading disorders that could be attributed to the particular pattern and severity of their information processing deficits.

Historically, learning disablities in general and reading disabilities in particular have been associated with problems in a variety of cognitive processes from definitional (Federal Register, December 29, 1977; Kavale & Nye, 1981), theoretical (Gibson, 1965; Gibson & Levin, 1975; Johnson & Myklebust, 1967; LaBerge & Samuels, 1974), and empirical (Krupski, 1980; Morrison & Manis, in press; Torgesen & Kail, 1980; Vellutino, 1977) perspectives. However, the connection between specific patterns of information processing deficits and poor reading performance has been complicated by the failure of single syndrome hypotheses to account for the great diversity among such children (Satz & Fletcher, 1980).

The feasibility of forming more homogenous groups of learners by using empirical, multivariate classification techniques has been demonstrated by several investigators usin, neuropsychological and psychoeducational variables (Doehring & Hoshko, 1977; Lyon & Watson, 1981; Satz & Morris, 1981). The present study departs from past subtyping efforts in that information processing variables that reflect cognitive processes associated with efficient reading performance were selected for study. In addition, data on reading performance that assess a variety of subskills were collected to determine the external validity and educational relevance of the resulting information processing subtypes.

The selection of specific information processing variables was based on Mackworth's (1971) general information processing model of the reading process and was supplemented with previous research evidence that the processes selected discriminated between normal and disabled readers. Mackworth's (1971) model emphasized the role of attention, visual and verbal encoding processes, and short-term and long-term memory processes. An important aspect of this model was the interplay between different components. For example, encoding processes and short-term memory processes were not viewed as independent of the meaning and prediction functions of long-term memory. Although the model suggested serial processing, a feature of most information processing theories, the processes were viewed as interdependent. Thus, a deficit in phonetic encoding would not be interpreted in isolation but rather in concert with operation of the information processing system.

The variables selected for study were representative of the model as opposed to exhaustive. Generally speaking, the reading process demands a) sustained attention to the task; b) transformation of the visual stimulus to a phonetic or semantic code (encoding); c) retention of the transformed stimuli in short-term store via strategies to allow interplay between the encoded stimulus and long-term memory (capacity); d) long-term memory organization to facilitate retrieval; and e) overt or covert recognition of the stimulus as a word. These specific reading processes are facilitated by a speed factor or the rapid transition from one process to the next that enhances efficient use of the limited capacity system.

Results from empirical investigations support the selection of attention, encoding, short-term capacity, memory organization, and speed of recoding as candidate processes that distinguish disabled and normal readers. Both laboratory research and classroom observations suggest that sustained attention is related to learning problems (Feagans & McKinney, 1981; Keogh & Margolis, 1976; Krupski, 1980; McKinney & Speece,1983). Although phonetic and semantic encoding are usually studied in isolation, both coding processes have been implicated as problematic for reading disabled children (Ceci, Lea, & Ringstrom, 1980; Mark, Shankweiler, Liberman, & Fowler, 1977; Torgesen & Houck, 1980; Vellutino, 1977). Also, research has implicated inefficient and unorganized memory strategies in both short-and long-term memory and has found support in several investigations (Bauer, 1979; Tarver, Hallahan, Kauffman, & Ball, 1976; Torgesen, 1977, 1980; Wong, Wong, & Foth, 1977). Finally, speed of recoding as measured by "rapid automized naming" tasks has differentiated reading disabled children and normal readers on verbal and nonverbal stimuli (Denkla, 1976; Morrison & Manis, in press; Moore, Kagan, Sahl, & Grant, 1982; Spring & Capps, 1974).

In summary, the literature on information processing in learning disabled readers suggests a relationship between a number of specific cognitive processes and poor reading performance. However, these processes have been studied in isolation, providing little information regarding the relationships among the processes. More importantly, reading disabled children have been studied as though they represented a homogenous group and, further, the impact of cognitive deficits has not been related to specific reading deficits.

METHOD

Subjects

Learning Disabled Readers. Subjects for this study were selected from an urban school district located in the southeastern United States. The learning disabled (LD) children were identified by school personnel as needing special education service according to federal and state criteria. Specifically, state identification criteria required a 15-to 20-month grade discrepancy between current and expected achievement in at least one academic area for learning disability placement in the early primary grades. Calculation of expected academic level was based on the results of an intelligence test. All learning disabled children were receiving special education resource room services and were members of regular education classes.

In order to select an LD sample that was comparable to other samples used in LD research on reading and information processing (Vellutino, 1979), several screening criteria were developed. These criteria were a) chronological age of 9 or 10 years by the school system's entrance cut-off date making them eligible for third or fourth grade placement regardless of retentions; b) a WISC-R verbal score of 85 or above in order to be considered in the normal range of aptitude; c) as a control for SES factors, mother's educational attainment had to be 12 years or more for the child to be retained in the study; d) a 1.5-year discrepancy between expected grade level (based on years of schooling) and Gray Oral Reading Test (GORT, Gray & Robinson, 1967) score was necessary to insure that the children demonstrated a reading disability. The GORT was administered by the research staff to all LD children meeting the first three criteria. It is widely used as part of reading diagnostic batteries (Bond & Tinker, 1973; Salvia & Ysseldike, 1978; Wilson, 1972) and consists of 13 passages graded in difficulty. The obtained grade level score reflects number of oral reading errors and the time, in seconds, required to read the passages.

From an initial pool of 113 LD children, 62 (55%) met all four criteria. Five children were dropped due to chronological age; 24 children were dropped because of low verbal IQ; 16 children were dropped due to mother's education; and 6 children failed to meet the GORT reading criterion. During the course of the study, two children moved from the school district, and one child could not be tested because of uncooperativeness in the test settings. Thus, the final research sample consisted of 59 LD children. Table 1 summarizes subject characteristics.

INSERT TABLE 1 ABOUT HERE

Average Achieving Readers. Selection of the normally achieving sample was based on the same general criteria used for the LD sample: chronological age of 9 or 10 years, verbal IQ within the normal range, mother's educational attainment of 12 years or more, and reading performance between +-1 year of their current grade placement based on GORT performance. Since inclusion of normally achieving children was for the purpose of establishing a mean level of performance on which to compare the information processing performance of the LD children, it was not necessary from a design perspective to sample an equal number of children. One-third of the LD children were randomly selected to serve as matches for the normally achieving children. The subsample of LD children was proportional to the total LD sample in terms of sex, race, and expected grade placement.

The regular classroom teachers who served the subsample of LD children, nominated children in their classrooms who were of the same sex and race as the LD child and who, in the teacher's opinion, were reading at grade level. The criterion of average reading performance was adopted to exclude superior readers who would be expected to add variablity that would exaggerate group differences (Satz & Fletcher, 1980). Children were randomly selected from the teachers' lists and were administered the WISC-R verbal scale and the GORT by the research staff. The final sample consisted of 21 children who met the age, aptitude, SES and reading criteria. Table 1 presents subject characteristics of the non-LD (NLD) sample.

Information Processing Tasks

The experimental tasks were drawn from the educational and psychological literature on information processing and reading. Of utmost importance was the selection of tasks that provided a measure of the process at the individual child level. For example, the release from proactive inhibition paradigm is often used as a measure of encoding (Wickens, 1972; Kail, 1976; Kail & Schroll, 1976). However, pilot testing indicated that individual scores could not be interpreted meaningfully apart from the aggregate due to wide variability among children. Thus, a different task was developed and is described below. For each of the tasks, practice trials were provided to ensure understanding of the task requirements.

Test-retest reliability for each task was determined on a pilot sample of third grade children (n=11 unless otherwise noted). The testing interval was 6 weeks. The children represented a wide range of reading ability according to the teacher's estimate.

Sustained Attention. An audiovisual checking task developed by Margolis (1972) was used as the measure of sustained attention. The task involved listening to an audiotape of digits being read at a rate of 1 per second while checking the appearance of the digits presented visually in a test booklet. The 10-page booklet contained 5 test pages and 5 filler pages to avoid an end effect. Each page contained 15 rows of digits with 13 digits per row. Each page had a colored line down the left-hand margin, and each row was identified by a letter. The voice on the audiotape indicated page color, row letter, and when to turn the page to facilitate correct placement.

The children were required to monitor the match between the digit heard and the digit seen in the test booklet. The task was to draw a line through the digit if there was a match; the digit was circled if there was a mismatch. Of interest to this study were errors of omission or the failure to detect a mismatch. The dependent measure was the decrement in performance between the first two and the last two test pages.

Children were tested in groups of three or four members and the session, including practice, was 40 minutes in length. Test-retest reliability over a 6-week period with the pilot sample (n=8) was .76, which compared favorably with the .72 coefficient reported by Margolis (1972).

Encoding. A paired associates task based on an encoding paradigm developed by Ackerman (1980) was used to tap both phonetic and semantic encoding. The stimuli were 81 probe-target word pairs typed on 3x5 index cards in primary print. Of the 81 word pairs, 18 pairs represented a semantic association (e.g., finger-nose), 18 pairs represented a phonetic (acoustic) association (e.g., pie-try), and 45 pairs had a neutral relationship (e.g., net-glass). All words selected had a frequency of occurrence of at least 50 per million; although 75% the words had a frequency of 100 or more per million (Thorndike & Lorge, 1944).

The 81 word pairs were used to construct semantic, phonetic, and neutral triads. There were 9 triads of each type. The semantic and phonetic triads were composed of 2 pairs of semantic (phonetic) words and 1 neutral pair to avoid a mental set toward the materials. The neutral triads had 3 neutral pairs. The task was designed such that each type of triad was presented consecutively in a test set and then followed by a 60-second distractor task before presentation of the next test set.

The word pairs within a triad were each exposed for 4 seconds and the child read the word pair aloud. After presentation of the three pairs, one of the probe words was shown and the child was asked to recall the appropriate target word within a 10-second interval. Although only 1 probe-target pair was scored for each triad, the number of probes shown depended on the scored probe position. That is, to avoid a serial position effect in which the last item presented was easier to recall than the first, the scored probe in the third position was preceded by probe words from the first and second positions. Similarly, a scored probe in the second position was preceded by probing the first position.

For each type of triad (semantic, phonetic, neutral), each position was probed three times, resulting in 9 possible answers per type of triad. Within a test set, each scored position was probed once, providing an equal distribution of scored probes across the task.

The measure of interest was the number of semantic and phonetic target words correctly recalled. To separate encoding effects from other factors extraneous to encoding (e.g., rehearsal), the score on neutral triads was subtracted from both the raw semantic and raw phonetic scores. Pilot data indicated that the adjusted scores were appropriate in that the correlation between semantic and phonetic unadjusted scores of .39 dropped to .06 after the adjustment.

Children were tested individually in a quiet room in the schools. The test session lasted approximately 25 minutes. Test-retest reliabilities for phonetic and semantic scores were .70 and .57 respectively based on a pilot sample (n=11) of third grade children.

Short-Term Capacity. A digit span test was used as the measure of short-term memory capacity. Series of digits, ranging in length from 3 to 9 digits, were audiotaped at a rate of 1 digit per second. Two sequences of each length were constructed such that no digits were repeated within a sequence, no immediate ascending or descending pairs were used, no double multiple jumps were included (e.g., 2-4-6), and no consecutive sequences had the same ending or beginning digit. Each sequence was preceded by a prerecorded "Ready" signal followed by a 5-second pause. One second after the presentation of the last digit in a sequence, the word "GO" was recorded to indicate to the child the opportunity for recall of the sequence.

The capacity measure was the total number of digits recalled in correct sequence. Partial credit was given for digits that occupied the correct ordinal position when counting from beginning or end of the sequence.

Children were tested individually and testing ended when 3 consecutive errors were made. Test-retest reliability for the pilot sample was .64.

Memory Organization. Category clustering, a sort-recall paradigm, was used. Twenty nouns, evenly distributed among five taxonomic categories (furniture, body parts, tools, transportation, animals) typed on individual 3x5 index cards were the stimulus materials. Each category contained two words that were considered good exemplars of the category and two words rated as poor exemplars based on children's typicality judgments (Bjorkland, Thompson, Ornstein, 1983). Use of good and poor examplars was an attempt to avoid automatic and well-learned associations in order to tap more deliberate memory organization strategies (Lange, 1979). To the extent possible, words were selected from the AA or A frequency categories compiled by Thorndike and Lorge (1944). Seventeen words met this criterion with 3 words having a frequency of 35 occurrences per million or greater.

Three sort-recall trials were given. Children were not informed about the inherent relationships among the words but were told to group the words in order to facilitate recall. For each sort, the children read each word aloud and placed it in a square on a sort board which contained 7 squares. Children were instructed to make at least 2 but no more than 7 groups. Following each sort the child was asked to free recall as many words as possible. Between sorts, the examiner shuffled the word cards such that no two members of the same category were contiguous.

The measure of interest was the degree of clustering in the output as derived from the Ratio of Repetition method (RR, Bousfield, 1953). This measure is calculated by dividing the number of category repetitions in a recall trial by the total number of items recalled and is independent of the total number of items recalled (Murphy, 1979). Mean RR across 3 trials was the dependent measure.

Children were tested individually. The task took approximately 20 minutes to complete. Test-retest reliability on the pilot sample (n=11) was .77.

Speed of Recoding. Two separate speed tests were administered. One consisted of reading 8 digits (1, 2, 3, 4, 5, 6, 8, 9) and the other consisted of reading 8 high frequency words (and, all, come, did, had, play). For each task, the eight stimuli were randomly repeated to obtain 6 rows of 8 items each. These arrangements were typed in primary print on one side of an 8 1/2 x 11 card. Additionally, the individual digits and words were typed on separate cards for practice purposes.

The child was required to read the 48 digits and words as quickly as possible and was told to not worry about mistakes. Speed was recorded to the nearest tenth of a second by the examiner which provided the measure for both digits and words.

The task was administered individually and lasted approximately 5 minutes. Test-retest reliability on the pilot sample (n=11) was .83 for digits and .92 for words.

Reading Achievement

Five subtests from the Woodcock Reading Mastery Test (WRMT, Woodcock, 1973) were used to assess reading subskills to evaluate the subtypes formed on the information processing tasks. The five subtests included letter identification (manuscript and cursive), word identification, word analysis (decoding of nonsense words), word comprehension (understanding relationships among words) and passage comprehension (cloze passages). The split-half reliabilities for the subtests range from .79 to .99 (Woodcock, 1973).

Evidence for both content and construct validity was cited by Salvia and Ysseldyke (1978). Only LD children were administered the WRMT.

General Testing Procedures

The information processing tasks were administered in three separate sessions, which lasted approximately 30-40 minutes each. Session 1 was comprised of the encoding task. Session 2 included memory organization, short-term capacity, and speed of recoding. These three tasks were administered in a predetermined random order. In Session 3, the sustained attention test was administered. This was the only session in which groups of children were tested. Following administration of all information processing tasks, the WRMT was given to the LD children.

Data Analysis

Cluster analysis represents a family of empirical techniques that has the purpose of identifying homogenous subgroups of subjects within a heterogeneous sample (Everitt, 1980). As the learning disabled population is often described as heterogeneous in terms of strengths and weaknesses across a wide variety of measurement domains, cluster analysis techniques are well-suited for exploring the underlying strcture of an LD sample (Satz & Morris, 1981). Hierarchical cluster analysis was used in the present study to classify children based on the information processing variables. This method begins with every subject as his/her own cluster and successively merges subjects/clusters until all subjects who show a common response pattern are contained in a single cluster. The formation of clusters is defined by the investigator's choice of a similarity measure and an algorithm that provides the rule for joining observations (Anderberg, 1973). Correlation was chosen for the similarity measure in the present investigation, as the primary interest was in profile shape as opposed to elevation or scatter (Cronbach & Gleser, 1953). A correlational measure groups children who have similar patterns of strengths and weaknesses regardless of level. Thus, obtained subtypes reflected information processing syndromes. Ward's minimum variance method was the algorithm chosen with the average linkage algorithm used as a check on the obtained subtypes. Both will be described below.

Cluster analysis is not based on probabilistic statistics and, as such, there is no "one" best solution to a clustering problem. Thus, one does not have specified alpha levels to guide selection of a particular set of clusters from several alternative solutions. Therefore, a three-stage data analysis plan was devised.

First, after examining the cluster solutions resulting from Ward's algorithm, candidate solutions were plotted by cluster. At this step, individual scores were plotted around cluster means to determine which solutions produced the most cohesive plots. In addition, the cluster profiles were examined for interpretability from an educational and psychological perspective. These procedures resulted in a 6-cluster solution. Ward's method employs a minimum variance function to join subjects/clusters such that within cluster variance is minimized (Johnson & Wichern, 1982).

Second, to validate cluster solutions that emerged in the first stage of the analysis, converging evidence was sought on the stability of the cluster solutions. Because random data will produce clusters, this type of internal validation is critical in assessing the adequacy of the cluster solution (Morris, Blashfield, & Satz, 1981). Three methods of validation were used: split sample replication, clustering with the average linkage algorithm, and clustering the total sample of LD and NLD children. For cluster replication, two-thirds of the LD subjects were randomly selected and reclustered. A high degree of membership concordance between the original and replication clusters, as assessed by the kappa statistic, provides an indication of cluster stability (Lorr, 1983; Morris et al., 1981). Use of a different algorithm, average linkage, provides a check on the first solution. Cluster members defined by this algorithm are more similar to each other, on the average, than they are to members of any other cluster (Lorr, 1983). For this validation, step one above was repeated with a 6 cluster solution also emerging. Then the two solutions were compared to determine if the clusters were defined by the same children. The final internal validation step, clustering the total sample, has been referred to as "data alteration" (Morris et al., 1981). The addition of subjects should not change the LD membership of the original clusters if the solution is stable.

The final step in the analysis was validation of the chosen cluster solution on external criteria. Given that a cluster solution has reasonable internal stability, it is then crucial to demonstrate that the clusters differ on educationally relevant variables. Multivariate analysis of variance (MANOVA) was used to assess cluster differences on the reading achievement subtests of the WRMT.

Results

Internal Validation

The stability of the 6 cluster solution was assessed via reclustering 40 randomly selected children from the original sample of 59 LD readers, application of a different algorithm, and clustering the total sample of LD and NLD children. The split-sample replication solution, in comparison with the solution based on the entire LD sample, yielded a kappa (k) value of .45, $p < .001$. This result in conjunction with a visual inspection of the cluster plots produced by the split sample, indicated that cluster membership and cluster interpretation were similar.

Comparison of the 6 cluster solutions produced by Ward's method and the average linkage algorithim yielded k = .71, p < .001, indicating a high degree of similarity between the two methods. Visual inspection of cluster plots produced similar interpretation of the clusters between the two methods. Clusters produced by the data alteration method in which the total sample of LD and NLD children were used also supported the 6 cluster solution. Comparison of the LD and total sample 6 cluster solutions produced k = .71, p < .001.

The results of the internal validation procedures converged on the stability of the 6 cluster, minimum variance solution. Children in the individual clusters had a high probability of remaining together regardless of sample size, algorithm used, or the addition of other subjects.

In addition, the 6 clusters were significantly differentiated by a MANOVA on the information processing variables used for subtyping $F(35,255) = 6.73$, $p < .05$, with all 7 univariate tests significant ($p < .001$). Since the clusters were formed by minimizing within cluster variance, differences at this stage were expected. Thus, this analysis provided an indication that further analyses with external variables may be profitable.

Cluster Interpretation

Figure 1 illustrates the cluster means for each of the 6 LD subtypes. The graphs were based on the NLD mean and standard deviation for each task. Thus, the mean of 0 represents the mean performance of the NLD sample and the profiles represent LD subtype differences plotted relative to the performances of the NLD children.

Viewing the 6 clusters as a whole, perhaps the most striking aspect of the profiles was the general deficit on the speed of recoding variables across the clusters. No other variable consistently defined each subtype although short term capacity as measured by digit span was low for 4 clusters. Excluding Cluster 5, all subtypes had a specific strength ($\geq$ 0) on one information processing variable. These strengths were distributed across the variables with the exception of speed of digit and word recoding.

Cluster 1 (n=9). Children in this subtype consistently scored below -1 S.D. of the normal comparison group on the digit span task which indicated that different short term memory capacity was the distinguishing characteristic of this profile. Speed of recoding for both digits and words was also a deficit area although moderate in relation to the other subtypes. Sustained attention and memory organization were relative strengths with profile points at the mean, however, this subtype exhibited no outstanding strengths in information processing. Although a 3 to 1 male-female ratio was evident in the total LD sample, this cluster contained 5 girls and 4 boys. Thus, girls were overrepresented in this subtype.

Cluster 2 (n=12). The extreme deficit in the speed of recoding tasks was the salient characteristic of children in this subtype, which, in conjunction with a semantic encoding deficit, distinguished this cluster from cluster 1. Although memory organization was a strength, the speed of recoding problem led to the speculation that children in this cluster may be the most reading impaired of all the subtypes.

Cluster 3 (n=10). This cluster demonstrated the lowest sustained attention of all subtypes which was accompanied by a speed deficit. Phonetic encoding was a strength relative to the performance of the NLD children.

Interestingly, the children in this subtype were relatively more successful with tasks that used words as stimuli (encoding, memory organization) than with tasks that used digits to tap processes (sustained attention, short-term capacity, speed of recoding digits).

Cluster 4 (n=10). The salient feature of this subtype was the strong performance on the sustained attention task. This positive aspect, however, was coupled with deficits in both forms of encoding and speed of recoding. Only cluster 2 obtained lower speed profile points. Although sustained attention may compensate to some degree for the inability to quickly recode, the overall portrait suggested a specific problem in dealing with words.

Cluster 5 (n=9). This pattern is differentiated from Cluster 4 on the basis of poorer sustained attention and a less severe speed of recoding profile. This cluster represented the "flattest" profile of the six with no clear information processing strengths although short term capacity and memory organization were elevated. This suggested that children in the cluster may exhibit some ability in using memory strategies. Given the absence of a strong performance on any variable, children in this cluster may be best characterized as borderline relative to the NLD children.

Cluster 6 (n=9). This cluster was composed exclusively of males and demonstrated a strength in semantic encoding. This attribute was in direct contrast with a deficit in memory organization which also required manipulation of semantic information but in terms of long term storage and retrival. The apparent short term vs. long term memory dichotomy was obscured by a weak performance on the short term capacity task. Similar to the other 5 clusters, this subtype was also defined by a deficit in speed of recoding.

External Validation

Given that the 6 subtypes were internally valid and presented distinctly different patterns of strengths and weaknesses on the information processing variables, validation on reading achievement subskills was conducted. Raw scores on the five subtests of the WRMT provided the dependent measures for a MANOVA between clusters. The omnibus test was not significant, $F(25,265) = 1.47$, $p = .07$. Word comprehension was the only univariate result that approached statistical significance, $F(5,53) = 2.13$, $p = .07$, although interpretation of univariate tests in the absence of a significant MANOVA is not recommended. The marginal significance of the MANOVA precluded follow-up analysis.

Table 2 presents the percentile descriptive statistics on the reading achievement variables across clusters. A visual inspection of these data indicated that although there were no significant findings, children in Cluster 6 defined by a strength in semantic encoding demonstrated the most consistently high reading performance across reading subscales relative to the other LD clusters. On the other hand, children in Cluster 1 demonstrated the poorest performance across the reading skills. Cluster 1 was defined primarily by a short term memory deficit.

Insert Table 2 about here

Summary and Conclusions

This initial investigation on subtyping learning disabled readers on information processing variables generated both support for the role of cognitive porcesses in learning disabilities and skepticism regarding the importance of specific processes in reading subskills. The obtained subtypes demonstrated high internal validity which indicated that cluster membership was stable and provided an accurate account of the information processing differences within this sample of LD readers. The subtypes demonstrated neither a normal performance or a global deficit pattern across the variables. Both patterns have been evident in other subtyping studies that used neuropsychological or behavioral variables to form clusters (Lyon, Stewart, & Freedman, 1982; Satz & Morris, 1981; Speece, McKinney, & Appelbaum, ~~1984)~~ in press). The lack of normal and global deficit profiles suggested that all LD readers in this sample had difficulty in at least one aspect of cognitive processing.

Also of interest to cluster interpretation was the ubiquitous role of speed of recoding both digits and words in defining each cluster. This task tapped several aspects of input, integration, and output functions of the information processing system rather than a unitary process. Although not all children within a cluster demonstrated a speed deficit relative to the NLD children, the general nature of this problem supported other investigations that stressed reading disabled children's slow performance as a major contribution to reading failure (Denkla, 1976; LaBerge & Samuels, 1974; Hogoboam & Perfetti, 1978).

The external validation results did not support a relationship between specific information processing subtypes and specific reading subskill areas. Although this result was unexpected, it suggested that a deficit in any process may be responsible for poor reading. Caution must be exercised in this speculation as the information processing tasks chosen were representative rather than exhaustive of the variety of processes implicated in reading failure.

In general, the results of this investigation supported the importance of information processing variables in defining learning disabled readers relative to average ability readers and suggested that this group of LD children was heterogeneous in their patterns of cognitive processing. The subtypes that emerged are supportive of a variety of single syndrome explanations of reading failure but did not support any particular perspective. For example, Vellutino's (1979) hypothesis regarding verbal processing deficits was supported by the performance of Clusters 4 and 5 (encoding and speed deficits) whereas Torgesen's (1980) inactive learner hypothesis found support in Cluster 1 (short term capacity deficit) and Cluster 6 (capacity and memory organization deficits).

The tasks used in this investigation tapped reading processes at the single word level. The results suggested that it may be profitable to extend examination of cognitive processes to include activities that measure the "top-down" or context driven aspects of reading (Levy, 1982). By extending the range of information processing activities, it may be possible to more clearly define the sources of reading failure in a heterogeneous group of poor readers.

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Table 1

Subject Characteristics

		LD n=59	NLD n=21
Sex (%)	F	15 (25.4)	4 (19.0)
	M	44 (74.6)	17 (81.0)
Race (%)	Black	32 (54.2)	10 (47.6)
	White	26 (44.1)	11 (52.4)
	Other	1 (1.7)	0 (00.0)
Grade Expected (%)	3	23 (39.0)	8 (38.1)
	4	36 (61.0)	13 (61.9)
Age in Mos.	M	112.39	115.02
	SD	6.94	7.72
Mother's Education	M	13.1	13.1
	SD	1.4	1.6
WISCR			
Verbal	M	99.05	105.40
	SD	12.40	9.50
Performance	M	101.25	--
	SD	10.82	--
Full Scale	M	99.81	--
	SD	10.43	--
Gray Reading Test	M	1.83	4.06
	SD	.37	.64
Reading Delay in Years	M	2.28	.31
	SD	.47	.44

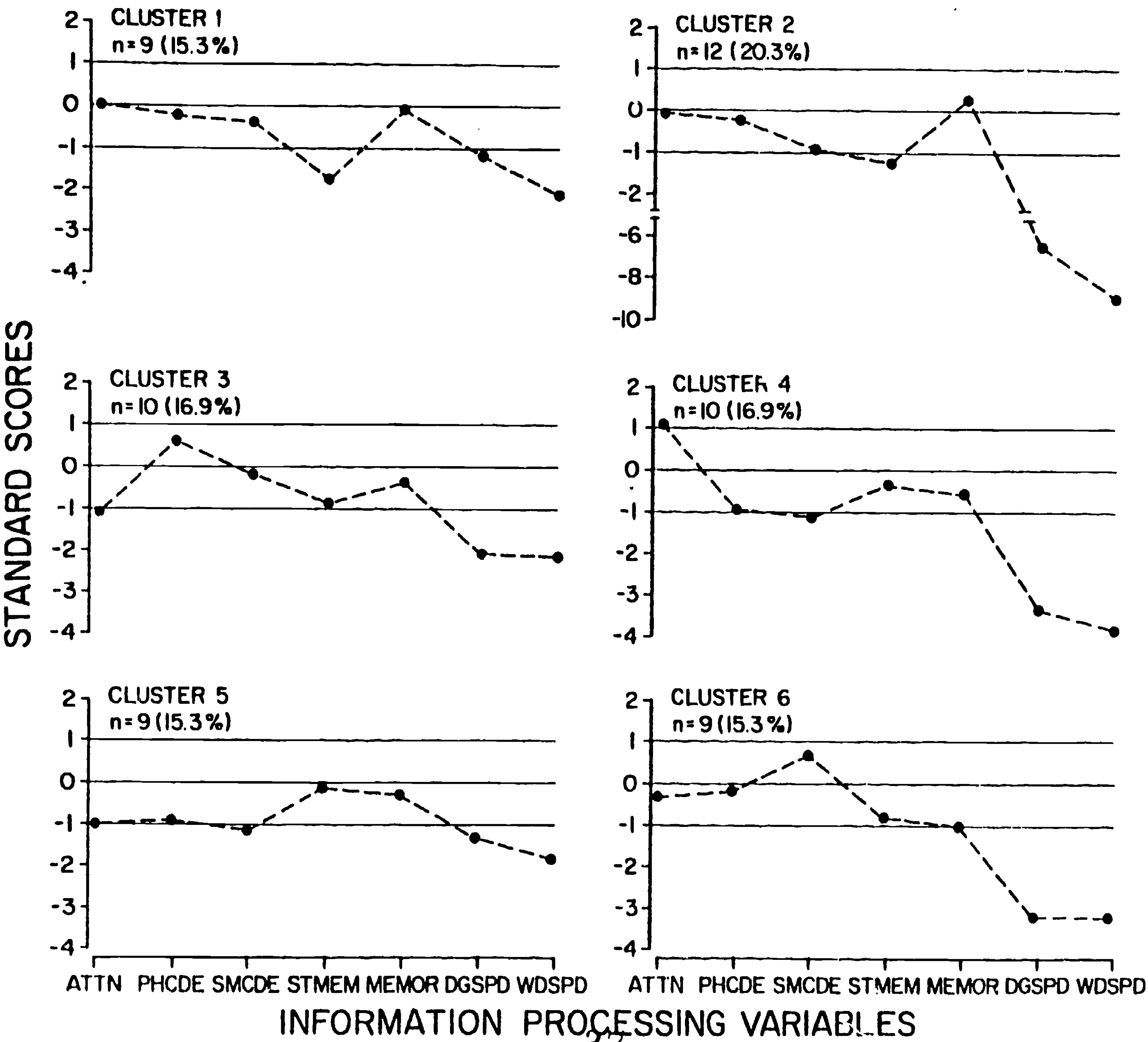
Table 2

Percentile Means and Standard Deviations on WRMT Subtests by Cluster

Subtest		Cluster 1	2	3	4	5	6
Letter	M	30.56	26.67	43.80	44.50	45.89	30.00
Ident.	SD	28.62	18.19	30.98	29.12	29.94	30.20
Word	M	10.89	11.50	19.30	13.30	9.89	18.33
Ident.	SD	15.20	10.71	18.66	10.64	6.27	14.64
Word	M	11.67	15.75	26.70	19.00	18.11	21.44
Analyses	SD	7.91	17.37	24.77	15.37	16.53	13.77
Word	M	12.00	19.00	11.90	14.50	14.22	29.78
Comp.	SD	16.86	17.46	13.66	14.32	9.05	16.25
Passage	M	17.89	12.67	18.60	17.10	16.78	21.00
Comp.	SD	10.68	10.40	13.32	11.67	14.17	14.02
Total	M	9.11	11.08	15.30	12.50	10.33	16.89
Reading	SD	10.30	10.87	13.96	9.62	7.92	11.13

Figure Captions

Figure 1. Mean profile of LD clusters based on information processing variables standardized relative to the normal comparison group. (SUSATTN = Sustained Attention; PHENCDE = Phonetic Encoding; SMENCDE = Semantic Encoding; DGTSPAN = Digit Span; MEMORG = Memory Organization; DGTTIME = Speed of Recoding -Digits; WRDTIME = Speed of Recoding -Words).


CLUSTER 1
n=9 (15.3%)
CLUSTER 2
n=12 (20.3%)
CLUSTER 3
n=10 (16.9%)
CLUSTER 4
n=10 (16.9%)
CLUSTER 5
n=9 (15.3%)
CLUSTER 6
n=9 (15.3%)
STANDARD SCORES
ATTN PHCDE SMCDE STMEM MEMOR DGSPD WDSPD
INFORMATION PROCESSING VARIABLES