SOME CHARACTERISTICS OF TWO LEARNING DISABLED SUBGROUPS IDENTIFIED FROM WISC/WISC-R FACTOR SCORE PATTERNS

by

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ABSTRACT

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Learning disabled boys were categorized on the basis of consistency of lowest WISC/WISC-R factor scores over time. The Consistent subgroup with lowest scores on factor 3 also displayed significant factor score discrepancy. The Inconsistent subgroup had varying lowest factor scores with no significant discrepancy, such variation not apparently related to a delay hypothesis. Patterns in the Consistent Factor 3 group could be suggestive of either a delay or deficit.

Group differences occurred frequently in patterns, rather than levels of performance, the Inconsistents displaying patterns similar to able learners. Disorders of sequential processing and abnormal right hemisphere specialization characterized the Consistent Factor 3 group, inefficient selective attention the Inconsistent group. Pervasive group differences in holistic versus sequential processing were related to the hemisphere specialization index and both were related to WISC-R discrepancy scores. Thus, factor score discrepancies may usefully define these subgroups. A model of hemisphere functioning was offered in explanation of these results.

RESUME

Des garçons souffrant de difficultés d'apprentissage ont été classés selon l'uniformité des résultats minima aux tests WISC/WISC-R sur une période donnée. Le sous-groupe ayant obtenu des résultats uniformes au facteur 3 fait également preuve de divergences significatives dans les autres facteurs. Le sous-groupe ayant obtenu des résultats non-uniformes enregistre des divergences dans les résultats minima, sans que ces divergences soient significatives, n'étant pas associées à une hypothèse de retard. Les résultats du groupe uniforme au facteur 3 suggèrent soit un retard soit un déficit.

Les différences entre les groupes portent fréquemment sur les variations plutôt que sur les niveaux de performance, le groupe non-uniforme présentant des variations similaires à celles des élèves normaux. Les désordres portant sur le processus séquentiel et une spécialisation anormale de l'hémisphère droit sont caractéristiques du groupe uniforme au facteur 3, tandis qu'une attention sélective inadéquate caractérise le groupe non-uniforme. Des différences de groupes généralisées au niveau du processus synthétique plutôt que séquentiel sont associés à l'indice de spécialisation hémisphérique; tous deux étant associés aux divergences des résultats au test WISC-R. On peut par conséquent définir ces sous-groupes par les divergences de leurs résultats. Un modèle de fonctionnement hémisphérique est proposé pour expliquer ces résultats.

Short title of thesis

LEARNING DISABLED SUBGROUPS

FROM WISC/WISC-R PATTERNS

Joan P. MacKenzie

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CHAPTER I

INTRODUCTION

Over the past two decades there has been a growing interest in learning disabled children, that is, children who experience severe and prolonged problems in school achievement in spite of normal intelligence, adequate home environment and the absence of physical and emotional handicaps (Kirk, 1963; Torgesen, 1975). Although research has flourished, comprehensive reviews of the burgeoning literature (Benton, 1975; Torgesen, 1975; Vellutino, 1979) have indicated that comparatively little is known about which factors actually contribute to learning failure in these children. Problems in perceptual functioning, intersensory integration, serial processing, verbal encoding, selective attention and the establishment of hemispheric specialization are among the most prominent of the variables currently hypothesized to account for their learning difficulties.

Perhaps one of the reasons for lack of consensus has been the tendency of researchers, thus far, to treat all otherwise normal children with reading and spelling problems as if they were a homogeneous group. Although it is now widely acknowledged that this learning disabled population is a heterogeneous one, the typical research strategy has been to compare the group as a whole to a control group of able learners of the same mean I.Q. Comparisons have been made on variables hypothesized to be related to learning failure, the discrimination of able and disabled learners usually having been based on the amount of academic progress made relative to that expected in terms of mental age (Cruickshank, 1977). If distinct subtypes of the learning disabled exist, then research based on undifferentiated samples would be misleading for it would not indicate whether the findings were typical of all learning disabled subjects or of just those from one or more of the possible subclassifications. Conclusions reached could be entirely dependent upon the sample used. It would appear to be unlikely that all learning disabilities could be traced to a disorder in a single psychological process but rather, it would be more probable that there are subgroups which conform to different diagnoses.

Although there is widespread recognition of the need to identify the possible subgroups among the learning disabled, certain methodological problems have hindered progress. Usually, a task is devised which is presumed to measure the psychological process hypothesized to underlie learning failure and groups are formed on the basis of similar levels of scores, ignoring the fact that equal scores are not necessarily arrived at by the use of the same process (Eysenck, 1967). Identification of performance patterns through the simultaneous appraisal of scores on a variety of measures (Rourke, 1975), use of more than one measure for a particular variable to allow for validation through convergence of results (Witelson, 1977), and/or repeated measurements to determine reliability and stability over time might help to minimize such error.

The use of samples with a wide age range may also have impeded advances in subtyping since there is evidence to suggest that processes which discriminate normal from retarded learners are different at different ages (Beery, 1967; Blank & Bridger, 1966). Yet, because cross-sectional designs are most frequently used, there is a scarcity of longitudinal data and little is known about whether or not it is the same child who performs poorly on different tasks at different ages or if it is different children who fail at the various age levels (Torgesen, 1975). The possibility that some individuals may present a stable disorder over time while others exhibit changing disabilities complicates any classification scheme, since in addition to determining the area of disability, the consistency of that disability over time must be considered.

That both stable and variable patterns of disability may exist has important theoretical implications. Within each of the theories currently advanced to explain learning failure, two views as to the underlying basis for the particular difficulty can be discerned: the developmental delay position, and the deficit position. The former hypothesizes that learning problems are a result of a lag in normal growth and development and generally assumes that the disabled child will eventually catch up to his age peers in the skills required for adequate academic performance (Rourke, 1976). The deficit model on the other hand implies that an underlying difference or dysfunction exists and there is no expectation that amelioration will occur. In cases where learning problems are prolonged, the delay hypothesis would predict changes in apparent disorder over the time span. Early disorders would ameliorate, but would be replaced by weaknesses in skills that appear and mature at later ages (Satz & Van Nostrand, 1973). Intuitively, the deficit hypothesis would predict stability; a dysfunction, once manifested, would not disappear with maturity, although, of course, additional deficits could be added in those processes that emerge at later ages.

Along with these theoretical concerns, there are important practical reasons for determining if consistency of a disability is a relevant variable in subtyping. Good diagnosis, in education as in medicine, must enable one to predict accurately the course a disorder will take so that suitable therapeutic interventions can be prescribed. Whether or not a long-term learning problem represents a delay that is corrected over time, but replaced by a subsequent disorder, or is a stable deficit requiring compensatory educational procedures is often known only with hindsight, if at all. Frequently, there appears to be an implicit assumption that if learning failure persists, the original underlying disorder has also persisted, and so in practice a permanent label is placed on a child after a single assessment, and no subsequent follow-up assessments are made. If disabilities are consistent, permanent labelling after a single assessment may be justified, and subsequent diagnostic assessments may not be required. Yet, if disabilities change over time, then repeated evaluations are indicated. It is evident also that the kind of educational interventions prescribed would vary with the hypothesized stability or variability of the disorder.

There is, then, an apparent need to know if consistent and inconsistent patterns of disability can be identified in learning disabled children, and, if so, if consistency or the lack of it is related to type of disability. A retrospective analysis of assessment data on learning disabled children who had received several successive evaluations over a period of time could provide a convenient and practical way of initiating research in this area.

Accordingly, a study in two parts was carried out. Children who had been clinically diagnosed as learning disabled, and for whom three WISC/

WISC-R assessments had been undertaken over their school years as part of that diagnosis formed the initial subjects of the investigation. In the first stage their WISC/WISC-R records were analyzed and subgroups were identified on the basis of a disability x consistency classification scheme. In the second stage the resulting subtypes were compared on selected variables hypothesized to be associated with learning failure to see if the formation of such subgroups might have diagnostic significance. The two stages of this investigation are reported separately.

CHAPTER II

IDENTIFICATION OF SUBGROUPS IN A LEARNING DISABLED POPULATION: STUDY NO. 1

A Review of Relevant Literature

Clinical intuition and empirical evidence tell us that not all disabled readers and spellers are the same. Yet, to recognize each one as an individual requiring uniquely appropriate educational treatments is not to deny that some of these children are more alike than others. To see the similarities among the diversities and therefore to conceptualize these children into identifiable groups on the basis of shared relevant characteristics is both theoretically and practically valuable: for the practitioner in justifying and delivering appropriate services and programs, and for the theoretician in exploring and explaining the causes of learning disabilities.

Early attempts to categorize children who experienced learning failure were based on techniques of exclusion. Researchers and clinicians ruled out those children whose learning difficulties could be explained by secondary factors such as known neurological impairment, sensory handicaps, subnormal intelligence, socioeconomic disadvantage and emotional disturbance, and they concentrated their studies on the others. Thus, the group which has come to be called "learning disabled" was initially identified and defined by what it was not rather than by what it was (Chalafant & Schifflin, 1969). Having excluded those whose disabilities fell into the previously defined categories, it seemed reasonable to suppose the remaining group might have a common disorder. However, it soon became apparent that this group was, itself, not homogeneous and subsequently there have been various attempts to discriminate subtypes within it by use of inclusionary criteria. Two main approaches have evolved: definition by type of academic skill failure, and definition by type of psychological process disorder. The selective review which follows is designed to examine the chief characteristics of research in these two areas.

Identification of Subgroups in Learning Disabled Populations

Subgroups based on type of academic skill failure: Some researchers have grouped disabled learners on the basis of their differential competency in various broad academic areas. For example, Warrington (1967), first alone and then with Nelson (Nelson & Warrington, 1974), discriminated disabled learners into two main groups: those who had difficulty in reading and spelling and those who had difficulty in reading only. They found group differences in the types of errors made, in IQ score patterns, and in verbal and performance intelligence test score patterns.

Rourke and Finlayson (1978) divided children with learning disabilities into three groups on the basis of achievement patterns in reading, spelling, and arithmetic. Group I was uniformly deficient in all subject areas, Group II was stronger in arithmetic and relatively weak in reading and spelling, while Group III was characterized by deficient arithmetic but average spelling and reading scores. In the search for cognitive correlates, they noted that Groups I and II were relatively competent in visuo-spatial skills as measured by the subtests of the WISC performance scale and the target test (Reitan & Davidson, 1974), while Group III showed relative strengths in auditory-perceptual abilities, which were assessed using the WISC verbal scale subtests and the Peabody Picture Vocabulary Test among others. The authors pointed out that definition of groups simply by level of performance in any one of the subject matter areas alone would have distorted and limited findings since it would have combined Groups I and III into one single classification labelled as deficient in arithmetic.

Other researchers have sought to identify subgroups on the basis of error types within a single academic area. Boder (1970), using an informal word recognition inventory, classified disabled readers on the basis of the kinds of spelling errors they made on words in their sight vocabulary and on unknown words. Three subtypes were identified: dysphonetic (children who make nonphonetic, unintelligible errors); dyseidetic (children who make phonetically acceptable errors but do not respond to words as wholes); and alexic (children who are weak in both phonetic skills and wholistic recognition). It was found that these patterns remained stable, even when reading scores themselves improved, which suggested that stable, qualitative differences existed. However, Holmes and Peper (1977), using Boder's scheme, found no such qualitative differences when proportion of error types was considered. They concluded that disabled readers were simply representative of the lower end of the continuum of a normal distribution of readers.

Other researchers have proposed classification schemes similar to Boder's. Ingram, Mason and Blackburn (1970) identified two types of poor readers on the basis of their performance on standardized academic skills tests: those with a general deficiency in phonetic analysis and word blending skills (audiophonic) and those who exhibited visual discrimination and orientation problems along with poor sight word recognition (visuo-spatial). Mattis, French and Rapin (1975), using such well known measures as the Benton Visual Retention Test, the Illinois Test of Psycholinguistic Ability and Raven's Progressive Matrices, found two groups similar to those mentioned above. In addition, they discriminated a third group of children characterized by poor speech articulation and handwriting deficits who were therefore seen as having an impaired motor system.

In an innovative study, Doehring and Hosko (1977) used a Q-technique of factor analysis in which subjects with similar test scores on thirty-nine variables were classified together. In this way, they identified three main groups of disabled readers. The first was characterized by slow oral reading, the second by slow auditory-visual letter association, and the third by slow auditory-visual association of words and syllables. They suggested that these groupings could be interpreted in terms of certain deficits in psychological processes - group 1 seemingly displaying a linguistic deficit, group 2 displaying intersensory integration problems, and group 3 disorders in temporal and phonological processes. This interpretation, along with the suggestion that the subtypes be used to guide the search for neurological determinants, implies that Doehring and Hosko saw the subgroups as reflecting underlying qualitative differences.

<u>Subgroups based on psychological process disorders</u>: The literature is rich with investigations comparing normal and disabled learners in various psychological processes. Far fewer studies have tried to differentiate subgroups within the learning disabled population itself on the basis of these processes. Perhaps this is because many researchers,

either implicitly or explicitly, have espoused a unitary disorder hypothesis to account for learning failure. A unitary theory assumes that a single factor underlies the learning problem and so research from this perspective seeks to demonstrate that dysfunction in a particular process such as selective attention, serial processing or auditory-visual integration is the crucial discriminator between normal and disabled learners. If dysfunction in a particular process is characteristic of the disabled group, then a unitary hypothesis assumes that this disorder is typical of all members of the group, and so subtyping is irrelevant.

Although a multi-process theory, which holds that more than one type of process disorder causes reading and learning problems, is becoming more widely accepted, it has yet to be translated into widespread research efforts to identify subtypes. The complexity and degree of integration demanded of research within the multi-factor orientation is undoubtedly intimidating, and the identification of well defined subtypes an arduous, time consuming preoccupation, as witnessed by the lifelong work of Eysenck (1970) in the field of personality subtyping. Nevertheless, there have been some noteworthy initial efforts, two most prominent and influential ones being those of Birch and of Myklebust and Johnson.

Birch (1962), in a theoretical paper, integrated evidence from the comparative and developmental sectors of psychology to support a 3-factor theory of reading disorder and proposed that reading disorders stemmed from failure to undergo the necessary developmental changes which take place over time in childhood, probably because of impairment in the nervous system. He hypothesized that three separate subtypes would be identified: (i) those who failed to establish intersensory equivalences, (ii) those who failed to establish hierarchical dominance of the visual system, and (iii) those in whom the process of visual analysis and synthesis was functioning poorly. Of the three proposed subtypes, the one that has generated the most research interest has been the group purportedly manifesting problems in intersensory integration, a point to be discussed in greater detail in Chapter III. Sufficient to say that, as Freides' (1974) comprehensive review paper indicates, the data are inconclusive and controversial.

Myklebust and Johnson (Johnson & Myklebust, 1962; Johnson & Myklebust, 1967) analyzed clinical case studies and delineated three subgroups based on disorders within the various sensory modalities. The first subgroup was identified as one with visual processing problems, the second and more numerous as those with disturbances in auditory processing, the third group was described as having trouble making visual-auditory associations, a problem akin to the intersensory difficulties described by Birch.

Groupings based on sensory modality have received considerable support in the literature. An earlier study of Ingram and Reid (1956) found similar subtypes and a detailed study by Doehring (1968) also identified groups based on modality weaknesses. He used 109 non-reading measures obtained from the Indiana Neuropsychological Battery, the Minnesota Aphasia Test and tasks designed to evaluate speed of sensory perception, reversed figure discrimination, word association, color form preferences, right left orientation, and visual, non-verbal memory. Three main groups were differentiated, the first characterized by poor visual perceptual skills, the second by speech and language disorders, and a third by problems in both the visual and auditory-language areas. Zangwill (1962), on the basis of clinical observations, also found visual and auditory subgroups, each of which he associated with a different etiology. He suggested that the visual problems could be genetically based while the auditory language problems could represent maturational differences in the cerebral hemispheres.

The pervasiveness of auditory versus visual subtyping is also reflected in what is commonly called the modality preference literature where, in order to prescribe suitable educational interventions, subgroupings of disabled learners are formed on the basis of their strengths and weaknesses in the various sensory modalities. This practice derives from an assumption of long standing that learning failure can be overcome by capitalizing on modality strengths. Tarver and Dawson (1978) reviewed fifteen studies where remediation was attempted on this basis and concluded that there was strikingly little support for the practice. Similar conclusions have been drawn by Derevensky (1978). Thus, it appears that, at present, subgroupings based on modality processes, although supported by the subtyping literature, have little therapeutic value. This inability to translate visual-perceptual and auditory-language subgroups into meaningful educational correlates for the purposes of developing academic skills has also been documented by comprehensive reviews of such attempts by Hammill and Larsen (1974) and Larsen and Hammill (1975). Although many reasons might be offered for this failure, it is commonly agreed that a major problem is the lack of valid and specific tests to measure the various processes on which the subgroupings are based in the first place.

From this review of the literature, it can be noted that the two main approaches to subtyping are not mutually exclusive. If classification on the basis of academic skill performance is the initial step, then the next step is to identify psychological processes associated with the skill types. If subdivision is determined by performance on psychological process variables, then these processes must be meaningfully related to relevant academic skills. As we have seen, the results of both lines of investigation often have led to subgroupings associated with dysfunction in either the visual or auditory modality. Finally, a shared goal of both approaches is the desire to discover the underlying determinants of the subgroup differences which at this level often reduces to a common interest in brain-behavior relationships.

There are certain disadvantages associated with each of the two classification schemes. The use of broad academic criteria often obscures the multifaceted nature of these skills and so heterogeneity as to type of difficulty is likely to occur in the groupings. Moreover, by the time this type of diagnostic subtyping can be carried out, the disabled child must have already experienced the very failure one seeks to avoid through the use of the procedure. Early identification, and perhaps prevention, is not possible. Subdivisions based on specific competencies within a subject area may overcome the first problem but not the latter. The difficulties associated with subgroup definition on the basis of psychological process variables center around the questionable psychometric properties of the tests designed to measure the different processes. Such tests often lack specificity. For example, essentially the same task, that of matching an auditorily presented sequence of taps by selecting its visual counterpart composed of black dots on paper and vice versa, has been variously interpreted as a measure of auditory-visual integration (Birch & Belmont, 1965), spatial to temporal transfer (Rudel & Denckla, 1976), and attentional capacity (Ross, 1976). Moreover, the reliability of these tests is often undetermined. Needless to say, few data in the way of age-related changes in test performance are also available.

There is one test in wide general use, however, about which much information has accrued. The WISC/WISC-R (the Wechsler Intelligence Scale for Children, Revised) is an instrument highly regarded for its published reliability and validity coefficients, the consistency of its factor groupings and its stable age norms (Matarazzo, 1972; Stattler, 1974). Increasingly, its value as a diagnostic tool, quite apart from its use as a quantitative index of intellectual functioning, is being recognized (Glasser & Zimmerman, 1967; Lutey, 1977; Stattler, 1974). Its usefulness as a device to differentiate learning and reading disabled subtypes has been explored by many researchers and it has a place within either of the foregoing categories of subtyping investigations.

Subgroups based on WISC/WISC-R subscale scores: Early investigations gave promise that observed discrepancies between verbal and performance IQ scores could be used to discriminate disabled readers or learners from the rest of the population, since low verbal IQ scores relative to performance IQ scores had been found to predominate in the group (Altus, 1956; Belmont & Birch, 1966; Hirst, 1960; Robeck, 1964). However, Vernon (1971), reviewing studies that supported the low verbal-high performance discrepancy in the group, cautioned that the evidence was not strong enough for the pattern in itself to be used diagnostically, since other studies had indicated that a low performance-high verbal pattern could also occur within the learning disabled group (Ingram & Reid, 1956; Kinsbourne & Warrington, 1963). The possibility of using these two patterns to identify subtypes within the disabled populations, however, remained a distinct possiblity.

Kinsbourne and Warrington (1963), who were probably among the first to study correlates of reading disabled subtypes based on such verbal and performance IQ patterns, grouped reading disabled subjects on the basis of 20-point or more discrepancy between subscales. One group had normal verbal and low performance scores while the other had normal performance and low verbal achievement. They found that the latter group exhibited evidence of language disorder while the former had difficulty with finger differentiation, constructional tasks and mechanical arithmetic. Of central interest is a study by Reed (1967) indicating that the significance of the verbal-performance patterns appeared to be age related, with lower verbal than performance scores differentiating poor readers only among the older children. Rourke and colleagues (Rourke & Telgedy, 1971; Rourke, Dietrich & Young, 1973) also found interesting age differences when classifying children according to subscale discrepancies. In the earlier study with older children from 9 to 14 years of age, they found no support for their hypothesis that the disabled groups could be identified by differential accuracy of right and left hand performance on psychometric tasks, but they did observe that the high performance-low verbal children performed significantly better on the psychomotor tasks than the other groups. In the subsequent study with younger children 5 to 8 years of age, Rourke, Dietrich & Young (1973) did not find the same clearcut differences between the groups. However, since these studies were cross sectional, it can not be determined whether individual children changed groups with age or whether it was different individuals who were found within the various groups at different ages.

While the foregoing studies indicated that correlates of the IQ discrepancy subgroups may depend on age, other studies found that meaningful differences between such subgroups were difficult to demonstrate. Wener and Templer (1976), studying a group similar in age and IQ to that of Rourke and Telgedy (1971), failed to confirm that verbal-performance discrepancies were good predictors of psychomotor skill. Neel (1976) administered a diverse battery of perceptual and cognitive tasks to low achievers who had been classified into the three IQ-score discrepancy groups. A discriminant analysis indicated that the groups so formed were just a result of the original classification scheme and were not due to any significant differences between subjects on the perceptual-cognitive tests. Cermak, Goldberg, Cermak and Darke (1980) also used the IQ score discrepancies to subdivide populations of both older and younger learning disabled children. They concluded that none of the groups defined in this way performed significantly below normal controls on a task which required retention of verbal material across varying time intervals, and moreover, that this was true at both younger and older age levels in their sample.

Inability to clearly and consistently define the characteristics of subgroups based on WISC subscale discrepancies suggests that these subdivisions may be too broad for diagnostic significance. The scores derived from such a wide variety of tasks could mask crucial age and individual differences in processes required to perform those tasks. The major subgroups so formed may themselves be composed of subgroups. There is also the possibility that the tests which are used to produce the verbal and performance scales may not be adequately classified. For example, the coding subtest may be more of a verbal test than Wechsler originally believed (Estes, 1974; Huelsman, 1970; Royer, 1971). In addition, there appears to be some disagreement about what magnitude of discrepancy between the subscales may be considered to indicate a true difference (Kaufman, 1976).

Subgroups based on WISC/WISC-R subtest scores: The search for a typical WISC/WISC-R pattern for disabled learners had also led to investigations into typical subtest profiles or patterns. Huelsman (1970), in reviewing 23 studies, concluded that while low subtest scores in each of information, coding and arithmetic subtests were characteristic of the disabled group as a whole, none of the studies had provided satisfactory evidence as to the applicability of subtest patterns to individuals. In his own study, he demonstrated that none of the poor readers had low scores in all three subtests, only 6% had low scores in two of them and 64% were not weak in any. He attributed these startling results to the presence of subclasses within the total disabled group.

Studies to identify subgroups based on test scores, subsequent to the Huelsman review, have proved to be similarly inconclusive. Lutey (1977), analyzing some 30 studies using subjects broadly defined as learning disabled and a further 60 studies with subjects more specifically defined as reading disabled, determined that the most commonly observed low scores were in the arithmetic, information, digit span and coding subjects. However, she concluded that the use of individual subtests for diagnostic purposes was not defensible, largely because of lack of reliability in subtest scores. Similar conclusions have been drawn by Matarazzo (1972) who noted that three decades of research had failed to substantiate the use of individual WISC subtests for clinical diagnosis. Lack of specificity as to what each subtest measures and the fact that two people who obtain the same scores may have arrived at it by quite different processes has made subtest profiles difficult to interpret and use as a basis for subtype classification. It is possible, however, that the recent trend toward use of scores from clusters of related subtests as determined through factor analysis might help to overcome this problem.

Subgroups based on WISC/WISC-R factor analytically derived clusters: Factor analysis is a mathematical procedure by which a small number of new variables is derived from the intercorrelational patterns of a larger number of variables. The WISC or WISC-R subtests when analyzed in this way are reduced to three main factors, each composed mainly of three subtests involving supposedly similar processes (Bannatyne, 1971; Cohen, 1959; Kaufman, 1975). The work of Bannatyne (1971, 1974), frequently cited in the learning disability literature, suggested a tripartite recategorization into spatial, conceptual and sequential categories. The first factor (spatial) is composed of the block design, object assembly and picture completion subtests; the second factor (conceptual) includes vocabulary, similarities and comprehension, while the third factor (sequential) was originally composed of the picture arrangement, digit span and coding subtests. However, Rugel (1974b), as a result of his own analysis, suggested that the picture arrangement subtest be replaced by the arithmetic subtest, a refinement accepted by Bannatyne (1974).

A considerable number of factor analytic studies have supported the three factor composition of the WISC/WISC-R and the interpretation of the processes represented by factors 1 and 2 (Baumeister & Bartlett, 1962; Bortner & Birch, 1969; Cohen, 1959; Kaufman, 1975; Lombard & Riedel, 1978; Smith, Coleman, Dokecki & Davis, 1977), but there is a divergence of opinion as to what label should be assigned to the third factor. Some prefer to consider it related to attentional abilities (Cohen, 1952; Kaufman, 1975) while others (Ackerman, Dykman & Peters, 1976; Smith et al., 1977; Vance & Singer, 1978) support a sequential memory interpretation.

In spite of the lack of labelling consensus, reference to the factors has been shown to be useful in the identification of learning, particularly reading, disabled populations. Bannatyne (1971) reported that children with a diagnosis of genetic dyslexia, that is, with a familial history of reading problems, scored lowest in the factor three category. Factor one scores were highest and factor two intermediate. Rugel (1974a) recategorized the WISC scores reported in 25 published and unpublished studies of disabled readers and thus extended Bannatyne's findings with genetic dyslexia to disabled readers in general. Moreover, he demonstrated that this pattern of ascending factor scores (Factor 3 < Factor 2 < Factor 1) was not typical of normal readers. Smith, Coleman, Dokecki and Davis (1977) showed that school-verified learning disabled children were also characterized by this same pattern of abilities. They noted that 62% of these children scored lowest in the factor 3 category, 29% in the factor 2 and 9% in the factor 1.

As yet, few studies have explored the usefulness of these recategorized groupings for diagnostic and remedial purposes. Miller, Stoneburner and Brecht (1978) attempted to see if these factors significantly discriminated between learning disabled children who had been clinically diagnosed as having either visual or auditory perceptual deficits. They hypothesized that visual deficits would be associated with low factor 1 scores and auditory with low factor 2 and found that 83.6% of the visual perceptually handicapped but only 39.6% of the auditorily handicapped were properly cross-classified. The inability of Bannatyne's factor 2 pattern to correctly categorize auditory disabilities was not unique. Keough and Hall's (1973) factor analysis groupings (which are similar to Bannatyne's) and verbal-performance discrepancy patterns discriminated just as poorly. Although this failure was interpreted as evidence of the ineffectiveness of these factor techniques for diagnosis, it was also acknowledged that results may have been confounded by having a variety of perceptual disorders in the so-called auditory grouping, that is, the clinical diagnosis against which the factor 2 scores were validated could have been incorrect. The possibility also exists that the factor 2 cluster is being misinterpreted when considered as an indicator of auditory perceptual processes.

Of prime importance to the study which follows is the work of Ackerman, Dykman and Peters (1976) who explored the relationship between recategorized WISC patterns and academic skills over time. Comparisons between initial and 4-year follow-up assessment scores were made for learning disabled boys and their normal controls. The learning disabled subjects had been originally subdivided on the basis of activity level and neurological status but were retrospectively regrouped along with a control group of able learners in terms of type of academic skill competence or retardation. Eight different skill groups were identified, such as: superior achievers, superior readers but average arithmetic; average achievers in all skills; adequate reading and arithmetic, and so on. Learning disabled groups were characterized by rather modest overall intellectual skills in conjunction with disparity among the three factor scores while the most successful students had balanced cognitive abilities at a rather high level. Low factor 3 scores identified those with the most persistent learning problems.

It was noted that while relatively few subjects displayed reliable discrepancies between factor 1 scores, which might be considered to be representative of performance scale IQ scores, and factor 2 scores which might represent the verbal scale score, the low position of factor 3, for the most part, was maintained over the 4 year period from initial assessment to follow up. The question is naturally raised whether a longer term follow-up would confirm or reject these results. A retrospective classification of older learning disabled subjects, based on the stability or otherwise of the lowest factor score at each of several repeated testings, as well as the type of factor score disability, might provide a useful means of subdividing subjects in order to study the cognitive correlates of learning difficulty and learning failure.

Summary of Subgrouping Based on WISC/WISC-R Patterns

There appears to be considerable consensus regarding typical score patterns derived from the WISC/WISC-R for heterogeneous samples of learning disabled subjects. It has been found that low subtest scores in arithmetic, digit span, coding and information characterized the test results of these children as a whole. Moreover, independent research employing factor analytic categories also supports this pattern since the low factor 3 scores that typify the disabled are composed of the digit span, coding and arithmetic subtests. Further, the earlier, somewhat inconclusive, studies demonstrating that low verbal IQ scores relative to performance IQ scores are also typical of these children are not in conflict with findings regarding factor score patterns, factor 1 is composed of performance subtests, while factor 3, being more complex, is composed of two tests from the verbal scale and the one, coding, whose placement on the performance scale has been questioned. It may be that these factor scores are a more precise and statistically valid way of yielding WISC/WISC-R subtypes than the broader Wechsler subscales.

At issue, then, is not whether low factor 3 scores characterize the learning disabled as a group, since such a finding has been replicated many times, but whether this fact has any additional diagnostic or clinical significance. There is conjecture but no certainty as to the kind and nature of disability associated with low factor 3 functioning. However, it is possible that a dysfunction in a single process common to the three subtests is responsible for one particular type of learning failure. Again, it is not known if a factor pattern applicable to a group of individuals can be equally applicable to a single case, although this would be useful in clinical diagnosis and treatment. Nor is it known if the stability of a pattern within a single group over time as shown by Ackerman et al. (1976) is stable within the single individual. One might ask whether the low factor 3 pattern defines an important subgroup, over time, and if other demarcated subgroups can be found on the basis of other factor patterns. It would appear that an analysis of longitudinal test data to determine consistency or inconsistency of disability as indicated by lowest factor scores in individuals over time might provide some answers to the foregoing questions.

Studies of Patterns of Disability Over Time

The issue of whether or not areas of weakness remain stable or consistent over time in reading or learning disabled children has important practical implications. Whether or not repeated diagnosis is necessary and what type of remedial or compensatory intervention might best be used are problems that are directly related to the variability and stability of the disorder. The assumption of consistency in human growth and development is a fashionably common one despite considerable counter-evidence. Clarke (1972), citing detailed results from longitudinal studies in the areas of intelligence, personality and scholastic achievement, demonstrated that variability with respect to an individual's position relative to that of his peers was the rule both in growth curves and in patterns of change. Evidence that patterns of deficit in psychological processes and academic skills change with age, the deficits identified varying with the age at which testing is conducted, has been produced by cross-sectional (Benton, 1962; Sapir & Wilson, 1967; Reed, 1968; Rourke et al., 1971, 1973), longitudinal (deHirsch, Jansky & Langford, 1966; Rourke & Orr, 1977; Satz & Friel, 1974) and retrospective studies (Belmont & Belmont, 1978). On the other hand, in terms of WISC/WISC-R scores, low factor 3 scores have been shown by Rugel (1974) and Smith et al. (1977) to have some stability across age in learning disabled children with Ackerman, Dykman and Peters (1976) concurring that area of deficit or disorder remained constant over time for their group of children. It is necessary to examine further the hypothesized stability in terms of different theories of developmental delay or of continuing deficits.

Theories of developmental delay. It is an accepted developmental principle that, although individuals mature in accordance with invariant patterns, they do not necessarily do so at the same rate (Gesell, 1956). Yet, in most educational systems there appears to be an overriding assumption that mastery of certain tasks should take place at a certain time and children are expected to pass these academic milestones in accordance with their chronological rather than their maturational ages. Since it has been reasonable to suppose that children with slower individual growth rates are at a disadvantage relative to those with average growth rates because their capabilities are like those of younger children, it is not surprising that a large number of theorists and practitioners attribute learning failure in otherwise normal children to a developmental delay in those skills necessary for the mastery of tasks the educational system has deemed age-appropriate.

Studies of various processes hypothesized to be related to academic success, such as perceptual motor functioning (Bender, 1938, 1956), selective attention (Hagen & Hale, 1973), serial processing (Torgesen, 1977), hemispheric lateralization (Bryden & Allard, 1976; Satz, Bakker, Teunissen, Goebel & Van der Vlug, 1975) and intersensory integration (Birch & Belmont, 1965) have indicated that growth in these capacities is age-related in the normal population, with agreement that visual motor skills develop rather early while others such as selective attention mature somewhat later. Evidence that learning disabled children exhibit behavior like that of younger normal children in many of these areas has been provided by Bender (1957), Bakker (1972), Corkin (1974), Koppitz (1971) and Tarver, Hallahan, Cohen and Kauffman (1977).

This notion that learning disabilities result from delays in normal developmental sequences is not new and may be traced at least to the time of Orton (1925), who espoused a theory of developmental lag in hemispheric dominance, and Bender (1938, 1957), who postulated immaturity in the visual perception of patterns. The developmental studies of Gesell (1924, 1957), Eustis (1947), Olson (1949), and Ames (1969) suggested ways to gauge the progress of learning and development in normal and learning disabled children but did not explain intra-individual differences in the growth rates.

More recently, Satz and colleagues (Satz & Sparrow, 1971; Satz & Van Nostrand, 1973) have presented a clearly articulated and testable developmental theory of learning failure. They argued (Satz and Van Nostrand, 1973) that since neurological studies of learning disabled children have failed to provide conclusive evidence of structural damage or alterations to the left hemisphere, the crucial problem involves not a structural change but a lag in functional development, the result of delayed acquisition of skills rather than the loss of them. This theory proposed earlier in less detailed from by deHirsch, Jansky and Langford (1966), hypothesizes that disabled readers of at least normal intelligence and without emotional or social handicaps have a lag in the maturation of the left hemisphere, which affects skills in primary ascendancy at a given age, the observed pattern of disorders changing with increasing maturity. Thus, the Satz theory provides a framework to account for the diversity of problems presented by dyslexic children in the so-called Gerstmann syndrome (left-right confusion, poor finger differentiation, sequencing errors, impaired verbal skills). It is also consonant with what is presently known about impaired left hemisphere function since the work of Lenneberg (1967) and Geschwind (1968) have supported the hypothesis of progressive differentiation and lateralization of the language function in the left hemisphere, and Semmes (1968) has extended the explanation so as to include such non-language skills as finger differentiation and right-left discrimination by proposing that sensory and motor capabilities are represented in the two hemispheres, focally in the left and more diffusely in the right. In accordance with the Satz theory, then, two main hypotheses of interest to this investigation could be conceived: (1) Younger, but not older, disabled readers would be more delayed in visual motor tasks than normal children; (2) Older, but not younger, disabled readers would be more delayed in language skills than normal children.

Cross-sectional research with disabled children of various ages (Kinsbourne, 1971; Sabbatino & Hayden, 1970; Satz, Rardin & Ross, 1971; Van Nostrand, 1972) has provided some support for these hypotheses without clearly demonstrating that younger disabled children show more delay in visual motor tasks than in language tasks. Additional evidence from ongoing longitudinal studies by Satz et al. (1974, 1977) has produced much the same evidence. However, Jansky (1979) among others (Benton & Pearl, 1979) has suggested that inadequate basal tests precluded satisfactory evaluation of language skills in the young subjects of Satz' sample and Vellutino (1977), reviewing research results, has concluded that perceptual and perceptual-motor abilities do not discriminate good from disabled readers.

The deficit approach. The deficit approach has conceptualized learning disabilities within the framework of a medical or disease model and suggests there is some sort of abnormality in cerebral structures or function that underlies the failure to acquire age-appropriate academic skills. The responsible factor may be brain damage or aberrations in cortical organization. A long history of support for this position has stemmed from observations that individuals with known brain damage frequently manifest specific learning problems. In 1896, Morgan attributed a reading disorder to defective development of the angular gyrus since reports had documented such problems in adults with disease in this region. Hinshelwood (1904, 1917) modified this presumption to limit abnormalities to the left angular gyrus only. Today, it appears that bilateral parietal anomalies are often implicated in reading and spelling disorders (Benton, 1975; Geschwind, 1968; Spreen, 1976).

While one line of research based on the deficit hypothesis has centred on efforts to localize the focal area of the brain for reading disorders, another has sought evidence that learning disabilities are the results of atypical hemispheric organizational patterns (Witelson, 1976 a; Bryden, 1970; Zurif & Carson, 1970). Non-medical interest has been fostered by recent developments in non-invasive dichotomous stimulation techniques which have provided information about right-left hemispheric aberrations (reviewed later in greater detail) and suggested that interference of one hemisphere in the functioning of the other might be a major source of process disability.

Yet another line of research within the deficit model has studied relationships between brain and behavior. In this approach, diagnosis is based initially on surgical evidence of known structural damage to certain areas of the brain. The behavior of subjects with this structural damage is observed and so certain behaviors become associated with certain structural abnormalities. Henceforth, diagnosis of structural damage in other subjects is made on the basis of observed behaviors only. Goldstein (1936) was probably the first to do this in studying brain-damaged war veterans, while Werner and Strauss (1940) adapted the procedure to the study of impaired children. As a result, the label MBD (minimal brain damage) came to be associated with learning impaired children, whether or not evidence of actual brain damage existed.

Support for the notion that neurological insult is related to learning disorders also grew from studies with other groups of children with known neurological damage. Studies of cerebral palsy victims showed them to display the perceptual dysfunctions which are often associated with reading and spelling deficiencies (Cruickshank, Bice, Wallen & Lynch, 1965), and premature infants are reported to have a later high incidence of reading disorders (Balow, Rubin & Rosen, 1976; Kawi & Pasamanick, 1958).

Against such evidence, it must be admitted that significant differences in behavior have been found between those with actual confirmed brain damage and those in whom brain damage was only inferred (Reitan & Boll, 1973). Gaddes (1968), too, had shown that among a heterogeneous brain-damaged group the only poor readers were those with damage in the left parietal region, and that in the vast majority of poor readers no inference or presence of brain damage existed.

Many of these earlier investigations attempted to use a cut-off point on each measure so as to discriminate between brain-damaged and normal individuals. A different and more promising approach came from the work of Reitan and his associates (Doehring, Reitan & Kløve, 1961; Matthews & Reitan, 1963; Reitan, 1955, 1964, 1974; and Reitan & Davidson, 1974). Using a technique of simultaneous appraisal of scores on a variety of measures, they demonstrated that verbal and performance scales of the WISC and related measures are differentially sensitive to impairment of left and right hemispheres in brain damaged older children and adults, a relationship not found with young children. This use of verbal and performance IQ's and their discrepancies has proved to be a powerful tool in the hands of those who espouse a deficit theory.

Perhaps the most comprehensive studies of learning disabled children, inspired by the deficit approach in general, and the work of Reitan in particular, are those of Rourke and colleagues (Rourke, & Telgedy, 1971;

Rourke, Young & Flewelling, 1971; Rourke, Dietrich & Young, 1973; Rourke, Yanni, MacDonald & Young, 1974; Rourke & Finlayson, 1975, 1978). Rourke (1975) summarized the evidence from his investigations and concluded that, while older learning disabled children conformed to the patterns of the brain-damaged adults studied by the Reitan group, younger children did not always do so. Interestingly, although some of the tests did not discriminate the neurologically impaired at a younger age, the WISC discrepancy patterns did so effectively. The possibility exists, however, that broad WISC subscale patterns may be insensitive to age differences. Since the two of the three factors used to explain WISC scores are verbal in nature, alternating low functioning on these two factors might be responsible for the different results obtained with younger and older children. A factor score discrepancy approach might, therefore, increase the discriminative properties of a differential analysis.

The consensus that younger disabled children do not show the same patterns as older children (or brain-damaged adults) had led Reitan (1974) to conclude that a fuller understanding of the relationship between brain and behavior would have to await a better understanding of the effects of age or development which seems to imply that there is an interactive effect between deficit and development. Taylor (1969, 1976) and Buffery (1970) for their part have shown that the differential effects of lesions are related to the rate of maturation of the hemispheres, with the left maturing more slowly than the right, and both hemispheres of boys developing more slowly than those of girls. Thus, they argue, the left hemisphere is more vulnerable to insult than the right, particularly in boys, and this may account for the preponderance of boys in learning disabled populations. The evidence that deficits can be affected by developmental factors, and thereby take on a developmental guise, makes discrimination between delay and deficit patterns difficult in the extreme. One must conclude that each theory accounts for the existence and/or behavior of a subgroup within the learning disabled population, and that some interaction between deficit and lag may account for a further proportion of this population.

Comparisons of deficit and lag pattern. The greatest clarification within this cloudy area may come from the paradigms presented by Rourke (1976), who described comparative growth patterns of normal and disabled learners between the ages of 6 and 11 years. For normal readers, some skills might show continuous growth over the age range from 6 to 11 years; others might mature early but reach an asymptote before age 6, thus showing a plateau over the age span; others might show late growth after a low initial level, and still others might show an alternating pattern of spurts and plateaux. Graphically, these are presented in Figure 1, which was adapted for illustrative purposes from Rourke (1976), and in tabular form, these paradigms might be depicted as follows:

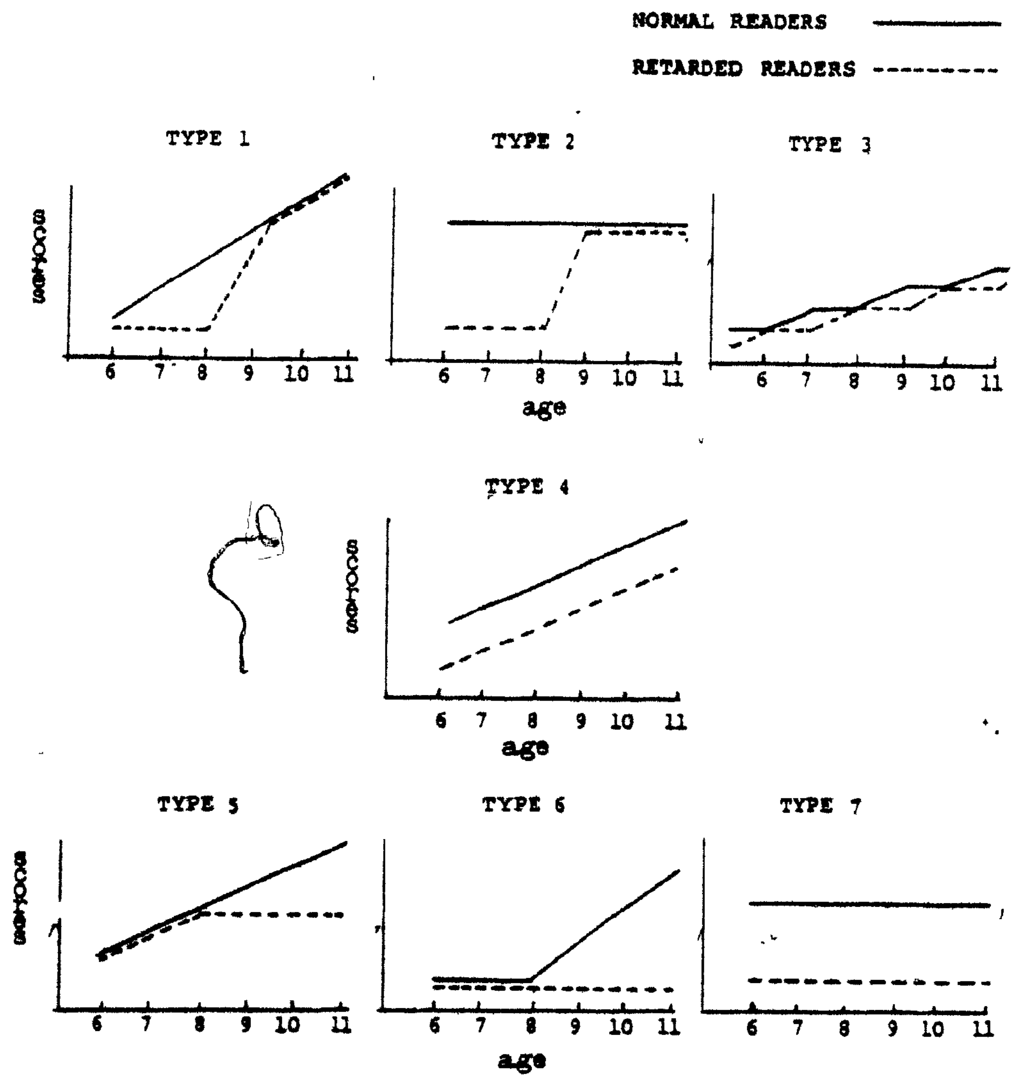


FIGURE 1.

Rourke's (1976) Seven developmental lag-deficit paradigms comparing normal and retarded readers.

Table 1

Rourke's seven deficit-lag paradigms

Type	Normal readers	Retarded readers	WISC subtest correlates
type 1	continuous growth	initially low scores followed by catch-up	object assembly
type 4	continuous growth	no catch up but continuous growth from a low level	digit span coding arithmetic
type 5	continuous growth	early growth but also early plateau and no catch up	
type 2	early maturing with plateau from age 6 onward	early low scores but later catch up	
type 7	early maturing with plateau from age 6 onward	plateau formed at a low level; no catch-up	
type 6	low initial level but a late emerging skill or spurt	plateau at a low level	
type 3	alternating periods of plateaux and growth	delayed alternation plateaux and growth with eventual catch up	picture completion comprehension

Types 1, 2 and 3 were designated as patterns of delay since they were characterized by eventual improvement in the disabled group. Types 5, 6 and 7 were labelled deficit patterns since no such improvement occurred. Type 4 remained ambiguous with growth at a lower but parallel position throughout the age span from 6 to 11 years, so it could not be determined if eventual catch-up might take place.

Information presented in Table 1 suggests that factor 1 scores might follow a type 1 pattern given that the object assembly subtest is a constituent. Factor 2 scores might be predicted to follow a type 5 pattern since they include the similarities and vocabulary subtests. The digit span, coding and arithmetic subtests comprising factor 3 conformed to type 4 and so it too might be predicted to follow this growth trajectory. If so, factor 3 disorders which have been observed in reading disabled populations (Rugel, 1974a) should be apparent at an early age and should present a consistent problem over the elementary school years.

Deficit-lag etiology and the consistency variable. From the foregoing (Table 1 and Figure 1), it must appear that whether a learning disorder is a manifestation of a deficit or a lag can be determined only if longitudinal data are available for many individuals over an extended age range. Equally, the consistency or variability of the disorder can be determined only from repeated measurements upon the same individuals, again over an extended period of time. It is pertinent, therefore, to ask whether the consistency/inconsistency variable is related to the deficit lag nature of the disability.

Rourke's paradigms suggest that if there was eventual catch-up, then the original disorder was the result of a delay; if there was no improvement, or if there was further divergence, then the disorder was a deficit. In the case of long term problems, a delay hypothesis would predict that early emerging disorders would ameliorate with time, being replaced by other disorders in processes which occur at a later stage of development. In accordance with the developmental observations of Gesell (1952) and the theories of Piaget (1952), one might predict that the sequential emergence of disorders would be found first in factor 1, then factor 3, and finally in factor 2. Yet, an underlying deficit could also affect a variety of skills, which emerge developmentally, and an inconsistent deficit pattern might emerge. Here, the early-to-emerge disabilities would be retained and later ones would be added. Thus, although consistency exhibited by an individual over a period of years might suggest a deficit, inconsistency would not necessarily predict delay. A final discrimination among those exhibiting inconsistent patterns would in the end be determined on the basis of whether disorders were sequentially replaced or cumulated.

This assumption of amelioration or catch-up in the theory of developmental delay is contested by some. Denckla (1977) has pointed out that, because of their distorted educational experiences, it is unrealistic to expect that the skills of disabled individuals will eventually equal those of the normal group. Spreen (1976) also questions Rourke's decision to decide the lag-deficit issue on the basis of outcome, asserting that a lag "may persist or prevent the child from acquiring essential skills during critical periods of his development" (p. 455). Although it is difficult to see how a developmental delay theory can be proved or disproved without this crucial catch-up test, in terms of its educational implications the issue of catch-up may be relatively unimportant. If a lag cannot be overcome because it has persisted through a critical period, then for purposes of remedial interventions it must be treated as a deficit. If, on the other hand, a disorder which is a deficit can be adapted to and overcome, then it has the same optimistic prognosis as a lag. For educational purposes, it is important to know whether certain patterns of disabilities may be predicted to persist over the years of compulsory schooling, with others predicted to change sequentially, and yet others to change additively.

In summary, the foregoing review has suggested that, to date, the most fruitful attempts to discriminate subtypes within the learning disabled population have involved the use of verbal-performance score discrepancies on the WISC or WISC-R subscales. Although some researchers (Reed, 1967; Rourke, 1975) have noted that particular disabilities are associated with certain of these subgroups, and that the patterns of these disabilities vary with age, others (Neel, 1976; Wener & Templer, 1976) have failed to confirm the findings, either in terms of the associated characteristics or the age variations. The use of recategorized WISC factor scores which derive from the same subscales as the verbal-performance dichotomy, but which provide finer discriminations might help to refine the groups and clarify results. It is of particular importance for educational practice to determine from longitudinal data the course certain disabilities may take, to examine the possibility that time patterns reflect etiology and to assess the usefulness of WISC factor scores for the identification of types of learning disabilities in individuals over time.

Two main questions are pertinent:

1. Can factor score patterns over time be used to identify learning disabled subtypes?
2. Can the patterns be interpreted in terms of deficit-lag paradigms?

The availability of a group of school-verified, learning disabled children, all of whom had received three successive WISC/WISC-R assessments over a period of several years within a single school system catering to a relatively homogeneous population, made possible an attempt to answer these questions.

Method

The procedures used in this retrospective study of children described as long term disabled learners will be discussed under several headings: the school system from which the sample of students was drawn, the sample selection, the defining test and test procedures, the classification procedures for establishing the two contrasting groups, and the methods for data analysis.

The School System

The sample of long term learning-disabled students was obtained from one of the predominantly English language school systems on the Island of Montreal, which serves approximately 16,000 students in 23 elementary and 5 secondary schools. For a number of years, this system has operated two general types of special education programs for under-achieving students, full time and "free flow". The full time facility has provided space for approximately 275 such pupils per year. Access to these self-contained classrooms was determined, but not guaranteed, by evidence of academic retardation of at least two years as assessed by standardized achievement tests, school recommendation and parental consent. It was an implicit goal, not always achieved in practice, that no student spend more than two years in such a class. The free flow program provided part-time, small-group or one-to-one instruction with special education teachers on a regular basis for learning disabled students enrolled in regular, mainstream classrooms. Selection was primarily through a diagnosis of learning disability by psychometric assessment accompanied by recommendation of school personnel. No specific achievement discrepancy was specified for admission to this type of program, but the general criteria that achievement must be below that expected in terms of the child's mental age and that one or other of the WISC-R subscale IQ scores should be within the normal range were accepted. It was the policy of the school administration to require evaluation of all students after two years of intervention through the services of a special education teacher, whether in a full time or free flow arrangement. These assessments, supervised by the school psychologists, were done by qualified psychometricians, four of five of whom had been with the board since the inception of testing.

The system itself services a largely middle to upper middle class constituency which is considered to be highly mobile. In fact, school population is now declining rapidly due in part to the outflow of parents to other parts of Canada. As a result, there are records of children for whom several diagnostic assessments have been made, and for whom some special interventions have been carried out, but who have subsequently left the system, and therefore were unavailable for study.

Selection of Subjects

Sixty-seven students for whom a third assessment had been conducted between September 1977 and January 1979 were identified and found to be present in the school system. Of these, 11 were girls who were excluded to avoid the possible confounding effect of sex differences associated with learning disabilities (Witelson, 1977b). In accordance with the accepted definition of learning disabled, the usual exclusionary criteria were applied here. Children with diagnosed neurological or primary emotional impairment, uncorrected sensory defects, mother tongue other than English, and IQ scores that fail to reach 90 on at least one of the Wechsler subscales were excluded from the sample. Following Douglas and Peters (1979), children diagnosed as hyperactive were also eliminated. Sample size was thus reduced to 49.

All subjects had been initially referred because of problems in pre-reading or reading skills, with other academic difficulties frequently being listed as well. Although standardized tests were used in the appraisal of these skills, no one test had been used consistently at any given age. However, comprehensive diagnostic reports on all subjects following each assessment gave a general confirmation, on the basis of these tests, of underachievement in reading relative to mental age, as determined from a WISC/WISC-R assessment. Thus, since the group of 49 met the criteria of unexplained academic failure, as well as the other usual exclusionary requirements, the general term, learning disabled, rather than the more specific term, reading disabled, has been used to label them (Torgeson, 1975).

Test Characteristics and Diagnostic Procedures

Although variation existed in the instruments used for the biennial assessments, an evaluation with the WISC was an integral part of each procedure. Since 1974 this has been replaced by the WISC-R. In the investigation which follows, some assumptions about the equality of the two versions have been accepted. In this, the evidence of a number of studies (Berry & Sherrets, 1976; Covin, 1976; Hamm, et al., 1976; Kaufman, 1975; Swerdlik, 1977; Weiner & Kaufman, 1979) has been acknowledged, evidence which suggests correlations of about .85 between the composite scores of the two versions. Factor structure has also been found to be the same (Kaufman, 1975; Lombard & Reidel, 1978; Paal, Hesterly & Wepfer, 1979). It is true, there exists some evidence that the WISC-R may yield lower scores (Covin, 1976; Paal, et al., 1979, Schwarting, 1976; Tuma, Applebaum & Bee, 1979), but this discrepancy is significant only when the WISC-R is administered first. In no instance did this sequence occur in the present study.

In each version of the test, it is possible by grouping the appropriate subtests to arrive at a verbal IQ, a performance IQ and through a standardized weighting procedure a full scale IQ. Additionally, in the present investigation, the standardized subtest scores were recategorized for each individual on each of three successive assessments, using Bannatyne's 3 factors (Bannatyne, 1974). Factor 1, labelled the spatial factor, was derived from the sum of Block Design, Object Assembly and Picture Completion subtest scores. Factor 2, labelled the conceptual factor, was obtained from the sum of Vocabulary, Comprehension and Similarities subtests, and factor 3, not labelled in this study due to lack of naming consensus, was derived from the sum of the Digit Span, Coding and Arithmetic standard scores. It should be remembered that the standard scores for each subtest are equated, having a mean of 10 and standard deviation of 3, and are derived from the raw scores according to procedures described in the test manual (Wechsler, 1974), and factor scores in a total population would have a mean of 30 and standard deviation of approximately 7.5 (Lutey, 1977, p. 234). Since the same items are used cumulatively in each separate subtest, there is a general assumption that raw scores will rise with increasing age. Constant age progress, therefore, is indicated if the standard scores of an individual subject remain the same over time. Merely scoring higher numerically on a raw score may not be sufficient to reflect expected age-related progress. Similarly, an apparent decline in standard scores does not necessarily reflect regression, but rather failure to maintain expected age increases.

Classification Procedures and Data Analysis

Recategorization of subtest scores for each of the assessments was made. The lowest factor score (of three) on each assessment for each individual was named as the area of disability or weakest factor. Those children for whom the same factor was the weakest on each of the three assessments were deemed to show a consistent profile. Those for whom no single factor score was lowest on each of the three determinations were classified as inconsistent.

Initial analyses of the defining variables across the three assessments were carried out for the total group to determine if the sample corresponded to the traditional heterogeneous groups of learning disabled children described in the literature. Analyses of variance (BMDP-77; 1977) for repeated measures were then performed in order to compare the resulting subgroups in terms of their IQ and recategorized factor score characteristics. Multiple mean comparisons were made using the appropriate Duncan procedures (Kirk, 1968).

Results and Discussion

Individual scores and descriptive statistics for the group appear in Appendix A. Summaries of the various analyses of variance on the data are contained in Appendix B.

Total Group Measurements

Preliminary analyses for IQ and recategorized factor scores were carried out for the total learning disabled population to determine its comparability with other heterogeneous learning disabled groups as reported in the literature. In addition, it was hoped to provide information concerning age related changes since the measures had been obtained longitudinally. Average age at first assessment was 93.5 months with an average interval of 34 months between first and second evaluations, and 44 months between the second and the third (Table 2). Referral backlogs which accumulated with time probably accounted for the time disparity between assessments.

Table 2

Age and IQ scores over 3 assessments for the total disabled population, n=49

	Assessments					
	1st		2nd		3rd	
	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd
Age (months)	93.8	11.9	128.0	12.9	172.4	14.3
IQ Scores						
Verbal	96.5	10.4	93.6	9.0	92.3	8.6
Performance	100.6	11.5	100.8	11.9	100.0	12.2
Full Scale	98.6	9.7	97.2	8.9	95.5	8.7

Performance IQ scores were significantly higher than verbal IQ scores on each successive assessment as indicated by the significant verbal vs. performance effect $F(1,48) = 15.62$, $p < .0003$ and the non-significant verbal x performance x time interaction $F(2,96) = 2.63$, $p < .08$. That is, the well documented low verbal-high performance discrepancy was maintained with increasing age. Separate analyses for each subscale IQ score over time indicated that the verbal IQ scores declined significantly $F(2,96) = 5.88$, $p < .004$ while the performance IQ scores did not $F(2,96) = 0.19$, $p < .83$.

Full scale IQ score also declined significantly over time, reflecting the verbal score decline $\underline{F}(2,96) = 4.12$, $\underline{p} < .02$.

An analysis of factor score values for the group over time revealed highly significant factor score $\underline{F}(2,96) = 29.70$, $\underline{p} < .0001$ and factor score x time effects $\underline{F}(4,192) = 4.56$, $\underline{p} < .002$ (Table 2). Multiple comparisons of mean factor scores at each assessment using Duncan's procedure (Kirk, 1968) revealed that although factor 3 was the lowest factor on all three assessments, it was significantly lower than all the others on only the first and second assessments (Table 3). On the third assessment,

Table 3

Recategorized factor scores over 3 assessments for the total learning disabled population

	Assessments						
	1st		2nd		3rd		Grand
Factor	$\bar{x}$	sd	$\bar{x}$	sd	$\bar{x}$	sd	mean
1	31.2^{ab*}	6.4	31.2^{ab}	6.7	32.3^{a}	7.8	31.6
2	30.9^{ab}	5.8	28.8^{bc}	5.4	27.6^{cd}	5.0	29.1
3	26.1^{cd}	4.9	25.2^{d}	5.2	24.6^{d}	3.7	25.3
Grand mean	29.4		28.4		28.2		

* Means followed by the same letter are not significantly different $\underline{p} < .05$.

factor 3 was not significantly lower than factor 2, but it was significantly lower than factor 1. Factor 1 was significantly higher than factor 2 on the final assessment only. It can be observed that these effects were due to the decline with increasing age of the factor 2 score, the value on assessment three differing significantly from that on assessment one as well as to the numerical decline in factor 3 and numerical increase in factor 1. The decrease over time in factor 2 also contributed to the previously observed decline in the verbal subscale IQ scores. Neither increasing age nor time significantly affected level of performance on either factor 1 or factor 3 (Table 3).

The results from this particular sample of long term learning disabled subjects were generally supportive of previous cross-sectional research since low factor 3 scores and the pattern of descending order factor 3 < factor 2 < factor 1, predominated for the group as a whole when mean scores were considered for all 3 assessments. However, the decline in the factor 2 scores and variations in the hierarchical factor patterns suggest that attention must be paid to age range in research pertaining to factor score variables.

Subgroup Classification

The results of the first step in classifying the total learning disabled group into subtypes on the basis of area of weakness x consistency appears in Table 4 where area of disability or weakness (lowest factor score) was determined for each individual on each assessment. It can be seen that almost two-thirds of the individuals obtained their lowest scores on factor 3.

There was a slight tendency for the number of individuals with lowest factor 1 scores to decrease and for the number with lowest factor 2 scores to increase. This may be broadly interpreted as minimal support for the prediction that disabilities would be manifested first in those skills which emerge early (factor 1) with problems subsequently being found in the later emerging skills (factor 2).

Table 4

Frequency and proportion of lowest scores
for each factor on each of three assessments
for the total sample

	Lowest Recategorized Factor Score						
	Factor 1		Factor 2		Factor 3		
Assessment	n	%	n	%	n	%	Total[1]
1	8	16.0	8	16.0	34	68.0	50
2	7	13.7	11	21.6	33	64.7	51
3	6	12.2	13	26.5	30	61.2	49
Mean proportion		14.0		21.4		62.6	

[1] when two factor scores were equally low, both were tabulated.

The second step in the classification scheme was to determine consistency of area of weakness, that is, to see if it was the same individual who received the lowest scores on a particular factor on each successive assessment. Consistent disability patterns were maintained by N=29 (59%) of the subjects while N=21 (41%) displayed inconsistent or changing areas of disorder (Table 5). Lowest factor 1 scores were obtained consistently by only one subject; three subjects were consistently lowest on factor 2; twenty-five were consistently lowest on factor 3. Thus, the consistent group was overwhelmingly composed of individuals who obtained lowest scores on the third factor. Moreover, three-quarters (74.5%) of those individuals who had their weakness in factor 3 on the first assessment maintained that weakness over the years of compulsory schooling. Thus, consistency and

Table 5

Classification of consistent and inconsistent long term learning disabled subjects based on type of disability as measured by lowest recategorized factor scores on 3 successive WISC/WISC-R assessments, n=49

	Consistent Disability N = 29 (59%) Lowest Score			Inconsistent Disability N = 20 (41%) Lowest Score		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
	no. of individuals*					
Assessment						
1	1	3	25	7	5	9
2	1	3	25	6	8	8
3	1	3	25	5	10	5

* Total number of individuals exceeds 49 on the first and 2nd assessments, reflecting that in instances when 2 factor scores were equally low for a particular individual, both were counted.

factor 3 are associated.

When the distribution of lowest scores by factor was analyzed for the inconsistent group using the Chi-square statistic, it was found that the distribution did not differ from chance on the first assessment ($\chi^2 = 2.67$, $p > .30$), or second assessment ($\chi^2 = 0.67$, $p > .70$), although the distribution on the third assessment was significant ($\chi^2 = 5.56$, $p > .05$). The expectation that the inconsistent group would clearly reflect a sequentially changing pattern of weaknesses (factor 1, factor 3, factor 2) once the consistent group was removed is not strongly supported for the pattern is similar to that found in the total group.

Although four subgroups emerged under the disability x consistency classification scheme, only two, one with consistently lowest scores on factor 3 (N = 25) and one with lowest scores changing from one occasion to the other (N = 20), were numerically important. Two groups, those consistently lowest in factor 1 (N = 1) and factor 2 (N = 3) respectively, were considered to be too small for subsequent analyses. Thus, the group with scores consistently lowest on factor 3, hereafter called Consistent Factor 3, and the group with variable lowest scores, hereafter called Inconsistent, formed the subtypes for which further comparisons were made.

Comparison of Consistent Factor 3 and Inconsistent Subgroups

Age and IQ scores. Summaries of the analyses of variance for data on subgroups appear in Appendix C. Age differences between groups at each of the three assessments times were minimal (Table 6). A t-test comparison for age at initial assessment $t(43) = 0.78$, $p < 0.44$ revealed no significant group differences which suggested that the early manifestation of learning problems was not more characteristic of one group than the other.

Table 6

Mean, Age and IQ values for Consistent Factor 3 and Inconsistent Subgroups, over 3 assessments

	Consistent Factor 3		Inconsistent	
	Age (months)			
Assessment				
1	95.1	11.5	92.3	12.8
2	128.6	13.3	127.3	12.7
3	172.9	12.7	171.7	10.4
	IQ Full Scale			
1	101.0	10.0	97.0	9.8
2	100.0	9.6	95.1	8.2
3	98.7	8.6	93.2	8.2
Overall Mean	99.9	9.4	95.1	8.4
	IQ Verbal			
1	96.6	9.1	96.8	11.2
2	95.4	8.1	92.3	9.9
3	93.8	8.6	91.6	8.8
Overall Mean	95.3	8.6	93.6	9.9
	IQ Performance			
1	104.4	11.9	97.5	9.7
2	104.0	13.0	99.0	9.7
3	103.8	11.6	96.3	11.0
Overall Mean	104.0	12.2	97.6	10.1

Full scale IQ scores declined over time in both groups $\underline{F}(2,86) = 3.51$, $\underline{p} < .03$ and were significantly lower for the inconsistent group $\underline{F}(1,43) = 4.28$, $\underline{p} < .05$. It is of interest to note, however, that had the two groups been compared only at the time of initial assessment, or only at the time of the second assessment, the full scale IQ differences would not have been judged significant. Separate t-test comparisons at the three age levels, $\underline{t}$ (43) = 1.41, $\underline{p} < .164$; $\underline{t}$ (43) = 1.88, $\underline{p} < .07$; $\underline{t}(43) = 2.20$, $\underline{p} < .03$, respectively, indicated that the two groups would have been found significantly different in IQ on the final assessment only. Thus, at age 8, and at age 11, there would have been no significant differences, and throughout the whole period from age 8 to 14, all the children in the learning disabled sample would have had IQ's of above 90 and by the usual convention would have been seen as falling within the normal range of one probable error from the mean (i.e. from 90 to 110 IQ).

Subscale IQ scores. When verbal and performance scores were analyzed together in a 2 (groups) x 2 (subscale scores) x 3 (age or time) repeated measured analysis of variance, the significant subscale IQ score effect, $\underline{F}(1,43) = 17.75$, $\underline{p} < .0001$ indicated that performance scores were significantly higher than verbal scores (Table 6). The non-significant factor x group effect $\underline{F}(1,43) = 2.44$, $\underline{p} < .125$ indicated that this was true for both groups. Thus, the verbal-performance discrepancy scores vary in the same direction in both groups.

There was a trend $\underline{F}(2,86) = 2.83$, $\underline{p} < .06$ for time to affect the combined verbal and performance scores. However, this effect was more meaningfully interpreted when the full scale IQ score, a weighted combination of the subscale scores, was analyzed and reported in the previous section.

Table 7

Comparison of recategorized factor scores on each of 3 assessments for Consistent Factor 3 and Inconsistent groups

	Groups			
	Consistent Factor 3		Inconsistent	
Assessments	$\bar{X}$	sd	$\bar{X}$	sd
	Factor 1 (spatial)			
1	33.6	6.2	29.3	5.9
2	33.9	6.8	28.8	5.5
3	35.7	6.1	28.5	6.5
	Factor 2 (conceptual)			
1	32.5	4.6	29.8	6.7
2	30.8	5.0	27.3	5.3
3	28.8	4.7	26.8	4.9
	Factor 3 (unlabelled)			
1	24.5	4.7	27.3	3.9
2	23.3	4.7	27.3	5.4
3	22.8	2.9	26.4	3.4
Overall Mean	29.53		27.91	

Table 8

Effects of time or age on factor scores, Consistent Factor 3 and Inconsistent groups combined

	Factors		
Assessment	1	2	3
1	31.6[a*]	31.3[a]	25.7[c]
2	31.6[a]	29.2[ab]	25.0[c]
3	32.5[a]	27.9[b]	24.4[c]

* Mean values followed by the same letter are not significantly different, p = .05, Duncan Multiple Range procedure.

Although the verbal scores declined more than performance scores, time x subscale effects were non-significant $F(2,86) = 2.14$, $p < .12$ as were the time x subscale x group effects $F(2,86) = 1.03$, $p < .36$. All this suggests that on the basis of these analyses, verbal and performance score comparisons were not particularly useful in defining the groups.

Recategorized factor scores. For purposes of comparison, Consistent Factor 3 and Inconsistent subgroups scores for all three factors were analyzed together using a 2 (groups) x 3 (factors) x 3 (assessment time or age) repeated measures design. The group effect $F(1,43) = 2.56$, $p < .12$ was not significant, indicating that the overall mean of the factor scores across all assessments did not differ significantly between groups (Table 7).

The non-significant time x group and time x factor x group interaction effects along with the significant time x factor effect suggests that the influences of time or increasing age on the factor scores was the same for each group. Factor 2 declined over time in both groups (Table 8). Although factor 1 scores increased over time in the Consistent Factor 3 groups and declined in the Inconsistent group, the interaction was not significant. It appears, then, that the sequential changes in lowest factor score in the Inconsistent group were of an additive nature. The factor 3 scores remained relatively stable in both groups over time, the decline in both groups being non-significant. Of primary interest, however, are the significant group interaction effects. The significant group x factor interaction $F(2,86) = 28.28$, $p < .000$ was explored using the Duncan procedure, which demonstrated that the groups differed significantly as to level of performance on both factor 3 and factor 1 (Table 9).

Table 9

Comparison of means of recategorized factor scores for Consistent Factor 3 and Inconsistent groups

Factors	Consistent Factor 3	Inconsistent
1	34.40[a*]	28.82[bc]
2	30.69[b]	27.93[bc]
3	23.50[de]	26.97[c]

* Means followed by the same letter are not significantly different, $p <$ .05, Duncan's Multiple Range Procedure.

The Consistent Factor 3 group was significantly lower than the Inconsistent group on factor 3 and significantly higher on factor 1, while the numerical differences for factor 2 were not significant. These factor score relationships over successive assessments are depicted in Figure 2 where levels of performance are also shown in relation to average levels in a total population derived from the standardization data (Lutey, 1977, p. 234). These data show standard deviation values of 7.5 for factors 1 and 3 and 7.8 for factor 2. Ranges for average scores are indicated by the shaded zones.

It should be noted that the significant group differences in level of functioning on factor 3 were not a necessary outcome of the selection procedure since the classification scheme was based on lowest factor score relative to other factor scores within each individual. It was, therefore, entirely possible for an individual to have a consistently lowest score on factor 3 that was nevertheless higher than the inconsistently low factor 3 scores of other individuals, if these individuals displayed yet lower scores

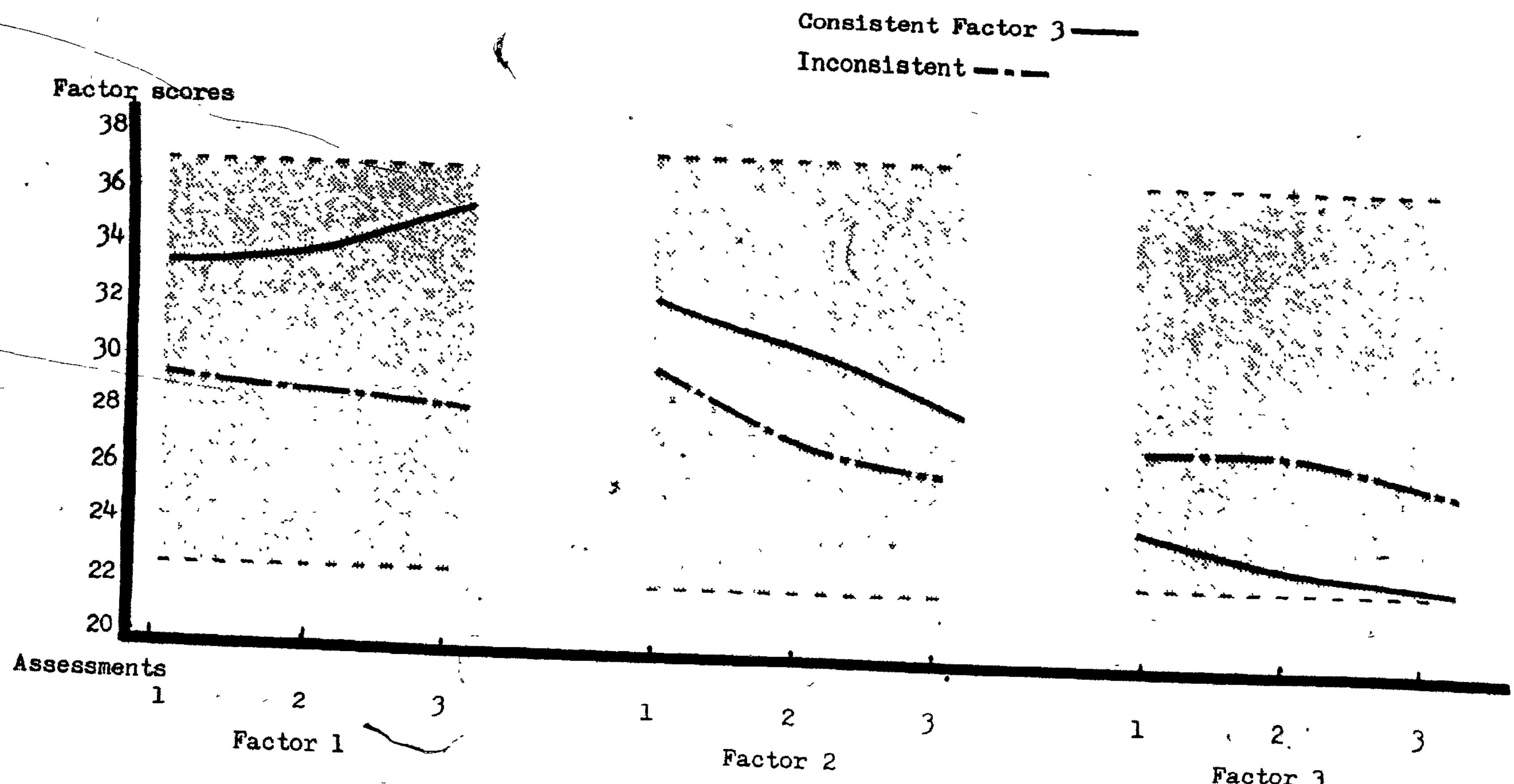


Figure 2. Comparison of WISC/WISC-R Recategorized Factor Scores for Consistent Factor 3 and Inconsistent groups over 3 assessments with shaded areas showing normal range of scores.

on one of the other factors.

Means of each of the 3 factors for the Consistent Factor 3 group were significantly different from each other (Table 9). In the Inconsistent group, however, none of the factor scores differed significantly from each other. This contrasting hierarchical factor relationship is clearly depicted in Figure 3 where it can be observed that the Consistent Factor 3 group was characterized by large discrepancies between factor scores but the Inconsistent group was not. These discrepancy patterns were characteristic of the groups on the first assessment and it should be noted that average discrepancy between factors 1 and 3 in the Consistent Factor 3 group equalled or bettered the significant 9-point level (Wechsler, 1974) on all assessments, being 9.1, 10.6 and 12.9 respectively. In the Inconsistent group, the disparities (2.0, 2.5 and 2.1) were non-significant.

It was possible that the factor score discrepancy patterns for the group within each group did not replicate the discrepancy patterns for the group as a whole. This could be particularly so in the Inconsistent group where varying individual factor score patterns could cancel out one another. Therefore, following Ackerman et al. (1976), disparity between factor scores for each individual profile was examined, with caution being exercised to ensure that the differences from a mean clearly exceeded the standard error of the mean ($S.E._m$) of the three subtests comprising each factor. In this case, if the true score is to be found within a range of 4 to 5 points from the obtained score (Wechsler, 1974, p. 29), then a reliable difference between factor scores must exceed nine score points. Using this standard, 65% of the protocols of the Consistent Factor 3 group showed significant discrepancies while 67% of the Inconsistent group did not. It appears that,

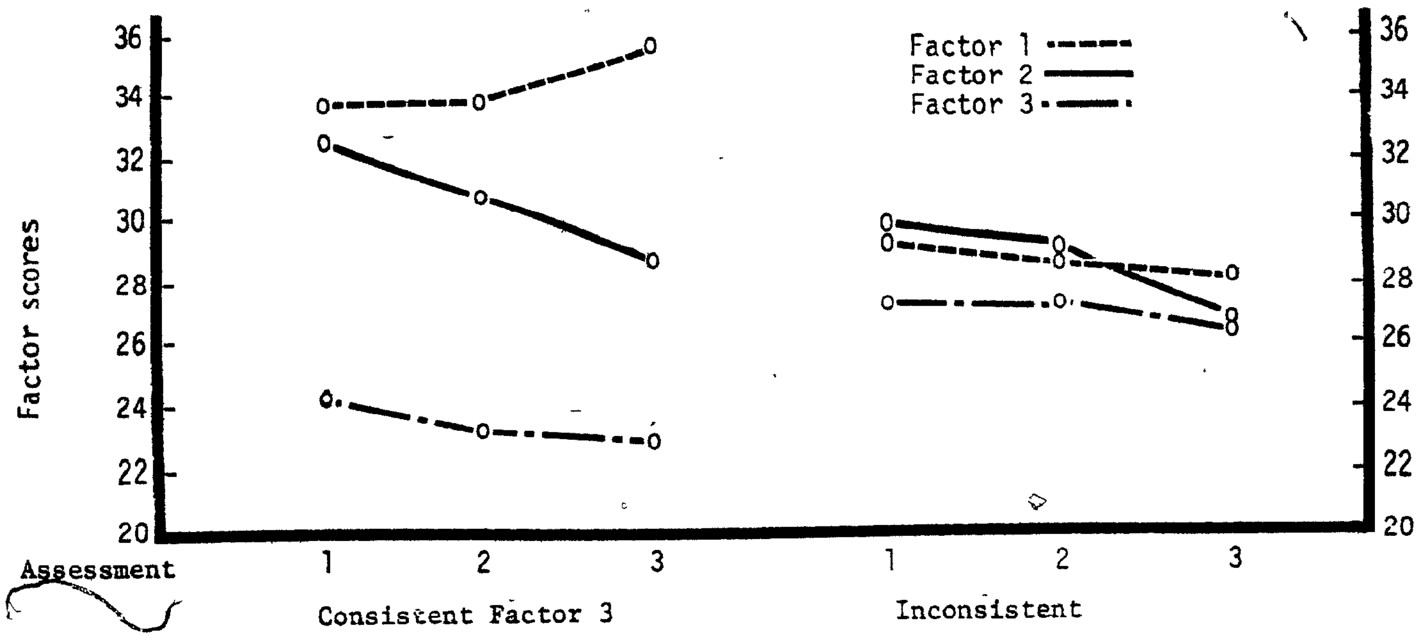


Figure 3. Comparison of group mean factor scores for Consistent Factor 3 and Inconsistent groups on three consecutive assessments.

for the most part, factor score discrepancy or the lack of it, which characterized the Consistent and Inconsistent groups respectively was also reflected in the protocols of the individuals within each group. The presence of these discrepancy patterns as a result of a classification based on consistency x disability is of particular interest since the subgroups so formed may be placed within the same context as subgroups defined on the basis of Wechsler subscale IQ patterns, with factor 1 representing the performance scale and factor 3, being largely composed of verbal subtests, representing the verbal scale.

Comparisons with Able Learner Patterns

Although it would have been of interest to compare these patterns of discrepancy and consistency among derived factor scores from the Wechsler scale for a population at similar age levels over time, no such data were available, and in fact, may not exist. The best available data for contrast as to general level of factor score performance is that from the WISC-R standardization sample. The range of average scores, that is scores ±1 standard deviation from the mean of 30 were depicted in Figure 2. All factor scores of both groups were within normal limits, although the factor 3 scores of the Consistent Factor 3 group approached the boundary.

Do able learners exhibit discrepancies in factor patterns? It is not possible to determine this from the standardization data. However, Ackerman et al. (1976) presented evidence to indicate that successful learners have balanced cognitive abilities. Although factor score data were not directly presented in their paper, and can only be estimated from graphs, they reported that adequate learners who did display disparate patterns generally had superior factor 1 and 2 scores along with average factor 3 abilities.

Inadequate learners with disparate factor scores tended to have below average factor 3 scores. Rugel (1974) summarizing evidence from many studies also indicated that low factor 3 scores did not characterize the WISC protocols of able or normal learners. Moreover, data presented in chapter 3 of this investigation show that on a single assessment at age 13.7 years, able learners drawn from the same population as the disabled learner sample in this study displayed non-discrepant factor patterns (Table 10, Chapter III).

On the basis of this information, perhaps one might conclude that significant factor score discrepancies, coupled with low factor 3 scores may be characteristic of inadequate learners. If this were so, then, the Consistent Factor 3 groups would conform to the typical disabled learner pattern, but the Inconsistent group would not.

Relationship of Factor Score Trajectories to Rourke's Paradigms

Having shown that factor score patterns over time can be used to identify learning disabled subgroups which might have potential educational, theoretical and clinical significance (questions to be examined further in study no. 2), it is now possible to see whether these patterns might be interpreted in deficit-lag terms. To do this, data provided by Wechsler in his Manual (Wechsler, 1974) must be utilized in order to proceed backwards from the standardized equivalent scores given at each age from 8 to 15 to find mean raw scores for the individual subtests and hence by summation for the three factor scores. In Figure 4, these data are provided graphically as trajectories for each factor separately and may be compared mentally with the trajectories hypothesized by Rourke in Figure 1.

For the standardization population, factor 1 scores show a steep initial incline to age 9 followed by smaller growth increments that decrease

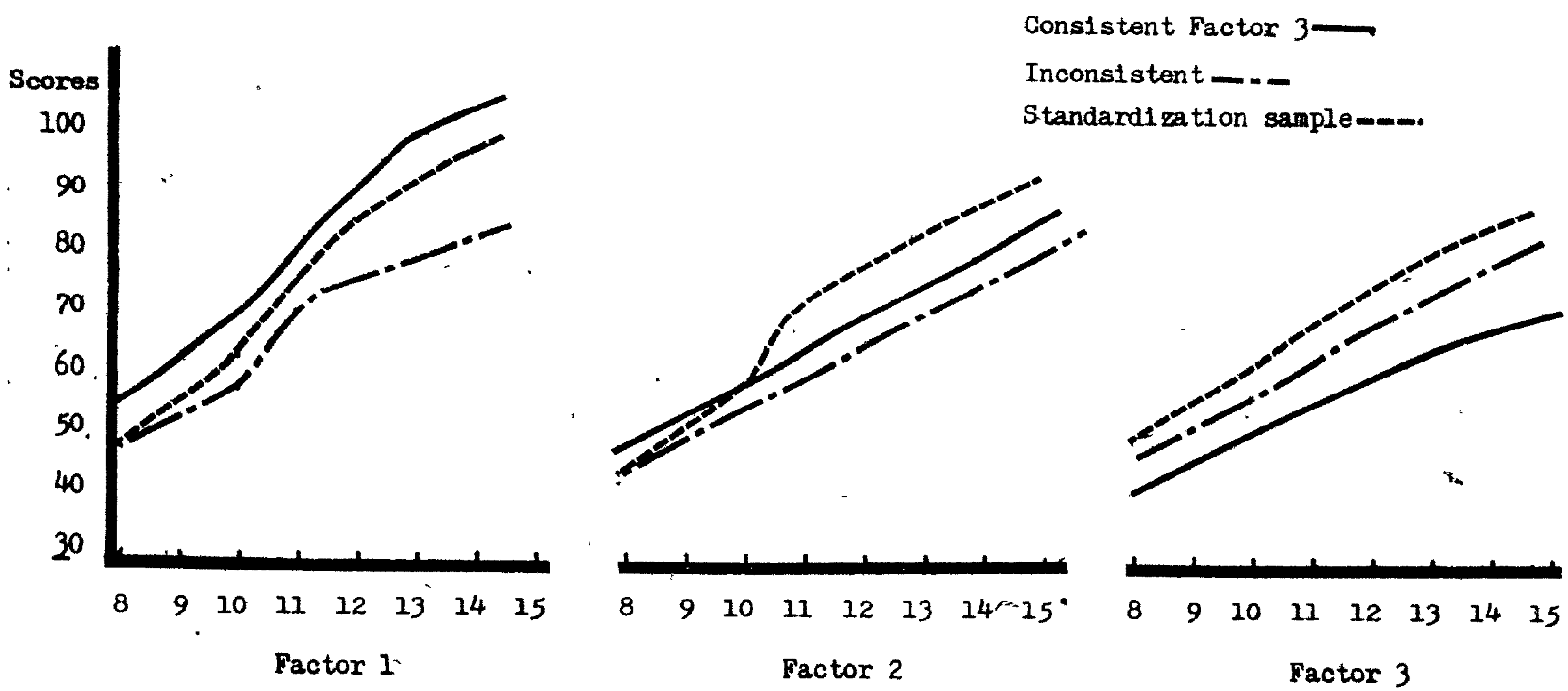


Figure 4. Comparison of WISC/WISC-R raw factor score growth curves for Consistent Factor 3, Inconsistent, and WISC/WISC-R standardization populations.

still further at age 13, being reminiscent of an early maturing skill illustrated by Rourke's type 1 paradigm. Factor 2 scores, after an initially gentle growth, take a spurt between ages 10 and 11 followed by a continuous but slower growth. This curve may be similar to type 3 with spurts and plateaux, or alternately to type 6, a late emerging skill. Factor 3 depicts even growth increments over the age span.

The curves obtained for the Consistent Factor 3 and Inconsistent groups have also been plotted on the basis of the three test assessments over the interval from approximately age 8 to 14. The limitation of only three fixed points, compared with the seven derived from the Wechsler population makes comment on growth patterns rather speculative.

For the two disabled groups, on factor 1, the Consistent Factor 3's maintained a high parallel level of performance relative to the standardization sample. The Inconsistents were parallel to the standardization population over the early years with a lower growth rate over the final years. On factor 2, both Consistent Factor 3 and Inconsistent groups failed to exhibit the growth spurt apparent in the standardization pattern between ages 10 and 11. This failure to replicate a late growth increment when skills had been initially equal, or nearly equal, could suggest a delay in the late emerging skill, or, perhaps a deficit if there were no eventual spurt. Catch-up remains a possibility that only testing at a still later date could substantiate. On the other hand, it should be noted that subtests comprising the factor 2 cluster are considered to be particularly susceptible to educational influences (Glasser & Zimmerman, 1967) and so it may be that the failure to "spurt", since it occurred in both groups, is related to their similar but relatively abnormal schooling experiences.

On factor 3, approximately equal linear curves are evident in both groups with that for the Consistent Factor 3 group showing a slow but steady decline in growth rate in comparison with both the Inconsistent and standardization groups. The patterns are reminiscent of Rourke's type 4 paradigm, and if true would extend his findings from age 11 to age 14. The lower initial score of the Consistent group and the slowly widening gap in comparison both with the Inconsistents and the Wechsler populations might be more suggestive of a deficit. In all cases, the paucity of testing occasions and the inability to proceed beyond age 16 prevent firmer conclusions from being reached. Thus, while the subgroups derived from factor scores show promise for examination of psychological processes which might be associated with such subgroups, the results of the inquiry in terms of lags and deficits has been far from clear cut.

Summation of Results: Study No. 1

A suburban school board, catering to a largely English-speaking, middle class population had maintained a system of remedial education for children labelled as learning-disabled, a local synonym for children who, despite adequate intellectual, social, emotional and medical backgrounds, have learning, particularly reading, problems. In the process, and as part of school policy, educational and psychological determinations of all such children were carried out at intervals of not less than two years. This made it possible to find remaining in a system with a declining enrolment, 67 children for whom three such determinations had been made by qualified psychometricians who had used either the WISC, or in later testing, the

WISC-R, along with standardized tests and teachers' reports in making initial and confirmatory diagnoses. Each child had remained in the school system, and by means of attendance within special classrooms or regular classes with "free flow" help, had participated within a supportive, presumably ameliorative school environment.

Questions have been raised in the literature as to underlying causes of long term learning retardation, in general of a lag or deficit in the psychological processes presumed to be related to the areas of disability, and of the possibility of shedding light on the question by looking at the consistency of disability patterns over time. Much attention has been paid to the interpretation of subscale scores from the WISC or WISC-R tests, in particular the verbal versus performance reporting of IQ scores. As a means of identifying the area and disability, it had seemed desirable to go beyond this dichotomy and to utilize instead the results of factor analyses of subtests incorporated in the Wechsler scales. Thus, factor scores were derived, the consensus being that factor 1 was spatial in nature, factor 2 was conceptual, while factor 3, which remained unlabelled, loaded highest on the three subtests of coding, arithmetic and digit span. It was then found that giving factor scores for each testing occasion for each child enabled us to find a group of 29 boys whose factor score patterns behaved in a consistent manner, that is, they had the same lowest factor of the three factors on each test occasion. Of these 25 (51% of the total sample) were even more distinguishable in that each was lowest on factor 3. This procedure enabled a comparison to be made with the remaining boys whose factor scores were such that a different factor might yield the lowest factor score from one occasion to another. These were labelled as

Inconsistents in contrast to the 25 above now referred to as Consistent Factor 3.

Comparisons as to age and WISC variables suggest that the two groups so defined differed, not only as to level and consistency of performance on factor 3 over time, but also on factor 1. Moreover, it was observed that significant factor score discrepancies characterized the patterns of the Consistent Factor 3 group, but not of Inconsistents. Although groups did not differ as to age at which learning disabilities were first identified, nor as to level of IQ on the earlier two assessments, Consistent Factor 3 subjects did appear to score significantly higher than the Inconsistents on the final assessment, although mean scores remained within that range (90-100) of IQ broadly defined as of "average intelligence".

Contrasts over time between children classified as learning disabled, with the same socio-economic background, the same first language, and the same educational treatment (insofar as schools provide such treatments), and data derived from populations used by Wechsler in his test standardization should have enabled us to throw some light on the deficit/lag nature of their learning retardation. In terms of the seven paradigms of Rourke (1976), one could speculate that the pattern of disability for the Consistent Factor 3 group seemed akin to Rourke's paradigm 4, which could be indicative of a deficit or a lag. Only evidence from older ages, as well as at more frequent intervals for younger ages would lead to confirmation or rejection. Both groups showed a decline in conceptual (factor 2) scores over the tests, and this could be reminiscent of paradigm 6, a late emerging deficit. Contrary to expectations, no evident support could be marshalled for a pattern of sequentially emerging disabilities in the Inconsistent group, as predicted by a maturational delay, nor was there evidence of "catch-up" or significant improvement in early-to-emerge disorders. Deficit diagnoses on factors 2 and 3 must await testing at still older ages.

CHAPTER III

CHARACTERISTICS OF CONSISTENT FACTOR 3 AND INCONSISTENT SUBGROUPS: STUDY NO. 2

The second stage of this study is an attempt to further define the two main subgroups differentiated on the basis of WISC/WISC-R factor patterns during stage 1. These subgroup distinctions are of general interest if they can be shown to possess diagnostic relevance or to contribute in a more specific way to our understanding of the nature and causes of learning disabilities. One way to demonstrate such significance would be to show that the groups differ in terms of disorders in the psychological processes currently hypothesized to underlie learning failure. Moreover, if the differentiating psychological processes could be shown to be related to low level of functioning on factor 3 or to factor score discrepancies, then the classificatory and diagnostic value of the WISC/WISC-R would be considerably enhanced.

The Consistent Factor 3 group which is homogeneous as to lowest factor, and so perhaps to dysfunction, forms the majority of the original population and is of central concern. An attempt has been made to compare them with the Inconsistent group which is of the same age, is drawn from the same school population, has had learning problems over a similar extended period of time, and has not differed from them in any systematic way insofar as educational treatments have been concerned. There are certain advantages to this use of a second learning disabled group for comparative purposes when searching for causes of learning failure. Torgesen (1980) has pointed out that abnormal educational experiences can create dysfunctions as well as result from them; a psychological process disorder may be the product rather than the cause of failure. However, if two disabled learner subgroups can be differentiated on the basis of a disorder in a particular psychological process, even though having had highly similar educational histories, then that process disorder may more logically be viewed as contributing to, not resulting from, aberrant learning experiences. Emphasis on such subgroup comparisons also allows for the use of measuring instruments with basal and ceiling levels that are restricted to the range of performance found within the disabled population. This, in turn, can minimize the effects of boredom and fatigue occasioned by the necessary extension of the test range to reduce ceiling effects in the able learners.

An examination of the literature regarding the relationship of learning problems to WISC/WISC-R Factor 3 scores indicated the direction for further study. First, there were the suggestions of Cohen (1952) who initially referred to factor 3 as representing "freedom from distractibility", only later to change the interpretation to that of "memory" (Cohen, 1955), before returning to his original explanation (Cohen, 1959). Kaufman (1975) has also preferred the freedom from distractibility label, as have Keough and Hall (1974), although under a slightly different name, attention-concentration. Others (Osborne & Lindsey, 1967) have defined it as numerical ability; still others have called it the anxiety triad (Lutey, 1977). A sequential memory interpretation, originally suggested by Bannatyne (1968) has recently gained favor, having been adhered to by Ackerman, Dykman, and Peters (1976), Smith et al. (1977), and Vance and

Singer (1978). Rugel (1974a), following his comprehensive review, has suggested that low factor 3 functioning could probably reflect both or either sequential memory and attentional problems.

In addition, however, it must be acknowledged that it is not only low factor 3 functioning that distinguishes the Consistent Factor 3 group. It is also characterized by disparity among factor scores while the Inconsistent group is not. It may well be that the imbalance between factors 1 and 3 determines consistency and is, therefore, of as great an importance as low factor 3 scores alone. Since factor 1 subtests are more likely to require information processing in the right hemisphere, while, correspondingly, left hemisphere processing is more likely to be involved in the material of the factor 3 subtests, the possibility suggested itself that factor score disparity patterns in the two groups might be related to different patterns of hemisphere organization.

There is ample evidence from the literature comparing normal and disabled learners to implicate poor serial memory (Benton, 1975; Torgesen, 1975; Vellutino, 1979), lack of attentional selectivity (Ross, 1976; Vellutino, 1979), and lack of hemisphere specialization (c.f. Benton, 1975) in reading/learning problems. Thus, the entire Inconsistent subgroup between the ages of twelve and a half and fifteen and a half, and an equal number randomly chosen Consistent Factor 3 subjects were compared with respect to these three variables, the performance of able learners being explicated in a general way by administering the same test measures to an able learner group drawn from the same school population. Prior to reporting this series of experimental investigations, the abundant literature concerning the development of these variables in the normal learner populations, and the evidence concerning differences between normal learners and heterogeneous learning disabled groups will be surveyed to provide a rationale for measurement procedures and a context for the interpretation of the subgroup differences.

Review of Relevant Research

Research Pertaining to Selective Attention.

Attention is an inferred construct and therefore difficult to define and measure. There appears to be a variety of interrelated aspects and, as yet, no common agreement in the literature on a taxonomy for the term. Although it is apparent that many authors who use the label "attention" are talking about one of the several aspects of it, it is also true that at times they may be referring to the same aspect, although using different terms. Various researchers have identified different components of the attentional process. For example, Dykman, Ackerman, Clements and Peters (1971) defined four aspects: alertness, stimulus selection, focusing, and vigilance. VanHover (1974), representative of the group concerned with physiological measures, has proposed three relevant components: orientation, sustained attention, and internal attention, each characterized by different patterns of electromyographic responses. Posner and Boies (1971), using an information processing model, have identified three empirically separable aspects: alertness, selectivity, and processing capacity. Moray (1970) has suggested that there may be as many as seven different facets.

An analysis of attentional models in relation to the classroom situation, where a child must not only effectively direct but also maintain his attention to pertinent stimuli, suggests that, from an educational vantage, attention may be usefully viewed as involving the two main aspects proposed by Berlyne (1970), intensive and selective. Intensive attention has to do with how much attention a person is giving to the stimulus field as a whole. It includes the concepts of alertness or arousal which is the readiness to attend to stimuli from moment to moment, and of vigilance which refers to ability to detect signals over an extended period of time. Selective attention on the other hand has a directional aspect and is concerned with how the attentional capacity is distributed among various elements of a stimulus field. It includes the notions of achieving a focus and resisting distraction from it. Presumably, it is this selective aspect of attention to which the various authors (Cohen, 1959; Kaufman, 1975; Keough & Hall, 1974) are referring when they suggest that factor 3 scores on the WISC-R are an index of freedom from distractibility, and is therefore the aspect of interest to this investigation.

The nature and importance of selectivity in attention is explained by theories based on filter models first explicitly proposed by Broadbent (1958). According to his theory, filtering or selectivity is necessary because of the limited processing capacity of a single channel system. Although this model has been variously adapted by subsequent researchers (Treisman, 1969; Deutsch & Deutsch, 1963; Norman, 1968), the central notion has remained intact.

Any review of the literature relating selective attention to learning disabilities is made difficult not only by the confusion surrounding the attentional labels but also by the diversity of instruments and procedures purporting to measure selectivity and by the inconsistency of the terminology used to refer to the children under study. In relation to the latter problem, the terms brain-damaged, minimal brain dysfunction, hyperactive, reading retarded, underachiever, and learning disabled have frequently been treated synonymously by researchers. However, it is proposed to confine this summary to studies which concern children who, from the available descriptions, appear to conform to the usual definition of learning disabled, that is, those who experience difficulty in the acquisition of academic skills, chiefly reading, despite adequate intellectual, emotional characteristics and social and educational advantages (Kirk, 1962).

For the purposes of this review, tests which required the subject to select or respond to relevant stimuli in the presence of irrelevant background cues were considered to be measures of selective attention. Within this parameter, two main types of studies concerning selective attention can be identified in the literature: those measuring differential effects of distraction on task performance, and those measuring incidental learning. In the former group of studies, susceptibility to distraction has been assessed by relative deterioration in task performance under conditions of distraction, as opposed to non-distraction. The distractors may be proximal to or even embedded in the main task or may be quite separate from or distal to it. The assumption is that the distracting stimuli capture the single attentional channel of susceptible subjects, thereby interfering with the performance of the task. Decrements in task performance are presumed to be indirect measures of the amounts of distracting stimuli processed. In the incidental learning studies, a direct measure of the amount of incidental information processed or retained is obtained. Subjects are instructed to acquire designated information and to ignore the incidental or extraneous stimuli which is presented along with it. Measures of retention of both the central (designated) and of the incidental (extraneous) information are obtained. Selectivity, or resistance to distraction, is presumed to exist when central retention is high and incidental recall is low.

Studies under conditions of differentiating distraction. Investigations under this rubric may well be classified according to the modality used, chiefly visual, as with the Stroop test of embedded figural material, and auditory as in the Wepman Test. Sometimes a more direct approach is made on reading itself under differing conditions of distractibility.

The Stroop Word-Color Test (Stroop, 1935) has a non-distraction phase in which subjects name the colors of rectangles and a distraction phase in which the colors are overprinted with other color names. The subject is required to ignore the printed word and respond by actual color. This test was used by Silverman, David, and Andrews (1963), who found longer response latencies and more errors with underachievers than achievers, but since the latter were significantly older, results must be considered questionable.

Variants of this procedure were also used by Alwitt (1966), who found normal and retarded readers to be similarly distracted by the test conditions and by Santostephano, Routledge, and Randall (1965), who, having eliminated the reading requirement by substituting the naming of colors of pictures and fruits in which the colors were inappropriate or contradictory, found the reading disabled to be more distracted than controls by the inappropriate colors. On another version where peripheral line drawings were used as distractors, Santostephano et al. (1965) noted no unfavorable effects for either group.

The embedded figures component has entered in the work of Keough and Donlon (1972), who compared two groups of learning disabled subjects (mild and severe) with the age norms for Witkin's rod and frame test (Witkin, Dyk, Faterson, Goodenough & Karp, 1962). Both groups of learning disabled were more adversely affected by irrelevant cues than normals. Sabbatino and Ysseldyke (1972) also differentiated learning disabled students into two groups (reading disabled and others), and gave the Bender Gestalt test (Bender, 1938) under usual procedures and again with designs embedded in an extraneous background. The two disabled groups did not differ from one another on the standard condition, but the poor readers were inferior to the others under the distracting conditions. Elkind, Larsen, and van Doornick (1965) also used an embedded figures task and found that their sample of disabled elementary school subjects made fewer correct discriminations of the relevant figures than controls. No non-distraction comparison was used, however.

Other studies have reported results when distractors and tasks are auditory. Lasky and Tobin (1973) studied the effects of white noise and auditory linguistic messages on the ability of first grade learning disabled children and normal controls to respond, orally and in writing, to verbal questions and to make a written response to written material. They found no differences between groups in the white noise condition which has been reputed to act as a buffer (Hallahan, 1975). The performance of the learning disabled group was adversely affected by the linguistic message while that of the normal group was not.

Nober and Nober (1975) administered the Wepman Test of Auditory Discrimination (Wepman, 1958) to learning disabled children and their normal controls at the grades 4 to 6 level in a quiet non-distracting setting and in a classroom setting where background noise was provided by a tape-recorded sound. The learning disabled group performed more poorly in the non-distracting setting, and while both groups performed more poorly under noise conditions, the learning disabled group was no more affected by this peripheral distraction than their normal controls.

Two studies have looked directly at the effects of distraction on reading skills. Samuels (1967) taught a group of pre-first and first graders, who were divided into good and poor readers, to discriminate words. Poor readers were more affected by descriptive pictures than good readers. Willows (1974), using a sample of good and poor readers at the sixth grade level, found that when red extraneous words were printed between the lines of a story the oral reading performance of poor readers was affected differentially by these distractors. They took longer to read the paragraphs and made more errors.

Taken as a whole, these studies seem to suggest there is an increased distraction effect for disabled as compared with normal learners, particularly if the extraneous cues are embedded within or proximal to the relevant stimuli. This appears to be true over a broad spectrum of tasks, in both auditory and visual modalities across a wide age range.

Further support for a developmental trend in selectivity comes from other studies still within the central-incidental paradigm, but using various devices such as visual discrimination and transfer (Crane & Ross, 1967; Siegal & Stevenson, 1966), reaction time (Pick, Christy & Frankel, 1972), a naturalistic film plot (Hale, Miller & Stevenson, 1968), or card sorting (Deikel & Freedman, 1976). Similarly, when incidental learning procedures have been carried out in the auditory modality using a dichotic listening task (Maccoby, 1967; Maccoby & Konrad, 1966, 1967; Hallahan, Kauffman & Ball, 1974a; Doyle, 1973), the developmental trend in central versus incidental learning has been confirmed.

From this background of general developmental findings, it is now possible to examine the results of these tasks comparing normal and disabled populations, and to explore such questions as: Do learning disabled children have poorer selective attention than normal learners? Do different strategies exist within these populations for dealing with central versus incidental information? Hallahan, Kauffman and Ball (1973) studied a small sample of 10 low achievers and an equal number of normal controls at the grade 6 level. Using a serial order presentation of the Hagen task in which the number of items varied from 4 to 6, they found no significant differences in incidental recall but they did find a significant difference in central recall in favor of the achievers. The central and incidental scores were negatively and significantly correlated in the higher achievement group but were positively correlated in the low achievers. Thus, although both groups processed the same amount of irrelevant information, the authors interpreted their results as support for the hypothesis of poorer selective attention in the underachievers on the

the assumption that higher central scores in the normals were the result of the giving up of incidental information in favor of the acquisition of relevant material.

Tarver, Hallahan, Kauffman and Ball (1976) used a similar serial order presentation of a 7-item version of the central incidental task to study the development of selective attention and rehearsal strategies in learning disabled boys. In the first experiment, these researchers compared a group of 8-year-olds to a group of normal controls. As with the earlier Hallahan et al. (1973) study, incidental recall did not differ significantly between groups but the normals recalled significantly more central information. Correlations between central and incidental recall were non-significant but were interpreted as support for the notion of inferior selective attention in the disabled groups since the two measures were negatively correlated in the normals and positively correlated in the disabled.

Is it defensible to conclude that group or age differences in selective attention exist when correlations measuring the trade-off between central and incidental learning, although in the same general direction as predicted, are low and non-significant? Can we then hold that increases with age in central learning scores are the result of declines in (the giving up of) incidental learning, especially when the increases are not accompanied by differences in incidental learning? Douglas and Peters (1979) think not. They argue that equal scores must indicate equal processing in the absence of other evidence since some factor other than the processing of incidental information could account for the differences in the central learning score. Hagen and Kail (1975), following a review of earlier studies, suggested that the increased use of active cognitive mnemonic strategies could account for significant age and group differences in central learning.

Tarver et al. (1976) recognized the anomalies in the results of their first experiment with 8-year-olds and suggested that central recall in the normal group could have been added by the attention-focussing properties of a verbal rehearsal strategy. In a second experiment with older (13 years) and intermediate (10 years) learning disabled children, they tested this hypothesis by inducing verbal rehearsal in half the group at each age level. When results were analyzed using the selective attention efficiency index (% central learning - % incidental learning), they concluded that verbal rehearsal had significantly increased selective attention efficiency. Yet, the increase in central learning was not significant at either age and the incidental recall did not differ between ages, nor was it affected by rehearsal conditions. As a result of this failure to produce a concomittant decline in incidental scores, the authors concluded that rehearsal skills were still developing in the disabled group and that studies with yet an older age group would be needed to confirm results.

Subsequently, Tarver et al. (1977), using the 7-item variation of the task, studied a group of disabled boys at mean age 15 years, 8 months. Incidental recall which had remained constant at the younger ages declined significantly at the 15-year-old level, supporting the usual developmental trend, but central recall which had increased over the age range 8 to 13 did not show the reciprocal increase at the 15-year-old level.

Correlational statistics also failed to support reciprocity. Once again, therefore, it may be hypothesized that it is something about the central task itself that is particularly difficult for disabled learners because once they give up extraneous information, they do not show the increases in central learning that have been reported for normal samples. The absence of a normal control sample in the above study, however, prevented direct comparisons and firm conclusions.

A study designed to directly compare disabled and normal populations at more than one age level was carried out by Pelham and Ross (1977) who used a 6-item version of the Hagen task presented in simultaneous or spatial fashion, with groups of children from grades one, three and five. Examiner feedback on correct positions for each animal was provided after each trial. Their results with young children are at variance with those of others since they found non-significant increases with age in central learning but significant declines in incidental learning in both groups. Correlations tended to become negative with increasing age as others might have predicted, but with the so-called trade-off occurring more slowly in the disabled group. The authors interpreted their results as reflecting a developmental delay in the disabled group. That the learning disabled actually recalled more information than the normals (equal central and higher incidental scores) suggests factors other than the processing of extraneous information may be having important unrecognized effects. In explanation, it might be noted that the 6-item version of the test might be simpler, pointing to the correct items might have helped to direct attention, and the young ages of the children should also be considered.

Studies using the central-incidental learning paradigm. The filter theory (Broadbent, 1958) which implies that attention can be channeled to only one stimulus at a time has led to the notion that there is a necessary "trade-off" between the acquisition of central information and information that has been indicated as incidental or irrelevant. Hence, distractibility can be measured by the amount of incidental or irrelevant recall stored during a designated learning task. In early studies, incidental learning scores were evaluated, using a repeated measures analysis of variance design, in relation to the proportion of central information retained (Hagen, 1967). More recently, Hallahan, Kaufman, and Ball (1974b) proposed the use of a "selective attention efficiency index" which was derived by subtracting the proportion of incidental learning from the proportion of central learning. Patterns of correlation have also been used since, if the giving up of incidental information results in higher central learning scores, selectivity of attention would be denoted by negative correlations between the two measures (Hagen & Hale, 1973).

The most frequently used task in this kind of study was devised by Hagen (1967) based on earlier prototypes (Atkinson, Hansen & Bernbach, 1964). A series of cards, each one containing a line drawing of an animal as the central object and a common household object as the incidental object, is presented in a particular sequence and the subject is told to remember the positions of the animals, but that he need not remember the other objects. When the array is concealed, the child is presented with a card containing the picture of one of the animals and is asked to designate its position in the original sequence, the number of correct responses being the measure of central learning. After the central learning trials are completed, the subject is unexpectedly asked to recall which of the various household objects had been paired with each of the animals. The number of pairs correctly recalled is the measure of incidental learning.

Using this procedure, relatively high incidental scores in relation to central learning scores have been observed in young children with central learning increasing from ages 6 to 14, and incidental learning remaining constant or registering only slight declines until ages 12 or 13, when the decrease becomes significant (Hagen, 1967; Hallahan, Kaufman & Ball, 1974a; Maccoby & Hagen, 1965; Weiner & Berezonsky, 1975). Since capacity to process both central and incidental information presumably increases with age, but only central scores increase, it is reasoned that extraneous material is being increasingly filtered out in favor of central stimuli. This hypothesis is supported if the correlation between the two indices becomes increasingly negative with age, a result which has received some support in much of the literature cited above.

A few studies have reported no significant decline in incidental learning at adolescence (Hagen, 1967; Hagen, Meacham & Mesibov, 1970), but the anomalous finding has usually been attributed to variations in materials and procedures. Certainly, as in Hagen's studies, added noise (Hagen, 1967), forced labelling (1970) or inclusion of incidental elements within the central stimulus itself (Hagen & Hale, 1974) could have interfered with preferred selectivity strategies. Also, if the central task fails to impose sufficient demands, and both central and incidental information can be comfortably processed, then incidental learning may remain high (Fraas, 1973; Siegal & Stevenson, 1966).

A further complicating note is entered by Swanson's study (1979a) with 9-year-old normal and learning disabled subjects. No significant group differences for either central or incidental recall were found using a 6-item spatial form of the task. Selective attention efficiency was not computed and correlational data were not given. The method of determining incidental learning was modified by asking for the match of each incidental item to its serial position in the final trial of the series. This may have made the incidental task so difficult that group differences were masked.

The often confusing and contradictory findings in the foregoing account may first of all be considered in the light of the methodological differences in the studies. Although all used Hagen's task, important variations occurred in its administration. In particular, the number of items and the spatial-sequential versus temporal-sequential nature of the serial presentation varied from study to study, and could have caused differences in central task difficulty (Berch, 1979). When this task is too difficult, some disabled children appear to engage in stimulus-seeking behavior, thereby increasing extraneous processing (Douglas & Peters, 1979). On the other hand, if the central task is too easy, both central and incidental information can be simultaneously processed and the predicted trade-off does not occur (Fraas, 1973). Also, opportunities for the use of preferential strategies in the deployment of time and rehearsal are greater on the spatial array than the temporal one since in the latter, attention is specifically focused on one item for a specific time. In those studies where significant group differences were found (Hallahan et al., 1973; Tarver et al., 1976), a temporal presentation was used which may suggest that there is something about this presentation mode that is differentiating the groups.

It is necessary, then, to re-examine the measures used and the rationale behind them. The use of the selective attention efficiency index (% central - % incidental learning) to compare groups presents certain problems since it can produce significant group differences even when none appear on either the central or incidental scores themselves. Further, if central learning increases, selective attention efficiency can increase although the processing of incidental information remains the same or even increases somewhat (Tarver et al., 1976, expt. 2). Also, this index does not differentiate those who process high central and high incidental information from those who process low central and low incidental information since both would receive low selective attention scores. It appears, then, that the selective attention efficiency index may be misleading if not considered in relation to other measures. In particular, its use should be restricted to indicating degree of discrepancy in instances when there are demonstrated significant differences in incidental learning scores.

A closer look at the practice of using correlational coefficients to determine relative development of selective attentional skills is also in order. It is possible that the correlations in many of the studies, since few are significant, are telling us that central task performance is often relatively independent of the amount of distraction experienced by the subject. A tenable and parsimonious hypothesis would state that, in the absence of differences in incidental learning or significant negative correlations between central and incidental scores, any differences in central learning are related to cognitive processes directly required for central task performance itself, a serial memory task.

All this seems to indicate that the different scores or indices which can be derived from the central-incidental task can be considered as measures of selective attention only under certain conditions and only when evaluated simultaneously rather than individually. Patterns rather than individual indices would be more instructive. The following represent some of the more common patterns and possible interpretations:

1. Low central learning and high incidental learning, with a significant negative correlation suggests distractibility.

2. Low central learning along with low incidental learning with a non-significant correlation suggests that low central learning scores are related to a process required for central task performance. On the central-incidental learning task, this would most probably be with a process related to serial memory functioning.

3. High central learning and low incidental learning with a significant negative correlation suggests good selective attention.

4. High central and high incidental, with a high positive correlation or no significant correlation, suggests that the central learning task is too easy and that the subject was able to process both without taxing capacity.

Summary and research objectives. The foregoing has suggested that certain patterns of poor performance on the central-incidental task can be indicative of poor selective attention while others may more properly be considered to reflect inefficient central task performance (i.e. serial order processing). Since problems in both selective attention and serial memory have been hypothesized to account for low factor 3 functioning on the WISC/WISC-R, it appears that the Hagen Central-Incidental task could provide an interesting vehicle to explore the distractibility vs. serial memory controversy in learning disabled populations differing significantly in factor 3 scores.

Further, if the Consistent Low Factor 3 subjects are characterized by distractibility on the central-incidental task, then one could also hypothesize that they would also perform below the Inconsistent group on an embedded figures measure which required them to identify a figure by resisting the distraction of the extraneous stimuli that surround it. Moreover, if selectivity of attention is the central process contributing to performance on these indices, there should be a significant negative correlation between number of items correct on the embedded figures test and the incidental learning scores from the central-incidental task. Accordingly, in addition to the central-incidental task, an embedded figures measure has been included in the expectation that results would converge, increasing the validity of the findings.

Research Pertaining to Serial Processing

Theories of serial functioning. Two main approaches to the study of the serial memory process can be discerned in the literature, each rooted in different psychological traditions. The first, the associational approach, stemming from Classical Greek thought, was extended by the British empiricists and later couched in the terminology of stimulus-response psychology, while the second, derived from the Gestaltists who indicated the importance of organizational factors either in the material itself or in the mode of its perception. The former is based on the theories of Hull (1935), who expanded Thorndike's idea that each item had some degree of association with every other item in the list, immediate and remote, forward and backward. Though passing through several reformulations emphasizing the role of positional cues (Young, 1962; Ebenholz, 1963), it has stressed contiguity as a sufficient condition for learning and the notion of the learner as passive during the process. The second approach, initially stimulated by Lashley (1951) and given impetus by the famous Miller paper of 1956, has emphasized the role of the learner. It was shown that the maximum number of units that could be processed was seven, plus or minus two. This limited capacity required that the subject in serial learning tasks must find means to circumvent this restrictive feature of his short term memory (STM). Organization by the process of chunking was hypothesized as the method of choice since the chunks themselves could be recoded into a heirarchy of information whose recall or retrieval was enhanced when the same organizational cues were used as in acquisition and storage. Free recall procedures with material presented in serial order used and developed by Johnson (1970), Mandler (1967) and Tulving (1968) have supported this view by showing that material is subjectively organized into clusters of conceptually related items. Jensen and Rohwer (1965) demonstrated that by organizing around two anchoring points (initial and final items) the subject obtained a spatial representation of the entire list, a theory akin to, but clearly different from, that of the positional cue associationists where passive rather than actively searching subjects appeared to exist.

As in other areas of research, differences rather than agreements are often magnified. Although some differences may have arisen because of variations in their experimental procedures, the associationists having favored unrelated item lists and multi-trial anticipation learning procedures, the organizationists related item strings and single trial free recall techniques, there is one phenomenon on which there is a measure of agreement and that is the phenomenon known as the serial position effect. Here the plotting of error proportions against item position has yielded a skewed bell-shaped curve where the first and last items were indicated to be the easiest to learn and remember. Attempted explanations of this common observation, however, have differed.

Associationists have postulated inhibition around central positions as a possible mechanism (Hull, 1935; Melton, 1963). Others have stressed the 'distinctiveness' of the initial and final list position (Murdock, 1974; Ebenholz, 1972). Still others (Buschke & Hinrichs, 1968; Palmer & Ornstein, 1971) have seen conscious rehearsal strategies being applied to transfer early list items to long term memory (LTM) while maintaining later items in STM. Crowder (1976) in a *rapprochement* of sorts has categorized these hypotheses as passive (inherent in the mechanism) or active (dependent upon the processes undertaken by the subject) and suggested that since serial position effects were found by both kinds of theorists any viable theory should partake of both kinds of explanation. His own work pointed to a primacy effect, resulting from a cognitive strategy determined at the time of acquisition, and a recency effect produced from positional distinctiveness inherent in the nature of the serial order tasks themselves. Some support has been offered by the work of Belmont and Butterfield (1969) with mental defectives who exhibited deficits in primacy but not recency positions and by Hagen, Jongward and Kail (1975), who showed that young children also failed to show a primacy effect but displayed a recency effect. Others (Tarver et al., 1977) have indicated that learning disabled children also have decreased primacy but not recency effect relative to normal learners their own age.

In brief, it appears that organizational theory has augmented associational theory by taking into account the limited capacity of the human information processing system and indicating ways which organization by an active subject could overcome capacity restrictions. This emerging integration of the two schools of thought has signalled the appearance of a number of hybrid models of explanation, notable among them being that of Atkinson and Schiffrin (1968), which distinguished between structural and voluntary control features. Under the former, there were physical attributes and fixed invariant processes which facilitated memory but were not under conscious control. There were also control processes which were under the direction of the subject and which could be selected and modified from a wide range of possible processes. Stated as a computer analogy by Hagen et al. (1975), "the structural features correspond to the hardware and systems program while the control processes correspond to those program sequences that can be established and modified at will by the programmer." In the model, the structural components included the sensory register, short term store and long term store. Since the first provided for only two seconds or less, a rapidly decaying literal copy of the physical stimuli, the short term store, had to rapidly select stimuli, within its limited capacity of seven plus or minus two, before incoming information displaced what was there. Only some control process such as rehearsal could retain the information in STM without loss. Transfer to long term store, again under a control process, could subsequently occur from some of the information and this could be retrieved as occasion demanded, given efficient retrieval control processes. To date, emphasis appears to have been placed on the study of these short term memory phenomena. For the present purpose, it may be possible to hypothesize that this aspect is featured on the tasks defined by factor 3 of the Wechsler scales. More importantly, study of the serial learning curve might offer help in deciding whether these learning disabled children are handicapped on serial learning tasks, and if so, whether the failure is in the use of inefficient active strategies, or in the lack of certain structural features. Perhaps a review of the literature examining the relationship between control processes and serial memory and learning disorders will throw more light on this topic.

Research Pertaining to Serial Processing: the Use of Control Processes.

Development of strategic behavior. Chi (1976) has presented evidence to suggest that age-related changes in the use of strategies are responsible for a major part of the observed improvements with age in children's memory. Similarly, Brown (1975) has indicated that memory tasks which do not require the use of strategic behavior are relatively insensitive to developmental trends. This implies that the age differences in memory span, previously believed to be due largely to changes in capacity, may actually be the result of changes in how that capacity is used. In support of this developmental view, many studies have indicated that certain strategies characteristically employed by older children are not used by younger children. Various methods have been used to determine this trend including: subjective reports of how children remember (Flavell, Friedricks & Hoyt, 1970; Matthews & Fozard, 1970); changes in hesitation patterns in subject-paced tasks which reflect chunking and cumulative rehearsal (Belmont & Butterfield, 1969; Torgesen, 1977a); direct observation of lip movements (Flavell, Beach & Chinsky, 1966; Keeney, Cannizo & Flavell, 1967; Kingsley & Hagen, 1967); and, more recently, the observation of primacy-recency effects in serial learning curves (Bauer, 1977; Tarver et al., 1976).

Flavell, Beach and Chinsky (1966) found that five, seven and ten-year olds who verbalized during the delay following presentation recalled more items. While 17 of 20 ten-year olds verbalized, only 2 of 20 five-year olds did so. Subsequently, Keeney, Cannizo and Flavell (1967) demonstrated that first grade students who did not verbalize could be induced to do so and their recall was then as good as those who had verbalized spontaneously. However, those who had been instructed to verbalize did not continue to rehearse without instruction and so their recall declined.

Using the familiar serial memory task adapted from Atkinson, Hansen and Bernbach (1964), Hagen and Kingsley (1968) studied rehearsal processes in children at ages four, six, seven, eight, and ten. One group at each age level was subjected to a forced labelling condition while the other served as a control. Recall in the control group where no instructions were given improved with age. In the label condition, although recall was facilitated at ages six and eight, that of the four-year olds and the 10-year olds did not show improvement over the age-related increases in the control group; in fact, recall was significantly poorer under the label condition in the 10-year olds. The authors, by analyzing the serial learning curves, concluded that the four-year olds did not rehearse, even under instruction. The serial curves of the 10-year olds exhibited a diminished primacy effect relative to the controls which was interpreted to mean that the requirement to label had interfered with their own spontaneous rehearsal strategies which must have been more facilitative than mere labelling.

Other studies with serial memory tasks have confirmed these findings by showing that children can be induced to rehearse cumulatively and increase recall (Kingsley & Hagen, 1969) but that the strategies were not produced spontaneously at a later date (Hagen, Hargrave & Ross, 1973). Similarly, poorer performance on a serial recall task under imposed rehearsal conditions has been replicated in adolescents and college students (Hagen, Meacham & Mesibov, 1970).

It appears then that there might be developmental milestones that signal growth in the use of strategic controls in serial memory tasks. At the youngest ages, there seem to be no voluntary memory devices and even under instruction these are not manifest. Typically, this is followed by a transitional stage in which the child uses the strategy when trained or requested to do so, but may not use it efficiently or spontaneously. That efficient strategies may be disrupted in older subjects when procedures normally considered to be conducive to improving recall are imposed, suggests that over time a child gains a varied, individualized repertoire of strategic controls and also develops skill in selecting and implementing appropriate strategies for particular tasks.

Flavell (1970) explained this individualized use of efficient strategies by hypothesizing the existence of what he called "meta" variables, which involved being aware of one's own role in the memory process. In a similar vein, Brown (1975) in a paper entitled Knowing, Knowing About Knowing and Knowing How to Know, defined this as having the "intention to be strategic" or "the plan to form a plan", (p. 111). It was described as being able to assess the task of knowing one's capabilities and of predicting performance so that appropriate strategies might be selected. This characteristic was assumed to develop with time and to be apparent in older children. Kail (1979) investigated the existence of such a generalized strategic factor in 8- and 11-year olds. A serial memory task, a free recall task presented in temporal order, and a recency judgment task were presented. It was concluded that there was a general strategic factor across tasks for the 11-year olds, but not for the 8-year olds, which supported the notion of an age-related trend in the development of "meta-related" behavior.

The literature, then, has indicated that there are three main developmental stages in the use of control processes on serial memory tasks in a normal population. First is a stage in which no strategic controls are used, even when training is given; this has been termed as "mediation deficient" (Flavell, 1970). Second is a transitional stage characterized by the use of controls but only under conditions of instruction; this has been called "production deficient" (Flavell, 1970). Finally, there is a stage evidenced by the use of meta variables in that spontaneous strategic behavior which is intentional, flexible, insightful and individualized is exhibited. Although the literature does not so state, failure at this stage might be labelled "meta deficient".

Comparisons of normal and disabled learners. A developmental delay hypothesis implying that learning disabled children develop strategic behavior, or go through these stages, at a slower rate than normal learners has received considerable support in the literature (Brown, 1975; Hagen, Jongeward & Kail, 1975; Tarver et al., 1977). An alternate hypothesis that failure to use strategic controls may be a learned behavior resulting from adverse educational experiences has been postulated by Torgesen (1980), while a deficit hypothesis suggesting that voluntary controls may be indirectly inhibited by deficits in involuntary structural processes, possibly stemming from a neurological source, has also been implicated (Spring, 1976; Spring & Capps, 1974).

Evidence that learning disabled children are impaired in the use of cognitive controls came initially from two studies that investigated verbal labelling skills during the performance of sensory integration tasks (Blank & Bridger, 1966; Blank, Weider & Bridger, 1968). Retarded readers were less successful in making intersensory matches and they also made more errors when instructed to label the stimuli. It was, therefore, inferred that deficient labelling skills were related to deficient integrative abilities.

Two studies (Torgesen & Goldman, 1977; Torgesen, 1977a) directly observed rehearsal practices in good and poor readers. In the first study, lip movements and whispered words were monitored as evidence of the use of rehearsal. It was concluded that good readers rehearsed more and that they also recalled more sequences correctly. In the second study (Torgesen, 1977a), similar conclusions were drawn and it was further inferred that the good readers "chunked" the stimuli while rehearsing.

Torgesen found that disabled readers were less able to make use of a categorical structure provided by an orienting task prior to serial presentation. From these studies, Torgesen concluded that reading disabled children engaged in less efficient strategies on serial memory tasks of unrelated items. According to the classification scheme, they would be production deficient, or perhaps meta deficient, but not mediation deficient.

Kastner and Richards (1974) compared recall strategies in third grade good and poor readers when novel and familiar stimuli were used. There were no between-group differences in level of recall with familiar, easily coded items, but good readers did significantly better than poor readers with the novel items. The authors found that three-quarters of the good readers reported using a verbal strategy while none of the poor readers did so. Moreover, good readers labelled the stimuli more rapidly. The authors pointed out that there was little support for a general labelling deficit in poor readers since they did apply labels to familiar stimuli. Rather, it appeared that the learning disabled used a less evolved, less efficient strategy, especially under more difficult conditions where labels had to be generated. Again, evidence suggested that the learning disabled did mediate but were less efficient and perhaps less skilled in choosing the best strategies.

Bauer (1977) investigated rehearsal techniques in 9- and 10-year old learning disabled and normal children by comparing immediate and delayed memory for serially presented eleven word strings under conditions of free recall. Immediate free-recall at the primacy position was poorer in the learning disabled groups but recency recall was similar. This was explained in terms of the Atkinson-Schiffrin model (Atkinson & Schiffrin, 1968) since items in primacy positions must have been placed in and retrieved from long term memory by use of control processes or they would have been superseded by more recent items in strings that exceed the short term memory capacity. Recency items on the other hand were considered to reflect a more passive form of memory, being influenced by structural rather than control processes. The recall of these items may depend primarily on the length of the echoic or iconic image (Posner & Keele, 1967). Bauer (1977), therefore, suggested that learning disabled children had less efficient rehearsal strategies for placing items in long term store but did not exhibit poorer structural attributes, such as poorer attention or presumably weaker echoic or iconic memory traces.

This interpretation has received further support from Bauer's findings that under conditions of delayed recall the disabled subjects' scores were lower than those of the controls for both primacy and recency positions, since under delay conditions both primacy and recency items must be rehearsed to be maintained. Since free recall rather than ordered recall was used, the possibility existed that different strategies for recall had neen used by the two groups. For example, it was possible to recall the strings in the order presented or to recall the most recent items first. However, no group differences were found and, in fact, 97% of all strings were recalled in the order presented. Thus, both normal and disabled learners had used a serial order recall strategy.

Tarver et al. (1976) investigated the development of verbal rehearsal strategies in learning disabled children at ages eight, ten and thirteen. In the first experiment, it was found that learning disabled eight-year olds did not produce a primacy effect in contrast with normal controls who exhibited a pronounced one. In the second experiment labelling and chunking was experimentally induced in half the subjects at ages 10 and 13. Increased recall and primacy effects were observed at both ages. However, it should be noted that the control group in whom rehearsal had not been induced also exhibited the primacy effect and the differences in the amount of recall between the experimental and standard conditions were not significant at either age. The presence of the primacy effect in the standard condition indicates that a mediational deficiency did not exist. That instruction failed to increase recall, particularly at the 10-year-old level, is somewhat puzzling and difficult to interpret since no normal controls were used to determine if the level of recall of the learning disabled was actually deficient at the older age levels. None-theless, the authors concluded that a developmental delay existed, presumably because of their findings at the 8-year-old level.

Swanson (1979b) investigated the mediational strategies of 9-year-old learning disabled and normal children on verbal and non-verbal serial memory tasks. Items were "nonsense" or unfamiliar 8-sided shapes. Following presentation, the children were asked how they remembered the items. No significant between-group differences were found in recall performance and the post test questioning revealed that few members of either group had labelled the shapes or associated them with anything familiar. Swanson concluded that some form of non-verbal rehearsal strategy had been used since, although there was no primacy effect, overall short term recall was comparable for learning disabled and normal subjects. In the second part of the study, both learning disabled and normal children were assigned to "named" and "unnamed" stimulus conditions. Children in the named condition were pretrained to use labels and instructed to use them on each trial. While pre-training and use of labels produced significantly superior recall in normal children, effects were negligible for the learning disabled, suggesting a mediational deficiency.

Research reviewed to this point seems to indicate that learning disabled children of school age are deficient relative to normal learners in their use of strategies on serial memory tasks (Blank & Bridger, 1966; Bauer, 1977; Kastner & Richards, 1974, Tarver et al., 1976; Torgesen & Goldman, 1977; Torgesen, 1977), though not necessarily deficient in the use of all strategies (Kastner & Richards, 1974; Swanson, 1977) or under all conditions (Kastner & Richards, 1974). Since primacy effects were not always absent (Bauer, 1977; Tarver et al., 1976), and since impaired performance was related to specific situations such as use of novel but not familiar stimuli (Kastner & Richards, 1974), it appears that they may be said to have a production deficiency but not a mediation deficiency, at least at older ages.

The findings of Swanson (1979b) and, to a similar but less clearcut extent, of Tarver et al. (1976) that learning disabled children as old as 13 years did not show gains over their learning disabled peers even when instructed in the use of sophisticated verbal strategies, raises the possibility that they may be deficient in some other aspect related to serial recall performance. While some studies have implicated structural control variables such as temporal order perception (Bakker, 1972) and slow encoding speed (Spring, 1976; Spring & Capps, 1974), it is also possible that a meta-variable has affected these children's strategic behavior. In a speculative but well-reasoned paper, Torgesen (1977b) has suggested that learning disabled children are inactive learners and simply fail to engage themselves adequately in learning tasks, perhaps because they have learned to avoid involvement or perhaps because they are unaware of the degree to which such active involvement is necessary in certain learning situations. If being an active learner means having a repertoire of strategies and being able and willing to match them to the needs of the task as Brown (1975) suggests, then one way of assessing the degree of involvement would be to vary a task by altering its external organization, (and consequently the control processes required for mastery) and to monitor performance both as to level of recall and type of strategies used.

Some researchers (Parker, Freston & Drew, 1975; Pike, 1977) have studied recall on strings that varied as to linguistic structure. Their results might be interpreted to mean that older learning disabled subjects are characterized by a relative inability to use appropriate strategies on tasks with varying organization. Parker et al. (1975) administered five-word lists with differing levels of external organizations and found that learning disabled subjects approached each variation in the same way. Pike administered six-word serial lists to grade 5 and 6 students grouped as good and poor readers. These lists were presented auditorily without stress or intonation and were varied along semantic-syntactical organizational lines in order to produce three versions: meaningful, anomalous sentences (which retained syntactic structure but violated semantic rules), and random, unrelated word lists derived by permuting the order of anomalous sentences. She found that good and poor readers did not differ on recall of the random lists but did on the structured lists. Poor readers showed less variation in level of recall across strings, and also less variation in the type of recall strategies used.

To determine how the groups responded to structure in their use of strategies, serial learning curves were examined. Both able and disabled readers produced the classical bowed curve on random lists. However, on the syntactically organized lists, the good readers produced curves that reflected that they had organized or chunked units in accordance with structure, but the poor readers still produced the serial curve suggesting that they had not responded to list organization. Both groups organized the meaningful sentences but the recall curve of the good readers was flatter indicating they had responded to the meaningful string as a unit while the bowed serial effect was still detectable in the response curve of the poor readers.

Under free recall conditions, recall in presentation order is common in children as young as five with recall according to organizational relationships occurring later (Moely, 1968). Its use in situations where other organization is possible has been observed to be negatively correlated with amount recalled (Bauer, 1977; Pike, 1977), and so it appears to be a relatively immature or deficient control process. Its use in the face of more facilitative organization, especially in older children, may represent a failure to actively engage meta processes in order to match task and strategy.

Pike interpreted her results described above to mean that the poor readers were unable to exploit syntactic structure to reduce memory load because of a delay or difference in the development of syntactic competence. However, because no form of organization other than those containing syntax was used, it is not clear whether failure to respond to structure was due to a particular problem with syntax or with a more generalized failure to be meta-efficient, that is, to actively engage in an analysis of task needs and to match strategies accordingly.

Such a necessary control is provided in a task designed by Weener[1] (1978). In addition to unorganized, syntactically-organized, and meaningful strings, it also provides for a form of associational organization. Using this task, Weener and Sabbatino (1974) found age differences in normal children and differences among normal, learning-disabled and mentally retarded groups of children.

Summary and research objectives. Theoretical support for the notion that the difficulties in serial memory associated with reading failure could lie in the use of inadequate or inappropriate control processes has been presented. Research has suggested that disorders in the use of such control strategies, if they existed in long term learning disabled children at older age levels, would probably arise from failure to be meta-efficient rather than to be production or mediation deficient. Since low factor 3 scores were obtained consistently across a variety of tasks requiring some form of serial memory (arithmetic, digit span and coding subtests of the WISC-R) by the Consistent Factor 3 group, it is possible that their poor performance was related to meta-deficient strategies. If this were so, and if they were administered Weener's task under conditions of free recall, it would be expected that their resulting recall curves would reflect:

1. lower level of recall;
2. less variability in shape of curves and recall levels;

3. reduced primacy effects, if poor rehearsal strategies were used;

4. reduced recency effects, if poor recall procedures were used.

Additionally, in the quest for validity through convergence of results, all indices (level of recall, statistical analysis of recall curves and tabulations of report procedures) should be shown to confirm each other.

Research Pertaining to Serial Processing: Temporal Order Functioning

Studies of temporal order perception. Dysfunction that is specific to temporal order processing has been frequently advanced as a cause of learning disorders, largely on the basis of sequential errors that many disabled learners have been observed to make. For example, transposition errors occur in speech articulation, spelling and the recitation of serial lists such as months of the year. As well, inferior performance of the more formal psychometric indices, such as digit span (Huelsman, 1970; Koppitz, 1973, 1975) or Knox cubes (Corkin, 1974) has been abundantly documented. Yet, few theories have been offered to explain specific relationships between serial disorders and learning competence.

Bakker (1972) has presented a theory which implicates a disorder in temporal order perception (TOP) as a primary, centrally-derived cause of reading and language disabilities. Based on empirical evidence (Hirsch, 1959, 1966; Hirsch & Sherrick, 1961) that an inter-stimulus interval of 20 milliseconds is required to detect a succession of two stimuli, he hypothesized that some individuals, because of a disorder in the speed of processing stimuli, might have difficulty distinguishing the order of sequences such as phonemes in words. Since the inter-stimulus interval was invariant for a wide variety of stimuli, the ability to detect sequences was presumed to be derived from a central processing function and in terms of the Atkinson and Schiffrin (1968) model would be said to reflect a structural process.

Originally, Bakker (Bakker, 1967; Groenendahl & Bakker, 1971) had suggested that the serial ordering deficiencies noted in his investigations of disabled and normal readers were the result of verbal labelling deficits since the poor readers were inferior to normal readers only when meaningful, but not meaningless, stimuli were used. Subsequently, however, Bakker (1972) revised this interpretation and has stated that "Reading disturbed children do not seem to present any verbal labelling problems nor any temporal ordering problems as such, but difficulties which occur when verbal items are presented in a time scheme . . . In other words, the interaction between time and verbal code is disturbed and not so much the main factors." (1972, p. 67). It seems clear that Bakker now sees serial ordering deficits as related to the faulty perception of successive verbal stimuli rather than to poor retention based on faulty labelling or some other control mechanisms. In support of this view, he offered evidence that reading disabled children could label items even when they couldn't recite them in order.

The neurological and physiological basis for temporal order perception is derived from the investigations of Milner (1962,1967) and Efron (1963). The former, working with brain-damaged subjects, noted that damage to the left temporal lobe impaired sequential memory for verbal sequences, but not for non-verbal sequences such as those found in music. The opposite was true for damage to the right temporal lobe. Efron, by presenting a series of two stimuli, flashes of light and figures, and requiring subjects to indicate which stimulus was presented first, found temporal order perception to be mediated by the left hemisphere in the case of both flashes of light and figures. Although these studies were somewhat contradictory, in the opinion of Bakker the discrepancy could be resolved if one postulated that the identification of Efron's non-verbal stimuli requires verbal labels in order to be encoded and were, therefore, predisposed to left hemisphere processing.

Bakker's own studies (Bakker, 1967a, 1972) offer some support for his theory. In his first study, a random sample of primary grade children was asked to recall the serial order of pictures presented under two conditions, visual and visual/auditory (in the latter condition the subjects were asked to name the pictures aloud). Significant age differences were noted between the ages of six and six and a half under both conditions, but were greater for the visual/auditory condition which additionally produced sex differences, girls performing better than boys. Reading scores at older ages were correlated with temporal recall measures. The second study reported by Bakker (1972) compared normal and disabled readers of both sexes in the middle childhood years. Visual, auditory and tactile serial presentations of letters were made and subjects were asked to identify the serial position of designated letters in each set. Disabled readers performed more poorly on all the tasks and did not make as large age-related improvements as normal readers. However, Bakker pointed out that, while temporal order perception measures discriminated able readers from disabled readers regardless of input condition, they did not discriminate reading ability within the disabled group. This suggested the presence of subgroups and for the purposes of this investigation, encourages speculation that the Consistent Factor 3 subtype might manifest a temporal order perception disorder while the Inconsistent subtype would not.

While younger girls at ages 7 to 8 years performed better than boys, the boys equalled the performance of the girls at older ages. Bakker noted that these relationships would occur if a critical period existed for the development of temporal order perception and was associated with maturation of the left hemisphere, the earlier successes of the girls being related to earlier neurophysical development.

To check his assumptions that temporal order perception is a centrally-derived process, Bakker (1972) explored the relationship between reading and temporal order across several modalities. Evidence of the generality of temporal process disorder has also come from the work of other researchers who have compared learning and reading disabled groups using a variety of temporal order tasks, including perception and retention of rhythmic patterns (DeHirsch, Jansky & Langford, 1966; Keough & Smith, 1967, Sapir, 1966; Zurif & Carson, 1970), recall of bisensory digit strings (Senf & Freundl, 1971, 1972; Davis & Bray, 1975), ordering of Knox cubes (Corkin, 1974), and recall of dichotic stimuli (Zurif & Carson, 1970). These studies have consistently concluded that disabled readers perform more poorly than normal readers on measures of temporal order recall which would seem to support the hypothesis of centrally-derived temporal processing disorder. Certain considerations, however, militate against unqualified acceptance of this view. First, given that most studies demanded recall for item as well as order, it is difficult to tell whether it is gross memory or memory for order that is impaired. Second, if the disorder is in temporal order perception, the problem presumably occurs at input and tasks which measure retention do not really address the temporal order perception issue since poor performance could be due, among other things, to poor perception, poor control processes, or poor retrieval. Tests which systematically vary mode of presentation and retention might help to sort out these processes. Further, to determine if it is the temporal nature of the stimuli which is the problem (be it at input or output), studies which require simultaneous, spatial as well as successive temporal presentations, are needed to demonstrate that the problem is specific to temporally ordered stimuli.

To place these considerations in perspective, it is necessary to discuss the item versus order controversy and review those few studies that compare the learning disabled and normal populations on memory for item and order. The studies which contrast spatial and temporal processing normal and disabled learners will be discussed, and the sensory integration literature will also be reviewed since it may be interpreted to shed light on the spatial versus temporal issue. Finally, a means of separating out some of the confounding variables which impede assessment of temporal order functioning will be suggested.

Memory for item versus order. When the distinction is made between memory for order and memory for item, that is, when remembering which items were presented is separated from remembering what the order of the items was, the implicit assumption is also made that the two kinds of memory are supported by different processes and are operationally distinguishable. Brown (1958) and Crossman (1961) hypothesized the separation in memory of item and order by contending that, in a limited capacity system, the recall of one from short term memory requires a trade-off with the other. Memory for order was judged more difficult and loss of order information was considered to precede loss of item information, thus determining the span. This notion was consistent with Miller's findings (Miller, 1956) that length of memory span was quite invariant and independent of the nature of the items used.

Conrad (1964, 1965), however, has presented evidence to support the view that memory for item predominates and memory for order is simply derivative. His finding that more order errors occur in visual strings that contain acoustically confusable letter strings (bdp) than in non-confusable strings (lrk) supported his view.

Recently, other researchers have presented evidence to suggest that item and order are represented differently in memory. Bjork and Healy (1964) tested Conrad's assertion that transposition errors were a by-product of item loss and found that there was a different time course for retention of item and order information, a finding supported in studies by Estes (1972). Further, Healy (1974, 1975a & b) confirmed an observation previously reported by Aaronson (1968) that bowed serial learning curves were produced when order information was recalled, but not when item information was recalled. In view of these results, it does seem prudent to separate item and order variables when specifically studying the relationship between temporal order processing and academic skills.

Several studies have attempted to do this. Mason, Katz and Wicklund (1975) tested memory for item and order in good and poor readers by presenting strings of supra span (8 items) digits and consonants. The memory-for-item task required subjects to recall, without regard to order, as many of the digits or consonants as possible. Memory for order was tested by requiring reconstruction of aurally presented digit and letter series using a set of tiles representing all of the items in all the series. Good readers were better than poor readers on both order and item recall; but order memory was more strongly related to reading ability. However, on the memory-for-item task, the items were presented in a simultaneous visual-spatial array rather than a temporal successive one, and no indication was given as to whether consonant strings were of high, low or equal confusability under the two conditions. Therefore, results, for our purposes, must be considered inconclusive.

Noelker and Schumsky (1973) reported results of memory for 'position' and 'form' in nine-year-old retarded and normal readers. Their memory-for-position task required subjects to reconstruct a series in which black circles were interspersed with white following a 10-second delay. The memory-for-form task involved recognition of a previously presented nonsense shape from among an array of four nonsense shapes following a 10-second delay. Both tasks discriminated between good and poor readers but the position task, not surprisingly, discriminated best since it demanded recall while the form task asked only for recognition. Thus, the tasks were not of equal difficulty.

Senf and associates (Senf, 1969; Senf & Freundl, 1971, 1972) compared memory for bisensory stimuli in normal and reading disabled children. Although their purpose was to investigate intersensory integration, the measures they used also relate to differences in item and order information. In the bisensory task, two items (usually digits) were presented at the same time, one to the eye and one to the ear. After three such pairings, recall was required under a pair condition in which digits were recalled in the order presented, and in a modality condition in which digits presented digits. A gross memory measure (that is, a measure in which order errors were ignored) and an order error measure were taken. In the first study, Senf (1969) found no difference between reader groups for item retention, but under ordered recall conditions, the normal readers performed better than poor readers. In the second study (1971), normal readers performed better than poor readers on both item and order measures, but in the third study (1972), the reader groups were differentiated on item memory only. While the authors cited attentional difficulties as a possible explanation for these contradictory results, they also noted that the inconsistent findings may have been the result of different response styles in given samples of subjects. Once again, the existence of subtypes in the disabled reader groups emerged as a possible explanation for discrepant results. In a later study, Davis and Bray (1975) used Senf's bisensory task but they modified recall procedures to control for interference from multiple recall attempts and scored order errors as a proportion of total items recalled correctly. In this case, the disabled readers performed more poorly than controls on both the item and order indices.

Taken as a whole, these studies seem to indicate that learning disabled children have problems with retention of both item and order information. However, it should be noted that most of these studies did not truly separate order from item memory. Items varied from trial to trial and so, to recall the position of the item, it was also necessary to remember the item itself. A procedure such as that of Healy (1975a & b, 1977), which uses grids to hold item information constant, thereby requiring only the retention of order information, is needed to adequately test the hypothesis that low factor 3 subjects are characterized by poor memory for serial order. Further, if poor memory for order is related to faulty temporal perception, as Bakker (1972) has suggested, then disorders should be more apparent when ordered stimuli are presented successively in time than when they are presented in a simultaneous spatial array. The auditory/visual integration literature can be interpreted as revealing variations along spatial (visual) and temporal (auditory) lines to shed some light on this aspect of the problem.

Spatial versus temporal processes. Early sensory integration studies were designed to test the hypothesis that disabled readers had difficulties integrating or translating between visual and auditory stimuli. Birch and Belmont (1964, 1965) investigated the relationship by using a task which required matching aural rhythms in morse-like code with their visual representations in the form of dot patterns. They found retarded readers were less able than normal readers to equate the two stimuli. They did not, however, use the intra-modal matching tasks as a necessary control; nor, indeed, was the visual to auditory counterpart employed in their comparisons. Beery (1967) added the visual to auditory component and found that retarded readers had more difficulty on both tasks than normal readers. Muehl and Kremenak (1966) used all possible combinations of the visual and auditory stimuli thereby providing the necessary intra-modal controls. They established that both visual and auditory tasks predicted first grade achievement, but that the visual and auditory task was easier than the auditory to visual task for both able and retarded readers. The auditory to auditory task, an intra-modal comparison was the most difficult of all.

If the tasks in these early studies are re-interpreted as varying along temporal and spatial dimensions as well as auditory and visual, then the results not only indicated that the ability to equate temporal and spatial stimuli differentiated good from poor readers, but also that it was more difficult to match from the temporal to spatial, with the temporal to temporal matches being the most difficult of all. This supported the notion that problems could be related to perception of temporal order (TOP) since greatest difficulties occurred on tasks with temporal input. However, since quite different processes could be involved in handling temporal-spatial dimensions as compared with modality components, it was difficult to determine if the retarded readers had difficulty in inter-modal transfer, as suggested by the early researchers, or with temporal-spatial transfer. Subsequent studies have systematically attempted to sort out the confounding modality and temporal-spatial components by presenting stimuli requiring temporal spatial matches within the same sensory modality. Among the first to do this were Blank and Bridger (1966) using a task similar to that of Birch and Belmont (1964) except that temporally presented short flashes of light were used in place of temporally presented sounds. They found that retarded readers were less able than normal readers to match stimuli differing on the temporal-spatial dimension within the same modality. At the same time, no significant differences between reader groups were noted in matching spatial to spatial stimuli.

Rudnick, Sterritt and associates (1967, 1971, 1972) carried out extensive studies which attempted to assess the various roles of audition, vision, temporality and spatiality. Using flashes of light, morse-like code taps and dot patterns in all possible modality and dimensional combinations, Rudnick, Sterritt and Flax (1967) determined that a task requiring both auditory/visual integration simultaneously was no more difficult than a task merely involving temporal/spatial integration alone. Subsequently, it was determined that neither kind of integration in combination or alone was more difficult than similar comparisons not involving integration (Rudnick, Martin & Sterritt, 1971; Sterritt, Martin & Rudnick, 1971). In general, however, spatial patterns were easier to compare than temporal. Purely spatial tests were simplest; tests involving both spatial and temporal were intermediate in difficulty, while temporal to temporal were hardest. These findings, supporting those of Blank and Bridger (1967), were also corroborated in a study by Goodnow (1971) and served to demonstrate the relative unimportance of sensory modality. However, results were determined largely by samples of adequate readers, and so it was possible that the relationships among the various tasks would be quite different in a disabled group. Subsequent studies have provided the necessary disabled and normal reader contrasts.

Bryden (1972) compared performance of able and retarded readers at the grade six level by using all 9 possible presentation modes. In contrast to Rudnick and associates, he concluded that inter-modal matches were more difficult than comparable intra-modal ones, and that the spatial to temporal shifts were the most difficult of all. However, he combined all the visual to visual and auditory to auditory matches, whether temporal or spatial, in the intra-modal condition which masked the large differences between the easy visual to visual spatial matches and the difficult auditory to auditory temporal matches. This may have allowed the inter-modal condition to emerge as the most difficult. In agreement with the previous studies, he found that the most difficult tests were those which presented temporal stimuli as the input standard while those that presented the visual-spatial stimuli as the standard were easiest.

Although good readers performed better than poor readers on all of

Bryden's tasks, only those which required the matching of a temporal stimulus with either another temporal stimulus or a spatial array significantly discriminated between the reader groups. This provided some evidence that temporal order processing was difficult for the retarded reader group. However, there was a high degree of overlap between the two groups which Bryden interpreted to mean that temporal ordering difficulties were not universal among poor readers. Thus, the possibility of subgroups within the disabled sample was raised. The need for a study to compare subtypes of the disabled on the various forms of the spatial temporal tasks seems to be evident.

Vandevoort and Senf (1973) compared retarded and normal readers on four matching tasks, visual-spatial to visual-spatial; visual-temporal to visual-temporal; auditory-temporal to auditory-temporal; auditory-temporal to visual-spatial. Results indicated that the intra-modal visual-spatial and auditory-temporal tasks discriminated between the two groups while the other did not. Although statistical comparisons were not carried out, inspection of the means indicated that both retarded and normal readers found the intra-modal visual-spatial task easiest. In contrast to Bryden's findings, the results do not support an integration hypothesis for either the modality or spatial-temporal components; they do support the common finding that tasks involving temporal stimuli are most difficult.

The foregoing investigation (Vandevoort & Senf, 1973), moreover, presented further evidence of considerable relevance to the differentiation of subgroups of retarded readers. Intercorrelations among the four variables differed widely within and between the normal and disabled samples. Tasks were not highly correlated among retarded readers, the only significant one being a negative one between the intra-modal visual-spatial task and the intra-modal auditory-temporal task. This suggests there may be a subgroup weak in spatial processing but adequate in temporal processing, while for other subgroups the opposite may be true.

The final study (Rudel & Denckla, 1976) to be reviewed compared a sample of normal and learning disabled subjects at various ages on four tasks: temporal to temporal, temporal to spatial, spatial to spatial, and spatial to temporal, all within the visual modality. Normal and learning disabled subjects differed significantly on the temporal/spatial, spatial/temporal and temporal/temporal forms of the task but not on the spatial/spatial. The order of difficulty from easiest to hardest was the same for both the normal and disabled groups: spatial/spatial, spatial/temporal, temporal/spatial, temporal/temporal, with the two latter tests not differing significantly from each other. Correlations among subtests were not reported for the normal group but correlations within the reading disabled group indicated that temporal/spatial, spatial/temporal, temporal/temporal correlated highly with each other while spatial/spatial correlated only with spatial/temporal. Only the integrative temporal/spatial task correlated with reading ability. Interestingly, they found that scores of normal subjects on the temporal/spatial task increased at early ages and reached a plateau at age nine. Scores also reached a plateau in the disabled group but at a younger age. The leveling off implied that not only did the disabled group not outgrow the problem, but they failed to keep up. This pattern would appear to conform to a deficit paradigm according to Rourke's (1976) scheme.

Several generalizations of concern to the present study may be drawn from the evidence presented in the foregoing investigations. First, there was common agreement that sensory modality is an irrelevant attribute when differences in integrative skills are assessed between normal and disabled reading groups. Contrary to conventional wisdom and early assumptions, the integrative tasks, be they of a temporal-spatial or visual-auditory nature, were not always the most difficult, nor were they the best predicters of achievement. Although certain inconsistencies existed in the reported research, for the most part matches from a spatial standard were easiest. Apparently, the opportunity to initially view the whole pattern facilitated making equivalences; or, perhaps the flexibility to allot rehearsal time, which simultaneous viewing allows, was the operative variable. Temporal to temporal matches were frequently the most difficult and were never easier than the temporal-spatial or spatial-temporal matches. Procedures that best distinguished the able from the disabled groups were those which required matching from a temporal standard.

That the tasks requiring matches along the spatial-temporal dimension have a hierarchical order of difficulty and do not all discriminate reading ability raises some important questions as to why these distinctions occur. It is difficult to determine from these studies whether the problem in the disabled groups is one of translation between temporal and spatial stimuli, in temporal processing itself, or both. Although studies which altered the visual stimuli so that they, like the auditory taps, could be temporally presented allowed the roles of modality and spatial-temporal dimensions to be assessed separately, the problem of conceptual equivalence for item (Blank & Bridger, 1966; Goodnow, 1971) still confounds the integrative process, even when the stimuli are presented within the same visual modality. The use of dots (spatial) and flashes (temporal) which are analagous but not equivalent stimuli demands a form of conceptual integration that is in addition to equating temporal and spatial attributes. Equating different stimuli, it is suggested, requires labels be applied separately to each of the stimuli (lights and dots), and then that these labels be seen as conceptually equivalent; two different items as well as two different dimensions must be remembered and matched. In short, conceptual equivalence and memory for items still confound attempts to assess the role of temporal order processing as opposed to temporal-spatial integration in learning disabled and normal subjects. There is a need to develop a task that will hold stimuli or items constant across spatial and temporal dimensions and so remove these complicating variables. Until this is done, the relative roles of temporal order processing and spatial-temporal integration in relation to learning failure will be difficult to assess.

Summary and research objectives. Evidence presented by Bryden (1972) and Senf and Vandervoort (1973) supported the existence of heterogeneity in their disabled samples and suggest that a study with subgroups of disabled learners is needed to determine if there are subsamples within the population, one conforming to a diagnosis of disorders in inter-modal integration and another conforming to a diagnosis of disorders in sequential processing. Further, although there appears to be some agreement as to the relative ease of spatial/spatial matches in both the normal and disabled samples, this is in conflict with Healy (1975a), who found that temporal order was easiest to recall in normal populations when item order was separated from item memory, item form being held constant. It was, therefore, decided to devise a task that would not only minimize item load, but would also hold items constant across spatial and temporal variations and to administer all possible forms of this task using temporal and spatial presentations and response formats within the visual modality to the subgroups defined in Chapter II. If poor sequential processing is associated with consistently low factor 3 functioning, then it might be expected that the consistently low factor 3 group would perform particularly poorly on the temporal/temporal variation of the task, and poorly on those forms that have temporal sequential components, that is, the variations requiring the matching of spatial and temporal stimuli. They should be distinguishable from those who have inter-modal integration disorders since the latter should perform relatively well on the temporal/temporal version with low scores only on those forms requiring equivalence matching. Further, it might also be possible to determine if temporal processing problems are specific to processes at either input or response and thereby in an indirect way, test Bakker's (1972) hypothesis that temporal processing disorders occur at perception. Additionally, comparisons both within and between groups on the other measures of sequential memory, which require: (1) memory for item as well as order (central learning on the Hagen test); (2) free recall procedures (Weener Strings); (3) the use of the auditory as well as the visual modality, should help to determine the general or specific nature of a serial memory disorder, if indeed one is found to exist in the Consistent Factor 3 group.

Research Pertaining to Hemispheric Specialization

Early knowledge of hemisphere specialization was based on observations of behavior change following surgical intervention or injury to specific areas of the brain. However, during the past two or three decades, significant advances have occurred in such direct methods of studying hemisphere function. These include the Wada test (Wada & Rasmussen, 1960), which uses sodium amytal injected in the carotid artery to temporarily inhibit hemisphere function on the side injected; electrical stimulation of the cortical surface which elicits behaviors subserved by the underlying structures, (Penfield & Roberts, 1959); and commissurotomy which, by severing the corpus callosum as a therapeutic measure for epilepsy, allows independent contact with either hemisphere (Gazzaniga & Sperry, 1967). These direct invasive measures, while providing much reliable information, have been largely confined to use with a special segment of the population, the brain-injured or presumably brain-injured, who may, or may not, be representative of the total population.

Indirect non-invasive methods have also been used. Although formerly, assessment of handedness or eyedness was often relied on to determine dominance, more recently, encephalograms (e.g. Hughes, 1971) and evoked potentials (John et al., 1977) have been employed, usually for medical purposes. Of particular interest for an educational setting are the dichotomous stimulation techniques which present competing auditory, visual or haptic stimuli through the ears (Kimura, 1968), eyes (McKeever & Huling, 1971), or hands (Witelson, 1974). In response, the subject is asked to indicate what has been heard, seen, or felt. More correct detections are expected to be made by the ear, eye or hand that is contralateral to the dominant hemisphere, since each ear, eye and hand is predominantly connected to the opposite hemisphere. Although subject to inconsistency and error, these procedures are of value because they are non-invasive and can be used with normal subjects.

Two collections of research papers have summarized investigations into hemisphere asymmetry based on both direct and indirect measurement techniques (Dimond & Beaumont, 1974; Kinsbourne & Smith, 1974). These investigations have established that in most right-handed adults the right hemisphere subserves spatial, holistic, parallel or simultaneous, non-linguistic processing while the left hemisphere is specialized for analytic, sequential or successive, linguistic processes. Summaries of studies with children (Dennis & Whittaker, 1977; Witelson, 1977a) have also indicated similar results as early as the age of 2 and perhaps younger, which suggests that dominance patterns are present from a very early age. However, controversy has existed over the role development does or does not play in hemisphere specialization. In support of the maturation hypothesis, several lines of evidence documented by Krashen (1972) have indicated that certain differences in functional asymmetry of the brain exist between children and adults. First, more children than adults with right hemisphere damage manifest language disorder (Zangwill, 1967); second, injury to the left hemisphere before the onset of speech does not result in impairment of language function at maturity (Basser, 1962); third, speech and language function in children, at least until the age of five and possibly later, transfers to the right hemisphere when the left (language) hemisphere is injured (Hécaen, 1976). These observations, among others, have led to the assumption that the role of the right hemisphere for language processing is greater in children than adults. Lenneberg (1967), whose theoretical formulations are offered in support of this view, hypothesized that there is bilateral representation of language during the first two years of life and, henceforth, left hemisphere specialization for language function develops during childhood, being completed at about puberty.

This maturational view, however, has been recently challenged on evidence from neuroanatomical studies (Wada, Clark & Hamm, 1975; Witelson & Paillie, 1973), which showed the presence of asymmetric anatomical structures in the two hemispheres, behavioral measures (Caplan & Kinsbourne, 1976; Entus, 1977; Glanville, Best & Levenson, 1977), which documented lateralized responses in very young infants, and electroencephalographic data (Gardiner & Walter, 1977), which suggested that to some extent functional asymmetry has occurred at or prior to birth. Kinsbourne (1975) has strongly argued against the concept of progressive lateralization and has stated that the two lines of evidence can be reconciled by simply postulating greater neural plasticity in the early years. Witelson (1977a), following a comprehensive review of evidence derived from various sources including studies using indirect measurement techniques with normal subjects, concluded that hemispheric specialization for language could well be established or pre-programmed at birth, but that this did not preclude the possibility that further development of specialization could also occur. However, it would result largely as a secondary manifestation of the development of age-related cognitive abilities in the mode that had been pre-programmed for that particular hemisphere (analytical, sequential, focal for the left; holistic, simultaneous, diffuse for the right), the changes being additive rather than qualitative.

The issue as to whether or to what extent hemispheric specialization does or does not develop has important implications for cerebral dominance theories of learning disabilities. If cerebral specialization is progressive, then the popular maturation delay hypothesis (Satz & Van Nostrand, 1973) is of central importance. On the other hand, if cerebral lateralization is largely invariant from birth, both structurally and functionally, then it follows that learning disabilities, if they have such a neurological substrate, would be related to deficient or abnormal hemispheric organizational patterns. Precedents exist for the postulation of differences in patterns of hemispheric organization since it appears that some left-handed individuals have an atypical pattern (Rasmussen & Milner, 1975) and also there is evidence that the sexes differ (Witelson, 1977b).

The issue concerning the relationship between hemispheric specialization and learning/reading competence has been debated since the time of Orton (1925). He hypothesized the absence of cerebral lateralization for language as the neurological substrate of the various reading, spelling, and written language disorders. According to Orton, memory traces, "engrams", of perceived stimuli were formed as mirror images in both hemispheres but would be suppressed in the non-dominant hemisphere by the clearly dominant one. If, however, dominance was incomplete, then control would shift inconsistently between hemispheres, causing the orientation, reversal and sequential errors commonly observed in the reading and language disabled.

Although he saw "failure to establish the physiological habit of working exclusively from the engrams of one hemisphere" (Orton, 1928; 1966, p. 96) as the central problem, he did not specify cause, but the assumption of abnormal bilateral representation for language was implicit. Subsequently, the view that some nonspecific lack of cerebral dominance is responsible for learning disabilities has been maintained over the years (Critchley, 1970; Zangwill, 1962). In addition, several authors (Satz & Van Nostrand, 1973; DeHirsch et al., 1968) have specifically hypothesized delay in maturation of the left hemisphere, that is, a delay in the unilateral representation of language as the causal, underlying factor in learning failure. Others have argued for a neurological deficit in the naturally dominant hemisphere (Gesell & Armatruda, 1940), while still others suggest minimal injury or insult which possibly causes transfer of part of the speech function to the non-dominant hemisphere, giving abnormal bilateral language representation as the problem (Hécaen, 1976). Witelson (1976a) has hypothesized that the existence of non-verbal perception in the dominant hemisphere may account for the difficulties. It seems likely that some, any, or all of these positions might be represented within the total population of learning disabled children.

Studies of left hemisphere function. Kimura (1961) modified Broadbent's (1954) original selective listening task by presenting two series of digits simultaneously, one to each ear, and asking for recall. When correctly reported digits were analyzed according to ear of presentation, it was found that those presented to the right ear were reported more reliably. This right-ear-advantage (REA), subsequently replicated many times, has been interpreted as indicating left hemisphere specialization for language. Although the usual index has been number of items correctly reported by each ear subjected to a repeated measures analysis, some (Bryden, 1963b) have used ear order of report (EOR) on the assumption that the ear first reported in each instance is an indicator of the most direct connection to the language hemisphere. Others, in attempt to control for different levels of response between groups, have calculated an error or intrusion index which is the difference between ear scores as a function of the total score (Dorman & Geffner, 1974; Obrzut, 1979; Yeni-Komshian et al., 1975). Some researchers (Bryden, 1970; Leong, 1976) have used the incidence of side of greater accuracy to compare groups. Whatever the procedure, increasing asymmetry of ear scores have been taken to reflect increasing unilateral language representation. Whether or not the dichotic test is sufficiently sensitive to interpret degrees of lateralization, however, has been questioned (Kinsbourne, 1973b; Witelson, 1977a).

Using these dichotic procedures, it has been established that a detectable right ear advantage exists in the majority of right handers. It is true across a wide age spectrum: adults (Broadbent & Gregory, 1964; Bryden, 1963a; Kimura, 1961, 1963; Studdert-Kennedy & Shankweiler, 1970); school-age children (Berlin, Hughes, Lowe-Bell & Berlin, 1973; Goodglass, 1973; Kimura, 1967; Knox & Kimura, 1970; Ingram, 1975a; McLean, 1979; Satz, Rardin & Ross, 1971); preschoolers (Bever, 1971; Hiscock & Kinsbourne, 1977; Ingram, 1975a) and even infants (Entus, 1977). Summarizing 36 studies of children under the age of seven, Witelson (1977a) commented on the remarkable consistency of results, since over 80% of the studies found

REA even in their youngest groups.

Less conclusive are the results regarding the development of age related changes in the magnitude of the REA. Most studies with normal populations of ages varying from preschool to college appear to find no increase in asymmetry (Bakker, Hoepkins & Van der Vlugt, 1979; Berlin, Hughes, Lowe-Bell & Berlin, 1973; Goodglass, 1973; Kinsbourne & Hiscock, 1977; Knox & Kimura, 1970; Hynd, Obrzut, Weed & Hynd, 1979). Some, however, have reported increasing ear asymmetry (Bryden, 1970; Bryden & Allard, 1976; Satz, Bakker, Teunissen, Goebel & Van der Vlugt, 1975). Those finding no developmental trends have been criticized by Satz (1976) for using dichotic tests that do not have enough ceiling to measure differences at upper age levels, while Satz himself has been critized for using tests with insufficient base to tap existing REA at lower age levels (Kinsbourne & Hiscock, 1977). The use of consonant-vowel syllables which require simple, phonemic levels of processing rather than digits or words which require processing at higher semantic levels has also been suggested as a possible cause of inconsistency of results (Porter & Berlin, 1975). It should be noted, however, that most studies have used digits, and a recent study by Hiscock and Kinsbourne (1980) using dichotic digits ranging from single pairs to strings of four pairs per trial showed that, while there was a developmental increase in overall recall, there was no developmental increase in degree of asymmetry in children from three to 12 years of age. In the light of the methodological problems and the conflicting evidence, it must be concluded that the issue as to whether asymmetry is progressive or invariant is far from resolved.

Studies with learning disabled subjects alone or comparing disabled with normal learners have also produced inconsistent findings. Taylor (1962) was the first to report results with learning disabled children. He found no REA for boys aged 7 to 11, but did find an REA for girls. Kimura (1967) extended the study to older boys in whom she found an REA. All this was suggestive of a developmental trend since REA could develop later in boys than girls. These early studies, however, had no normal controls so it could not be determined if the magnitude of the REA varied as a function of the reading/learning problem. Subsequently, Bakker, Teunissen & Bosch (1976) have shown that an REA seems to be established earlier in girls than boys, with girls exhibiting laterality by grade 3 but boys not doing so until grade 5 or 6. Moreover, they noted different reading strategies appeared to be associated with different degrees of lateralization.

In other studies comparing normal and disabled learners, lack of an REA has been reported for disabled groups (Satz & Friel, 1974; Satz, Friel & Rudegeair, 1976; Witelson & Rabinovitch, 1972; Zurif & Carson, 1970). Others have found a significant REA in the disabled (Bryden, 1970; Leong, 1976; McKeever & Van Deventer, 1975; Satz et al., 1971; Witelson, 1976a; Yeni-Komshian et al., 1975). Although results concerning ear advantage are inconclusive for the learning disabled, it has been generally found that, both ears considered, their level of recall is lower than that of normal learners. This makes assessment of group differences regarding the relative magnitude of REA a difficult task. Of those who found a significant REA, Satz et al. (1971) and Leong (1976) reported that the magnitude of the REA was greater in the control group, while others (Witelson, 1976a; Yeni-Komshian et al., 1975) found no difference. Bakker, Smink & Reitsma (1973) found that at younger ages able readers demonstrated less asymmetry than disabled readers which later was interpreted to mean that in early years both hemispheres can mediate language, but in later years only the left can do so (Bakker et al., 1976). Using visual stimuli, Tomlinson-Keasey & Kelly (1979) have also shown that skilled readers display less hemispheric specialization for words than unskilled readers.

It is difficult to interpret these results given the possibility of basal and ceiling effects and the variability of response levels over age and between groups. That the majority of learning disabled children have an REA seems to be supported; it is not clear, however, if there is a difference in magnitude of the REA compared with normal learners or if REA develops later relative to normal learners. The presence of subtypes in the disabled group may have contributed to this confusion. Witelson (1977a) noted that learning disabled children with pervasive language disorders had dichotic scores suggestive of abnormal hemisphere specialization but those with specific reading disability did not.

One such study concerned with subtype differences was carried out by Obrzut (1979) who compared disabled readers grouped according to Boder's (1973) scheme - dyseidetic, dysphonetic and alexic. Surprisingly, the dysphonetic group, that is the group presumed on the basis of error types to have difficulty with phonetic and linguistic processing, was the only one to exhibit an REA. They also recalled fewer stimuli, both auditory and visual, on a bisensory memory task presented in a successive temporal format. The author suggested, with reference to the attentional hypothesis of Kinsbourne (1975) and the observations of Kinsbourne and Hiscock (1977), that perhaps the alexic and dyseidetic readers had distributed attention between two channels in an attempt to relieve boredom and that this lowered asymmetry. It was noted that higher variability occurred in left ear scores than right ear scores which suggested that some reader groups suppressed left ear scores while others processed them. If dichotic listening is an attention-related task and left ear scores may be considered to be intrusion errors as Obrzut suggests, then left ear scores may correlate with measures of extraneous processing on the Hagen central-incidental task and thereby help to define a distractible subgroup.

In conclusion, the literature consistently reveals the presence of a right ear advantage in normal learners across a wide age range, but there are inconsistent findings regarding the REA in learning disabled populations. This inconsistency may be reflective of heterogeneity, and therefore, abnormal hemisphere specialization in at least part of the latter population. It appears that it would be valuable to examine dichotic recall in specific subgroups of disabled learners and to relate the scores to other purported measures of left hemisphere function and attention in order to better understand the incidence and meaning of this variable in such children. The literature has also suggested that length of digit strings and length of assessment itself may affect results, and that these factors must be taken into consideration when designing dichotic listening tests for learning disabled children.

Studies assessing right hemisphere function. The role of the right hemisphere in reading and spelling problems is perhaps less obvious than that of the left. However, it has been demonstrated that perceptual analysis (Gibson, 1971) as well as linguistic operations are characteristic of the early learning to read process, and it has been observed that certain types of disabled readers and spellers make visual-spatial errors (Boder, 1973). Moreover, in studies of the brain injured (Levy, 1969; Milner, 1974), it has been found that atypical language representation in patients with early-occurring brain damage is often associated, not with lower verbal ability, but with impaired spatial skills, apparently because the right hemisphere is required to mediate both types of processes. The converse may then also be true, and impaired verbal ability may be reflective of involvement of the left hemisphere in spatial processing (Witelson, 1977b). This being the case, it seems that any attempt to relate hemisphere specialization to learning disorders should be concerned with the functional specialization of both hemispheres, not just the left.

Measures to tap right hemisphere function typically employ holistic, spatial, non-verbal material presented by eye, ear or hand in the familiar dichotomous stimulation format. However, unlike assessment for left hemisphere function where dichotic digits are frequently used, no one measure has been largely employed, and therefore, an integrated review of results is difficult to achieve. Right hemisphere superiority has been found in adult males when visual and auditory materials such as human figures and environmental sounds have been presented simultaneously to ear and eye (Bryden & Rainey, 1963; Fontenot & Benton, 1971; Geffen, Bradshaw & Nettleton, 1971; Kimura & Durnford, 1974). Similar results have also been found in the auditory and visual mode with children

(Knox & Kimura, 1970; Marcel & Rajan, 1975; Witelson, 1974, 1976a), even for those as young as 1½ months (Entus, 1977). Right hemisphere specialization has also been reported for haptic perception in adults (Benton, Levin & Varney, 1973; Dodds, 1978; Flanery & Balling, 1979) and in older school-age children (Flanery & Balling, 1979; Levy & Reid, 1976; Rudel, Denckla & Spalten, 1974; Witelson, 1974, 1976a). Consistent results with younger children in the haptic sensory mode await advances in test procedures as investigations have found that the tasks were too difficult even when one-handed stimulation was used (Flanery & Balling, 1979; Witelson, 1977a). Although a few studies using these procedures have reported non-significant asymmetry (Anderson & Barry, 1976; as cited in Witelson, 1977a; Reitsma, 1975), evidence for right hemisphere superiority in spatial, holistic processing in school age and older children seems to be well documented. Strong supporting evidence comes also from studies using electroencephalographic measures (cf. Witelson, 1977a for a review). In contrast to studies of left hemisphere asymmetry, sex differences have been reported (Marcel & Rajan, 1975; Knox & Kimura, 1970; Levy & Reid, 1976; Witelson, 1977b), with girls typically not showing the same degree of lateralization as boys.

Developmental studies are sparse in this area. Two of the most complete have been carried out by Witelson (1974, 1977b) who devised a dichotomous stimulation shape discrimination test, presented in the haptic modality. Since the discrimination of shape that is not readily coded verbally has been demonstrated to be largely a function of the right hemisphere (Milner & Taylor, 1972), two meaningless, "nonsense" shapes, not easily labelled, were presented simultaneously, out of view, one to each hand. Competing stimuli thus vied for transmission to the hemisphere specialized in processing such information. If the processing were in the right hemisphere, then the contra-lateral, or left hand, should have the advantage of initial direct transmission, and more correct detections should occur with it than with the right hand.

Witelson's response format required each subject to pick out the two palpated stimuli from a visual display of six shapes which had many of the holistic properties of the explored stimuli. Ten such trials were given and the number of correct responses were determined for each hand. It was found that normal boys ranging in age from 6 to 14 years had greater left hand accuracy, indicating right hemisphere specialization for spatial processing (Witelson, 1974). Similar results were also reported with a much larger sample of normal boys of ages 6 to 13 (Witelson, 1977b). The author interpreted her results to mean that normal boys demonstrated right hemisphere specialization as early as 6 years of age.

Flanery and Balling (1979) studied developmental changes for right hemisphere specialization in 1st, 3rd and 5th grade school children and a group of adults. They used a variation of the Witelson task but required a same-different response format in which the match was also to an haptic rather than a visual criterion. In addition, the authors reported that they changed some of the shapes to make them less amenable to verbal labelling. A measure called a laterality coefficient which corrected for differences in level of response between groups was also used. Contrary to Witelson, they found age differences in hand advantage. The left hand (right hemisphere) was more accurate than the right hand (left hemisphere) for fifth grade children and adults, but not for 1st and 3rd grade children. The authors attributed these effects to the greater sensitivity of their materials and procedures to age differences. However, it is possible that asymmetry in young groups was obscured by the difficulty of the task and by the same-different format which encourages guessing. Moreover, when data were analyzed using the same procedure as Witelson's (analysis of variance with repeated measures for hands), no age by hand interaction was found. It appears that further study with age appropriate materials and longitudinal samples will be needed before firm conclusions can be drawn regarding age trends.

Few studies have compared normal and learning disabled populations. Witelson (1976a) reported that dyslexic boys of ages 6 to 13 demonstrated no hand asymmetry on her dichhaptic task in contrast to normal male readers who exhibited a left hand advantage. Although the total number of correct detections did not differ between groups, the right hand scores of the poor readers were significantly higher than those of the normal group. On a task which involved letter shapes, a verbal rather than spatial stimulus, normal readers exhibited a right hand superiority whereas the disabled readers exhibited better left hand recognition. Moreover, they made more correct left hand detections than normal readers but fewer correct right hand detections. Witelson concluded that, taken in total, these results could mean that poor readers have:

(1) bilateral representation of spatial functions, that is, a lack of right hemisphere specialization for spatial processing;

(2) dysfunction in left hemisphere processing of verbal functions.

It was suggested that the reading difficulties in the disabled group could stem from the left hemisphere being required to perform the usual functions of the right hemisphere as well as its own. Interestingly, normal girls (who were good readers) also manifested bilateral spatial representation and so Witelson suggested that perhaps they might have greater neural plasticity which would account for their lower incidence of reading problems. She speculated that the brain may be a "sex organ" (1976b) with somewhat different cognitive specializations in males and females.

Some writers, for example Rourke (1978), Satz (1976), have found Witelson's interpretation somewhat perplexing. Objections appear to focus on the explanation that bilateral spatial representation can be at the same time indicative of enhanced plasticity in one sex, but of deficient functioning in the other. Further, Rourke (1978) has commented that it seems inconsistent that bilateral representation for spatial processing should be found in reading disabled boys since there is considerable evidence that they perform well on spatial tasks which demand integrity of the right hemisphere (Guyer & Friedman, 1975; Lyle & Goyen, 1969; Symmes & Rapoport, 1972; Vellutino, Steger & Kandel, 1972). Studies which have subtyped disabled readers according to visuospatial versus other competencies have found a low evidence of poor readers characterized by visuospatial problems (Boder, 1973; Mattis et al., 1975).

Although no other known studies have compared disabled and normal learners in the haptic mode, Marcel and Rajan (1975), using visual half-field procedures found that poor readers actually had greater asymmetry than good readers. On the other hand, Yeni-Komshian, Isenberg and Goldberg (1975), again in the visual modality, found poor readers to have less lateralization of function in that they showed deficient right hemisphere function for spatial material. Witelson (1976a) reported appropriate lateralization for good readers but no significant lateralization for poor readers. Pirozzolo (1978), reviewing these divergent results, suggested that subgroups may account for the contradictory findings. Given these inconsistent results and the speculation that reading disabled subtypes may exist with differing patterns of hemisphere specialization, it would be of considerable interest to examine the performance of the two subgroups in the present study on tasks representing both left and right hemisphere function. This is particularly so since the two groups have been shown to differ on Factor 1 subtests derived from the WISC-R performance scale which has been largely considered to reflect right hemisphere function, and on Factor 3 which is more representative of left hemisphere activities.

Summary and research objectives. In conclusion, the literature has suggested that there is considerable controversy over how much and in what way cerebral dominance develops. Some evidence has been presented to suggest that hemisphere specialization may not develop significantly over time, but may be relatively fixed and invariant from birth. If this were so, and if learning disabilities were related to patterns of hemisphere specialization, then one might hypothesize that the learning disabled would exhibit a pattern of lateralization that is different from that of normal learners. This is in contrast to the popular maturational delay hypothesis which sees a lag in the development of normal hemisphere specialization patterns as the basis for reading/learning disorders.

Although results from studies with disabled populations are less consistent than those with normal populations, there is some reason to believe that learning disabled boys may exhibit a pattern of hemisphere organization that is different from that of adequate male readers. The inconsistency of results with heterogeneous groups of disabled subjects has encouraged speculation that different subgroups of disabled readers and learners may have different patterns of hemisphere lateralization. Since the patterns of factor scores demonstrated by the Consistent Factor 3 and Inconsistent groups can be associated with WISC subscale discrepancies, and thereby related to hemisphere function, it would be of interest to determine if the Consistent Factor 3 group which exhibits atypical WISC-R factor score discrepancies also exhibits atypical hemisphere specialization patterns as measured by the dichotic and dichhaptic stimulation tasks.

It is recognized that, given the indirect nature of the measurement techniques and the questions regarding the validity of the instruments, evidence concerning hemisphere specialization must be interpreted with much caution. The literature suggests that 3 possible relationships and interpretations might be hypothesized: (1). If low factor 3 scores are associated with impaired left hemisphere function, then it might be expected that the Consistent Factor 3 group would fail to exhibit an REA relative to the Inconsistents who have significantly higher factor 3 scores. (2). However, if as Witelson suggests, deficient verbal-sequential functioning may be associated, not with abnormal left hemisphere specialization, but with abnormal right hemisphere speciali-zation for spatial processing that possibly interferes with verbal processing because both are in the left hemisphere, then it might be expected that the Consistent Factor 3 group would display a typical REA, along with atypical hand advantage scores on the dichhaptic stimulation task. Further, this atypical hand advantage pattern should be negatively correlated with performance on verbal, sequential tasks such as right ear dichotic recall and the temporal/temporal form of TESP. (3). Or, again, if as others have suggested (Kinsbourne, 1975; Obrzut, 1979), left ear scores (and presumably right hand scores) are intrusion errors reflecting failure to attend selectively to the central stimuli, then failure to display normal patterns of lateralization (REA and LHA) could be associated with low selective attention scores, high scores on incidental learning and low embedded figures performance. In particular, right hand and left ear scores should correlate positively with incidental learning scores, since all would be measures of susceptibility to intrusions.

Re-statement of General Research Direction

The foregoing review of developmental trends and differences in able and disabled learners in 4 main areas has pointed to the need for an investigation of these functions in subgroups within the learning disabled population. Specific research objectives concerning possible differences between the subtypes identified in Study No. 1 were stated at the end of each separate literature review, and so will not be reiterated here. Several broad questions can be posed to present an overall focus for the account of Study No. 2 which follows:

1. Do the two subgroups that differed as to consistency and levels of factor 3 functioning also differ as to levels of attentional selectivity and/or sequential processing, two processes which have been identified in the literature with factor 3 functioning?

2. Can the levels of functioning in the attentional and sequential processes be understood in relation to the control processes used to perform the tasks, or in relation to the levels of recall on tests varying as to spatial versus sequential presentation and response modes?

3. Given the observed subgroup differences in WISC-R factor score disparity, are there also subgroup differences in hemisphere specialization patterns as measured by dichotomous stimulation tasks?

4. Is there evidence to suggest that hemisphere patterns may underlie functioning in the other processes? Can the observed patterns of hemisphere specialization be related to the observed functioning in the other dependent variables and functioning on the WISC-R?

There now follows an account of the investigation designed to throw light on some of these questions.

Methods and Materials

Subjects

Subjects were drawn from the Consistent Factor 3 and Inconsistent subgroups defined in Part I of this investigation. To decrease variability in the age range, only those boys who were between the ages of 12 years 6 months and 15 years 6 months at the beginning of this test program were included. One individual was unavailable because of illness and so fifteen subjects remained in the Inconsistent group. For ease of analysis, an equal number of subjects was drawn at random from the Consistent Factor 3 population. Written consent for further testing was obtained from the parents and verbal consent was given by each of the 30 subjects.

Since no similarly tested group of able learners was available for study, access was obtained to a group of boys who were from the same school jurisdiction as the learning disabled samples and who were being studied concurrently in a developmental study of normal readers supervised by the Department of Educational Psychology, McGill University (McLean, 1979). This sample of able learners was originally selected by McLean (1979) on the basis of age (mean = 164.7; months standard deviation = 1.4) and teacher opinion concerning their abilities as average readers. Details of selection and sample characteristics are described more fully in McLean (1979). Because this group of normal learners differed significantly in I.Q. (mean = 116.0; standard deviation = 10.5) and in age variability from the disabled learners in this study, they were not included in direct statistical comparisons with the disabled subtypes but rather were studied to provide data as a basis for general contrast and interpretation. They are called "able" learners in this investigation to differentiate them from the "disabled" learners.

Instruments and Procedures

Achievement tests. Evidence about the general reading and spelling competence of the three populations was obtained using the age appropriate Speed and Accuracy subtest of the Gates-McGinitie Reading Tests (survey D-Form 2M or Survey Form 1M), the Slosson Oral Reading Test, SORT, (Slosson, 1963) and the spelling subtest of the Wide Range Achievement Test (Jastak & Jastak, 1965). These instruments are widely used standardized measures and yield results in terms of grade level and/or standard scores. Reliability and validity information are contained in the manuals accompanying the tests.

Tests of attentional selectivity. A six-item version of the well-known Hagen Central-Incidental Learning Test (Hagen, 1967) was administered in a successive temporal format according to instructions published by Tarver et al. (1976). Materials and specific instructions are in Appendix D . Each of the six cards pictures an animal and a household object and was displayed consecutively for 2 seconds, then turned face down in front of the subject. After the sixth card had been displayed, the subject was shown a card with only an animal on it and was asked to indicate which of the face-down cards had pictured that particular animal. The same animals and household objects appeared each time but the order was different (see Appendix D). The procedure was repeated 12 times, each serial positon probed twice in an order chosen at random. The same order was maintained for all subjects, but to control for effects of fatigue or boredom, the starting position in the series was systematically rotated among subjects. The number of correct position detections was the measure of central learning for a maximum total score of twelve. Following the completion of the serial probes, the subject was given a set of animal pictures and a set of household object pictures and was unexpectedly asked to pair or match them as they had been on the cards. This was the measure of incidental learning, for a maximum score of six.

Following the completion of the test, subjects were asked to describe and to demonstrate how they had remembered the order of the animals.

A second measure of attentional selectivity, a paper and pencil embedded figures test was also used in this study (Thurstone, 1944). This instrument presented the subject with a figure accompanied by four drawings. The subject was asked to determine if the designated figure was hidden in the drawings and to place a check mark beside the drawing if it contained the figure, a zero if it did not. Ten minutes were allowed for completion of the test which contained 35 items. Maximum score was (35 x 4) = 140. Complete instructions and sample items appear in Appendix D.

Measures of use of control processes. The Weener[1] Test of Varying Linguistic Structure consisted of ten-word strings that varied according to 4 levels of linguistic organization: no associations and no syntax (nasswo), no associations with syntax (nassw), associations without syntax (asswo) and associations with syntax (assw). Test materials and precise instructions for its administration appear in Appendix D. Six examples of each type of structure for a total of 24 strings were given in an order that was determined randomly. The strings were pre-recorded on tape and presented auditorily without intonation or inflection over headphones at the rate of approximately two words per second. A Wollensak cassette player[2] with listening station outlets for both experimenter and subject was used. Following presentation of each string, the experimenter stopped the tape and signalled to the subject to recall, in any order, as many of the words as possible. Score was total number of words correctly recalled. In addition, the order of report for each word was tabulated so that recall strategies could be inferred. All subject responses were recorded for verification of scoring.

A further measure of strategic control was obtained following the central-incidental task when the subject was asked to describe and demonstrate rehearsal strategies. Serial recall curves were then plotted to infer presence or absence of rehearsal procedures. Numbers of correct detections, corrected for response bias (Donaldson & Strang, 1969) were plotted against serial position.

Measures of temporal-spatial processing. A test to explore spatial versus temporal order processing (TESP) was devised for use in this investigation (Appendix D). TESP consisted of novel figures given in both spatial and temporal presentations and required both types of response modes. There were, therefore, four variations: spatial to spatial, spatial to temporal, temporal to spatial and temporal to temporal. In the temporal presentation forms, the figures or symbols appeared on separate cards. In the spatial presentations the figures appeared on grids. This technique allowed the same novel symbols to be used in both temporal and spatial modes and the confounding effect of item translation was eliminated. Skill in translation between spatial and temporal dimensions could then be more precisely determined. Since the same novel items were used at each level in the test and the subject was supplied with the items or figures, being required only to reconstruct the spatial or temporal order of the presentation, processing load for item was minimal, allowing order memory to determine the span. Pilot testing at grades 2, 4 and 7 indicated that all subjects as young as the grade four level could readily label the items. Instructions were designed to be intelligible to subjects as young as seven years. To insure the test could be used with younger children, practice trials with as few as 2 items were included and the test was devised in levels of varying difficulty as represented by varying numbers of symbols. Three test trials were given at each level. The order for presentation of the symbols was randomly chosen from all possible presentation orders at each level with the exception of the deletion of those orders which were represented by a diagonal on the spatial grid.

Every subject was given all 4 test variations, the order of administration being randomly determined for each individual. Presentations were one week apart. Time allowed for viewing the symbols varied according to the number of symbols in each presentation; one second was allowed for each. Therefore, on the spatial presentations 3 seconds was allowed for grids with 3 positions, 4 seconds for grids with 4 positions, and so on. An interval of 5 seconds was imposed between end of presentation and response, but no time limit was placed on the response. A score of one point was given for each correct response for a maximum of 12 points on each test form. Complete instructions for practice trials and for administering each form of the test appear in Appendix D.

<u>Measures of hemisphere specialization: Dichotic digits test</u>. The dichotic digits test presents verbal stimulation (digits) to both ears simultaneously so that more correct digits are presumed to be recalled from those numbers presented to the ear most directly connected (contralateral) to the hemisphere with language representation. It includes 24 three-digit pairs, twelve of which were presented on tape at the rate of two digit pairs per half second and the other twelve at the rate of two digit pairs per one and a half seconds. The tape, made available through the courtesy of Mr. Laughlin Taylor of the Montreal Neurological Institute, was a replica of that used by Taylor (1962) and

Kimura (1961) and was produced by the Department of Psychology, Montreal Neurological Institute. Because evidence in the literature (Obrzut, 1979) suggested that ear switching could occur as a result of boredom during lengthy test procedures, the number of trials was restricted to those considered necessary for reliable results.

Digits were presented by means of a Realistic Portable Stereo Cassette System Model #MD-200 with the earphones being counterbalanced both intra-individually and inter-individually to control for possible channel effects. Recall from the right and left ears was totalled separately. A grand total for both ears was also obtained. Total possible score for each ear was 72 with grand total being 144. A copy of the test and specific instructions for administering are in Appendix D.

Measures of hemisphere specialization: Dichhaptic stimulation test. This test was designed to measure non-linguistic, spatial processing and to enable inferences to be made concerning hemisphere specialization for such processing. It consisted of five pairs of non-linguistic "nonsense" shapes presented twice, once to the right and once to the left, for a total of ten trials each. For the test adminstration, the subject sat facing the examiner with a large cardboard screen placed between them to ensure that the subject could not see the shapes. Two small openings were provided at the bottom of the screen through which the subject placed his hands positioned with wrists flat and index and third fingers raised. The examiner placed a Bristol board, with the two shapes glued 4 inches apart, under the hands so that when the fingers were dropped the shapes were felt. The shapes were palpated simultaneously for ten seconds with the second and third fingers only and arm movements were prevented so that only contralateral and ipsilateral processing was involved. Following manipulation of the shapes, the subject was asked to respond by pointing with the index finger of the left hand to the two palpated shapes on a visual display of 6 shapes which contained the two palpated shapes, as well as two distractor shapes and two other shapes from the test materials. Different recognition displays were used for each trial. This procedure was repeated 10 times. Correct detections were scored for each hand separately and a grand total for both hands was also obtained. Total possible score for each hand was 10, with grand total being 20. Complete instructions and a description of test material are presented by Witelson (1974)[3].

General Procedures and Data Analysis

All testing was carried out during regular school hours in a private area made available for this purpose by the home school of each subject. The complete test program was carried out in four separate sessions held one week apart. Each test period lasted approximately one hour and, insofar as possible, the following schedule was maintained:

Day 1 TESP 1, Weener Test, Harris Test of Dominance.

Day 2 TESP 2, Dichotic digits, Central-Incidental Test.

Day 3 TESP 3, Dichhaptic Stimulation Test.

Day 4 TESP 4, Group tests: Reading, Spelling, Embedded Figures.

The standardized achievement tests for reading and spelling and the embedded figures test were administered in small groups jointly by the author and an assistant. The Weener Test of Varying Linguistic Structure and the Dichotic Digits Test were recorded on tape and administered by the assistant to part of the group. All other testing of the disabled learners was done by the author.

Data for normal learners were obtained jointly with McLean (1979). She personally administered the Wechsler Intelligence Test (revised), the Dichotic digits, TESP, (which she reported on as the MacKenzie Spatial-Temporal Test) and the academic achievement tests. The Central-Incidental Test, the Dichhaptic Test, the Weener Test and the Embedded Figures Test were administered concurrently by the author of this investigation.

Comparisons between learning disabled subtypes were carried out for all variables using analysis of variance procedures (BMDP77; 1977). Multiple mean comparisons were made using Duncan's New Multiple Range Test with appropriate error terms delineated by Kirk (1968). Inter-correlations among test scores were determined within and between groups. Stepwise discriminant analyses were carried out to see which tests best differentiated the groups. Finally, all measures which produced significant group differences were regressed against the various WISC-R factor score indices in stepwise fashion to determine which of the identifying factor score indices were best predicted by the differentiating measures.

Results and Discussion

Raw scores and descriptive statistics for all variables for the subsamples of disabled and normal learners are included in computer print out form in Appendix E.

The age, IQ and factor scores of the Consistent Factor 3 and Inconsistent subtypes as measured by the WISC/WISC-R over three assessments are presented in Table 10. Because these were selected subsamples of the populations described in Study No. 1, separate analyses of variance were carried out to ascertain if the comparative characteristics of the

Table 10. Means and standard deviations of defining variables for Consistent Factor 3 and Inconsistent learning disabled samples over 3 assessments, and for able learner groups on one assessment. N=15 each group.

	Consistent Factor 3		Inconsistent		Able Learners	
Assessment	Mean	sd	Mean	sd	Mean	sd
I						
Age	92.9	8.9	91.3	12.0		
IQ						
Full scale	101.7	11.5	98.3	9.7		
Verbal	97.0	10.5	98.1	12.4		
Performance	106.3	14.1	98.8	10.5		
Factors						
1.	34.5	7.1	30.5	5.9		
2.	33.3	5.0	30.3	7.5		
3.	25.0	5.3	27.5	4.0		
II						
Age	127.6	11.4	126.9	10.4		
IQ						
Full scale	100.5	10.3	94.2	8.3		
Verbal	95.7	8.4	97.1	8.9		
Performance	104.6	15.1	94.3	10.4		
Factors						
1.	34.6	8.1	27.5	5.2		
2.	30.3	5.4	27.5	5.9		
3.	24.1	5.0	27.0	5.8		
III						
Age	169.3	12.4	169.3	12.9	164.7	1.4
IQ						
Full scale	99.2	8.8	91.2	6.1	116.0	10.5
Verbal	93.7	9.2	90.1	8.3	113.1	10.1
Performance	107.2	11.3	97.1	8.9	115.8	12.5
Factors						
1.	37.0	6.3	27.1	5.9	36.1	6.2
2.	28.1	5.4	25.7	4.0	37.1	4.7
3.	23.2	3.1	26.4	3.7	34.9	6.4

groups were similar to those for the total populations. These analyses (Appendix F) indicated that the subsamples retained the characteristics of their total populations. That is, the groups differed over time on factors 1 and 3, but not on factor 2 with the Consistent Factor 3 group showing wide disparity and the Inconsistent group minimal variation across mean factor values. As before, there was a trend for the Consistent Factor 3 group to have higher performance scores, and therefore higher full scale IQ scores than the Inconsistent group, but the groups did not significantly differ on verbal IQ scores. Further, as before, full scale and performance IQ values differed significantly between groups only on the final assessment. Since it appeared likely that the increasing IQ disparity could be a result rather than a cause of differences in other psychological processes, and since the groups were matched on the verbal score, and had been equated on full scale IQ scores on the first and second assessments, it was decided not to covary IQ when carrying out subsequent comparative analyses.

IQ scores for the able learner group, which were for one test occasion only, appeared to be considerably higher than those of the disabled groups (Table 10). Factor scores were also at a high level and, like those of the Inconsistent group, had little variation or disparity. These findings are in general agreement with those of Ackerman et al. (1976) reported in Chapter II. Although mean age of the able learners was similar to that of the disabled groups, the wide difference in standard deviations was a factor that precluded making meaningful statistical comparisons between them and the disabled groups.

It should be noted that the two disabled groups were remarkably similar as to mean age and age variability (Table 10).

Measures of Academic Achievement

Mean grade level scores for reading and spelling measures were lower for the Consistent Factor 3 group than for the Inconsistents (Table 11), although t-test comparisons indicated that none of the differences were statistically significant.

Table 11

Means and standard deviations of reading and spelling achievement variables for Consistent Factor 3, Inconsistent and Normal Learner groups

Subject	Consistent Factor 3 Mean	Consistent Factor 3 sd	Inconsistent Mean	Inconsistent sd	Able Learners Mean	Able Learners sd
	grade levels					
Reading						
Speed	6.0	2.8	6.6	2.6	11.1	1.6
Accuracy	5.7	2.8	6.0	1.9	10.8	2.1
Word recognition	5.9	2.0	6.8	1.9	--	--*
Spelling	4.5	1.4	5.0	1.6	9.4	1.7

* Not administered because of insufficient ceiling on the test.

There was a trend for differences between the Consistent Factor 3 and Inconsistent subtypes to be significant on the speed index of the Gates-McGinitie ($t = 1.709$, $df = 8$, $p = .098$) and on word recognition as measured by the Slosson Oral Reading Test ($t = 1.801$, $df = 28$, $p = .083$). Since the latter test also required responses within a time limit, processing or response speed may be a variable that if tested with greater precision would show subtype differences. That scores on the two variables were significantly correlated in the Consistent group ($r = 0.73$, $p = .002$), but not in the Inconsistent group ($r = 0.27$, $p = .32$), supported this notion. In general, it must be concluded that the two disabled subtypes were not readily distinguishable from one another on the basis of these gross measures of achievement.

Inspection of the scores of the able learners, who it will be remembered, were drawn from the same school population as the disabled learners, and who were judged by their teachers to be "average" readers and spellers, shows them to be approximately 4 to 5 grade levels above the achievement levels of the disabled groups on all tested academic variables. Mean expected grade level, as determined on the basis of present age minus age of entrance according to regulations for the school system, was approximately 8.6 for both the disabled and able learner groups, indicating that both the disabled subtypes performed two or more grade levels below expectancy on all the achievement measures, with the able learners being two grades above in reading and one grade above in spelling. The disparity between actual grade level scores of those reported to be average learners and their teachers' rating is of interest and could suggest that the actual average learners (that is, those who would normally achieve at grade level) may have been subsumed in the learning disabled population.

Measures of Selective Attention

The central-incidental task. Consistent Factor 3 subjects processed significantly less incidental information than the Inconsistent group (Table 12). Since significant differences occurred on the incidental scores, it was considered appropriate to compare the groups on the selective attention efficiency index (% central learning - % incidental learning). The Consistent Factor 3 group was found to have significantly higher selective attention efficiency (Table 12). Therefore, contrary to hypotheses based on speculative comments in the literature that low factor 3 scores were associated with distractibility (Kaufman, 1975; Rugel, 1974), the Consistent Factor 3 group with low factor 3 scores did not seem to be as distractible as the Inconsistent group whose factor 3 scores were significantly higher.

Table 12

Comparison of incidental learning[1] and selective attention scores for Consistent Factor 3 and Inconsistent groups

Variable	Groups: Consistent Factor 3		Groups: Inconsistent				
	$\bar{x}$	sd	$\bar{x}$	sd	df	t	p
Incidental learning	1.7	.38	2.1	.53	28	2.10	.04
Selective attention	34.4	5.54	28.1	9.56	28	2.21	.04

[1] Square root conversion

No significant group differences in amount of central learning were found when a 2 (groups) x 6 (serial positions) analysis of variance with repeated measures for serial position was used (Table 13).

Table 13

Analysis of variance for central learning scores as a proportion of items correct at each serial position[1] for Consistent Factor 3 and Inconsistent groups

Source of variance	df	Mean square	F	p
between groups	1	4867.20	1.24	.27
error	28	3914.05		
position	5	3005.06	3.70	.004
position x group	5	380.85	.47	.87
error	140	812.21		

[1] Corrected for response bias (Donaldson & Strang, 1969).

The significant F value for positions was explored using Duncan's New Multiple Range procedure (Kirk, 1968) and revealed that higher scores occurred at the primacy and recency positions, but not at any other position (Figure 5). This was true for both groups as indicated by the nonsignificant group x position interaction.

Correlations between central and incidental learning scores were negative and nonsignificant in both groups (Table 14). The r value was

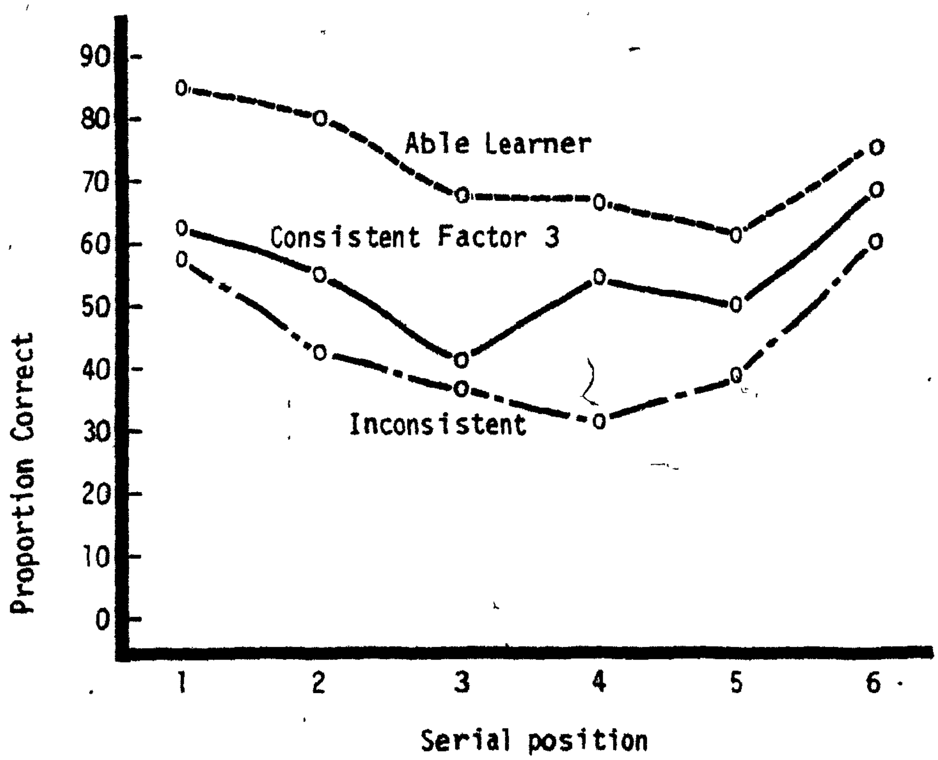


Figure 5. Central learning scores, proportion of items correct at each serial position for Consistent Factor 3, Inconsistent and Able Learner groups.

Table 14

Intercorrelations among measures of selective attention

within Consistent Factor 3, Inconsistent and Able Learner groups.

	Consistent Factor 3			Inconsistent			Able Learner		
	central learning	incidental learning	selective attention	central learning	incidental learning	selective attention	central learning	incidental learning	selective attention
embedded figures	-0.41	0.56**	-0.60**	0.47[t]	-0.17	0.33	0.34	0.06	0.21
central learning		-0.23	0.79**		-0.45[t]	0.79**		0.01	0.11
incidental learning			-0.75**			-0.90**			0.03

** $p < .01$

t $p < .10$

greater in the Inconsistent group, however, and approached significance ($p = .10$). Because of the large number of maximum incidental learning scores in the Inconsistent group, a ceiling effect may have attenuated the trade-off between central and incidental learning. It is therefore plausible that low central learning in the Inconsistent group could be related to a tendency to process incidental information, i.e., to be distractible.

Although the Consistent Factor 3 group processed fewer incidental stimuli, they did not perform significantly better on the central learning task. This, along with the nonsignificant nature of the central-incidental relationship encourages speculation that their failure to outperform the Inconsistent group in central learning was related to some cognitive process associated with the task itself. Thus, in terms of patterns of performance as developed from the review of literature (page 80), the Consistent Factor 3 group conformed most closely to pattern 2. The Inconsistent group, however, with low central learning, high incidental learning and a trend to significant negative correlations between the two scores conformed most closely to pattern 1 which has been previously interpreted as suggesting distractibility.

Embedded figures. Scores on the embedded figures task did not significantly differentiate the two groups (Table 15). Moreover, when the embedded figures scores were correlated with other measures of selective attention (Table 14), two very different patterns of relationships were obtained within each of the groups. In the Consistent Factor 3 group, the embedded figures scores were significantly correlated with the incidental learning and selective attention indices, but, surprisingly,

Table 15

Comparison of mean values on embedded figures scores for Consistent Factor 3 and Inconsistent groups

	Mean	sd	t	df	p
Consistent Factor 3	81.5	18.2	1.04	28	.31
Inconsistent	73.9	21.5			

in directions opposite to those that would be predicted if all were measures of selective attention since scores on the embedded figures task were positively related to scores on the incidental learning task and negatively related to scores on the selective attention index. In the case of the Inconsistent group, it was found that the embedded figures scores were not significantly related to either incidental learning scores or the selective attention index, although the relationships were in the direction predicted if all were measures of attentional selectivity. Given the foregoing results, it is not unexpected that associations between central learning and embedded figures were in opposite directions in the two groups (Table 14).

These results are in agreement with Peters (1979) who found there was little relationship among the various purported tests of selective attention and provide support for the contention of Douglas and Peters (1979) that studies using selective attention tests should not under-emphasize the importance of the other cognitive processes measured by these tasks.

Self-report of rehearsal strategies. The relatively high scores observed in the primacy position of the serial curves suggested that both learning disabled groups used some form of control strategy to maintain items in short term memory. This was confirmed by the subjective accounts of the individuals in which 10 of 15 in the Consistent Factor 3 group and 9 of 15 in the Inconsistent group reported using some form of cumulative rehearsal over the 12 trials with an additional two subjects in each group indicating they had used cumulative rehearsal for at least a portion of these trials. Other strategies such as paired association with position tag and labelling were also used by an equal number of subjects in each group with one subject in the Inconsistent group having reported using a non-verbal procedure. Thus, it appeared on the basis of self-report that the rehearsal procedures used were similar in both groups. Although the elevated, somewhat flattened portion of the serial curve at positions 4, 5 and 6 suggested that those in the Consistent Factor 3 group also might have used some form of chunking of the last three items, none of these subjects reported using this strategy, nor was it apparent when they demonstrated how they had remembered the animal positions. There is, then, no compelling evidence either from analysis of learning curves or from their own subjective accounts to suggest differences between these subgroups in the use of rehearsal. strategies on this task.

General comparisons with able learners. The literature had indicated that the expected response pattern of able learners at the age under investigation would be that of pattern 3 (high central scores, low incidental scores with a high negative correlation between the two).

But, in the present sample of able learners, although the mean proportion of correct responses on the central learning task was high, being over 80% with several individuals achieving maximum scores, incidental learning scores were also high ($\bar{X}$ = 3.1), and there was a zero correlation (r = -0.005; p = 0.98) between the two variables. Thus, a type 4 pattern was found, indicating that the memory load on the central task had probably not been sufficient to elicit a trade-off between central and incidental learning in this group.

An inspection of the serial learning curves of the able learners in relation to those of the Consistent Factor 3 and Inconsistent groups (Figure 5) indicated that the able learners' responses were relatively high in that portion on the curve (primacy) which Crowder (1976) has hypothesized to be under the influence of control processes such as rehearsal strategies. Differences between able and disabled learners were relatively less in the recency portion which is purported to be influenced by structural processes.

Rehearsal strategies in the able group, according to self-report, were characterized by cumulative rehearsal and by chunking. Demonstration revealed that these subjects verbally rehearsed at the end of every second or third item only. This form of chunking could have facilitated learning since it allows more time to attend to each individual stimuli and is of particular interest because none of the learning disabled subjects displayed this procedure during their demonstrations of rehearsal procedure.

Evidence Concerning the Use of Control Processes: Weener Strings

No group differences in total recall of words across all 4 levels of structure were revealed using a 2 (groups) x 4 (level of structure) analysis of variance with repeated measures on structure levels (Table 16). The significant group x level of structure effects indicated that there were group differences in response to levels of structure (Figure 6). It can be observed that there was greater variation in level of response to increasing structure in the Consistent Factor 3 group. Application of the New Duncan Multiple Range procedure (Kirk, 1968) revealed significant between group differences on recall of unstructured strings (nasswo) and in the recall of strings with both associations and syntax (assw) (Table 17). The Consistent Factor 3 group performed more poorly than the Inconsistent group on the strings without structure (nasswo) but better than the Inconsistent group on the strings which were most highly structured (assw). There were, however, no significant group differences on the strings with intermediate levels of structure, associations without syntax (asswo) and no associations with syntax (nassw).

Order of difficulty was the same for both groups with recall improving at each level of increased structure from nasswo through nassw and asswo to assw. However, the differences in difficulty between the unstructured strings (nasswo) and strings with syntactical but no associational structure (nassw) were not significant in either group.

Correlations among the test forms were somewhat different within each of the two groups (Table 18). In the Consistent Factor 3 group, relationships were high among all forms of the test which could suggest that a common factor may have operated across test forms to affect

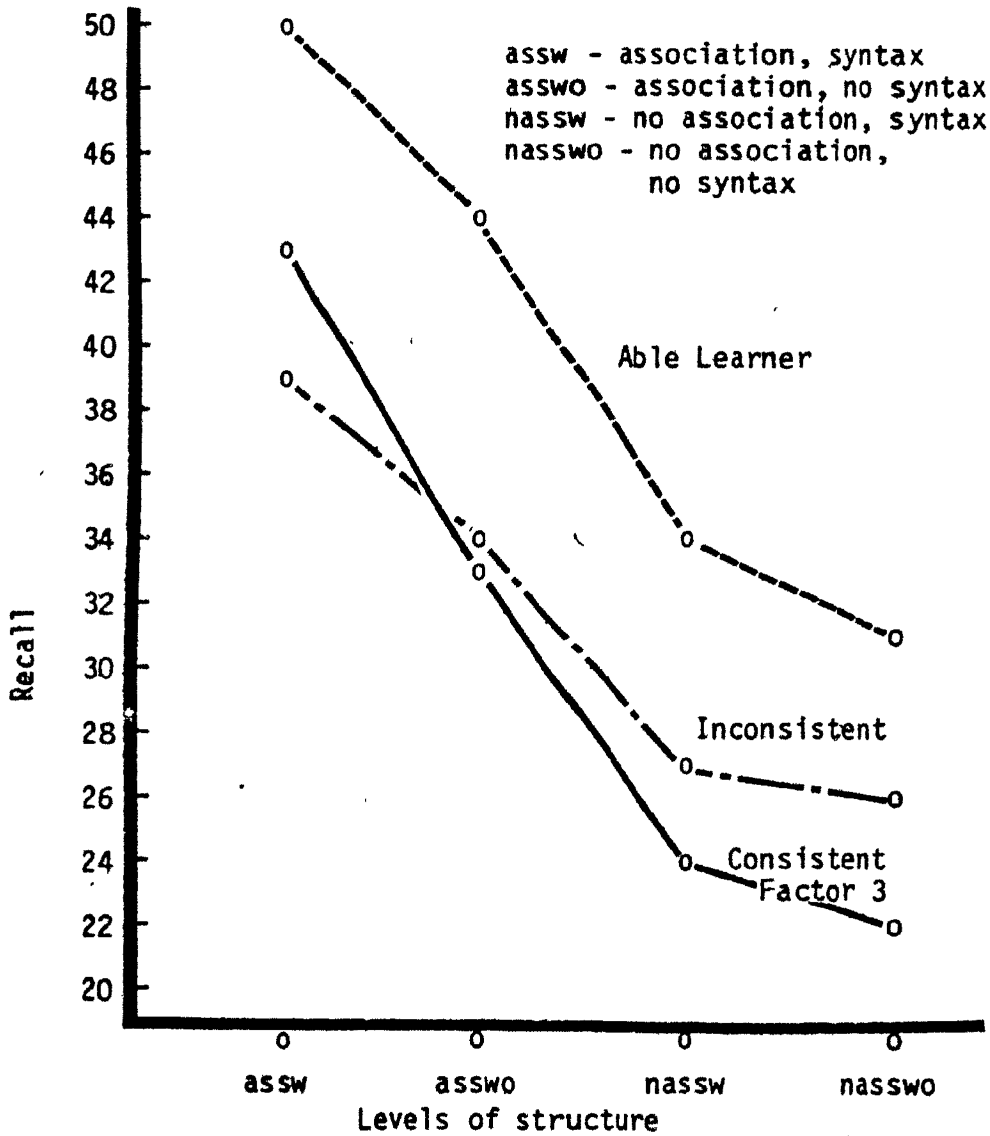


Figure 6. Mean scores obtained by Consistent Factor 3, Inconsistent and Able Learner groups on word strings varying as to level of structure.

Table 16

Analysis of variance for recall of word strings on 4 levels of structure for Consistent Factor 3 and Inconsistent groups

Source of variation	df	Mean square	F	p
between groups	1	21.68	.21	.65
error	28	101.86		
level of structure	3	1743.48	175.48	< .0001
level x group	3	89.43	8.99	< .0001
error	84	9.95		

Table 17

Mean values for level of structure for Consistent Factor 3 and Inconsistent groups

Group	Strings			
	assw	asswo	nassw	nasswo
Consistent Factor 3	42.5[a*]	32.6[b]	24.3[cd]	22.0[d]
Inconsistent	38.4[b]	33.7[b]	26.5[c]	26.1[c]

* Scores followed by the same letter are not significantly different.

Table 18

Correlations among the four forms of the Weener Test for recall of word strings varying as to structure, Consistent Factor 3, Inconsistent and Able Learner groups

	Consistent Factor 3			Inconsistent			Able Learner		
	assw	asswo	nassw	assw	asswo	nassw	assw	asswo	nassw
nasswo	.87**	.86**	.81**	.53*	.44	.27	.63*	.19	.35
assw		.77**	.83**		.89**	.55*		.54*	.71**
asswo			.74**			.78**			.55*

* $p < .05$

** $p < .01$

functioning in this group. In the Inconsistent group, correlations were generally lower and scores on the unstructured strings were related only to those on the most highly structured strings (assw).

To determine if the heightened sensitivity to structure observed in the Consistent Factor 3 group was equally true for the two main types of structure used, a 2 (groups) x 2 (associations) x 2 (syntax) analysis of variance was carried out (Appendix F, Table 4). Significant group interaction effects were found for both association, F (1, 28) = 14.04, $p < .0008$; and syntax, F (1, 28) = 11.08, $p < .003$. In both instances recall by the Consistent Factor 3 group was numerically lower than that of the Inconsistent group in the less structured conditions, but higher than the Inconsistent group in the more structured conditions. Thus, the results of both types of analyses supported the conclusion that the Consistent Factor 3 group exhibited greater variation in recall across differing levels of structure, and in accordance with interpretations in the literature, suggested that they were more sensitive than the Inconsistent group to the organizational levels. Therefore, they may also have had a greater use of facilitative control processes on those strings for which there were significant differences in recall level.

If group differences in level of recall on the unstructured (nasswo) and most structured (assw) strings were the result of differences in the use of appropriate strategies, then this should be reflected in group differences in (1) the shape of the recall curves (Pike, 1977) as supported by a group x serial position interaction effect when an analysis of variance for recall at each serial position is carried out; (2) recall strategies as determined by the order in which items were reported in a free recall procedure. Moreover, the two indices should confirm each other since order of report and accuracy of report have been previously demonstrated to be related (Bauer, 1977; Wilson, Witroyl & Hust, 1975).

Use of control processes on unstructured strings (nasswo). Serial recall curves for the unstructured strings were plotted for Consistent Factor 3 and Inconsistent subtypes using proportion of items correct as a function of serial position (Figure 7). The Consistent Factor 3 group produced a fairly typical bowed serial recall curve with an elevated recency portion at items 8, 9 and 10. The curve of the Inconsistent group appeared to be composed of two adjacent serial curves with elevated recall at items 1, 6 and 10.

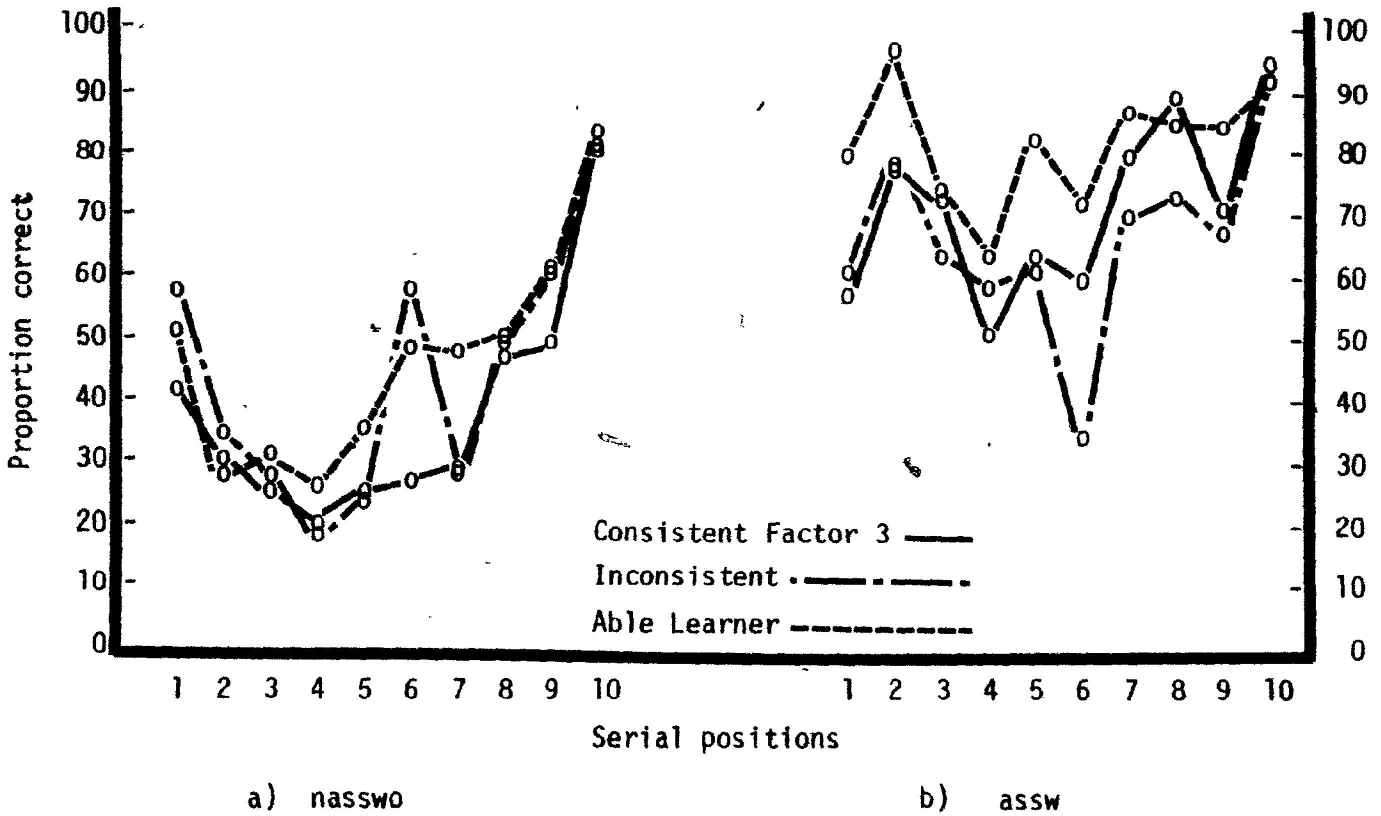


Figure 7. Mean proportion of correct responses at each serial position on strings without structure (nasswo) and on strings with association and syntax (assw) for Consistent Factor 3, Inconsistent and Able Learner groups.

Previous research has suggested that when free recall of serially presented items is required the most elementary strategy is to rehearse and recall items in the order of their presentation (Moely, 1978). This produces a typical serial recall curve (Pike, 1977). Use of more sophisticated rehearsal procedures such as chunking alters the shape of the curve with intervening elevated plateaux (Pike, 1977) since chunks tend to be recalled as units (Johnson, 1970). However, a facilitative strategy for supra-span digit strings would be to report the most recently presented items first (Bauer, 1977; Wilson et al., 1975) thereby taking advantage of the echoic memory trace and eliminating the need for rehearsal of the last few items. If this procedure were used, the shape of the recency portion of the curve should be elevated and flattened.

In accordance with these interpretations, then, the shape of the curve produced by the Consistent Factor 3 group would suggest that they had rehearsed the string as a serial unit with the elevated plateau at the end indicating an attempt to recall the items in positions 8, 9 and 10 as a chunk, perhaps from echoic memory, if these items were recalled first. The observed shape of the curve of the Inconsistent group would suggest a division of the ten items into two 5-word strings with separate rehearsal and recall procedures for each. The similarity of the curves for the two disabled groups at the primacy portion of the string is striking, suggesting that a similar use of rehearsal strategies to retain initial items may have occurred. If the statistically significant differences in recall level are a function of strategic control processes, then it follows they must have occurred as a result of the way the recency portion of the string was rehearsed and/or recalled.

To see if these observed differences in shape were reflected in statistically significant differences in recall at the various serial positions, a group by serial position analysis of variance was carried out (Appendix F, Table 5). A significant effect for serial position was found, $\underline{F}$ (9, 252) = 24.01, $\underline{p}$ < .0001, but there was only a trend for a group x serial position interaction, $\underline{F}$ (9, 252) = 1.69, $\underline{p}$ < .10. Thus, the observed differences in shape are not substantiated statistically. Comparisons using the combined group means for serial positions indicated that recall in the recency position (10) was significantly higher than at all others, with recall at positions 8, 9, and 1 being higher than those at all other positions except 10. So, if accuracy of report and order of report are related, both groups could have used recency recall which is considered to be a relatively sophisticated strategy (Wilson et al., 1975).

From a tabulation of order of recall of item within the strings for each individual, general types of recall strategies were determined on the basis of order of report. Three general types of recall strategies were detected (Table 19). The first, named "presentation order" recall, was defined as the report of items in the order of serial presentation with the initial report coming from the primacy position. The second, labelled "recency" recall, included those responses with an initial report of items from the last five positions of the string. The third main recall category was named "disorganized" since it included those responses which were characterized by random recall of isolated items from various positions in the list. It was considered that these responses reflected little or no discernible strategic control. No significant group

Table 19

Proportion of unstructured strings recalled using presentation order, recency and disorganized recall strategies by Consistent Factor 3, Inconsistent and Able Learner groups

Groups	Presentation order recall	Recency recall	Disorganized recall
Consistent Factor 3	24.5	62.2	13.3
Inconsistent	34.4	58.9	6.7
Able Learners	24.5	71.1	4.4

differences occurred in the frequency of use of these strategies (χ^2, (2) = 3.74, p < .15). That is, both groups demonstrated a preference to initiate recall from the recency portion of the string.

It should be noted that no individual in either group used one strategy exclusively so there were large intra-individual variations in the strategies used. This high intra-individual variation could be interpreted as reflecting an active, strategy-seeking process, the trying and rejecting of various procedures in order to enhance recall, and could provide some evidence that learning disabled subjects are active, not passive, learners.

In summary, although statistical trends for group x serial position effects were found which might prove significant if larger numbers of subjects were studied, it must be concluded that the differences between Consistent Factor 3 and Inconsistent groups in level of recall on unstructured strings were not a function of accuracy of recall at any particular serial position, nor of variations in recall order. Hence, by inference, differences in recall could not be attributed to differences in the use of rehearsal and recall strategies as they were measured in this investigation.

Use of control strategies on meaningfully structured strings (assw). Association and syntax facilitate memory by providing the meaningful structure that fosters recall in units or chunks (Johnson, 1970). The 10-item meaningful word strings (assw) were composed of two 5-item sentences, each of which included a subject, verb and object with adjectives modifying the subject and object. Responsiveness to this structure would be indicated by chunking the 10 items into two 5-word units and by rehearsing and recalling these units in presentation order (Pike, 1977). The recall curve would be elevated and flattened over those items that were chunked, but because the adjectives are less essential for meaning, they are less likely to be attended to and rehearsed as efficiently as the other parts of speech so that valleys would typically appear at positions 1, 4, 6 and 9 to denote this.

Visual comparisons of the curves produced by the Consistent Factor 3 and Inconsistent disabled groups revealed, as with the unstructured strings, that similarities existed except for position 6 (Figure 7b). This time, however, it was the Consistent Factor 3 group that had higher recall at this position. The similarity in shape of the curves with valleys at positions 1, 4, 6 and 9 and elevations at the positions occupied by verbs and nouns would suggest that both groups were aware of the meaningful structure and, as predicted, recalled the noun, verb and object combinations more easily than the adjectives. These observations were confirmed by an analysis of variance with repeated measures on serial positions (Appendix F, Table 6). The group x serial position effect approached, but did not reach significance, F (9, 252) = 1.89, $p < .06$. Multiple mean comparisons of the significant serial position effect, F (9, 252) = 16.44, $p < .0001$, indicated the curves of both groups reflected linguistic structure with adjectives being recalled significantly less frequently than the other parts of speech. When the strings were analyzed and the use of meaningful structure tabulated, it was found that 68.9% of the strings in the Consistent Factor 3 group and 67.8% of the strings in the Inconsistent group contained at least one linguistically structured chunk (Table 20). Taken as a whole, it appears that these findings may be interpreted to mean that no significant group differences existed in overall awareness of linguistic structure itself.

Table 20

Proportion of assw strings exhibiting use of linguistic structure by Consistent Factor 3, Inconsistent and Able Learner groups

	Meaningful chunks			Other
	Both sentences	One sentence	Total	
Consistent Factor 3	62.2	6.7	68.9	31.1
Inconsistent	40.0	27.8	67.8	32.2
Able Learner	75.0	25.0	87.5	12.5

When a further analysis of protocols was carried out, it was found that 62.2% of the strings in the Consistent Factor 3 group were recalled using meaningful chunks from both primacy and recency portions of a single string, whereas in the Inconsistent group only 40% displayed this feature. Neither group gave evidence of linguistic chunking in approximately 30% of the strings, and the Inconsistent group recalled proportionately more strings using meaningful chunks in only one sentence, usually the first, (χ^2, (2) = 16.01, $p < .003$). In the latter case, recall was usually present from the other sentence but did not reflect the inherent structure. No significant group differences were found in frequency to initiate recall from the recency sentence, (χ^2, (1) = 3.13, $p < .08$). This is not surprising since recency recall should not be particularly advantageous in the presence of meaningful linguistic structure.

Although these results suggest that differences in level of recall may be partly due to strategy, or meta-variables, since under conditions of linguistic structure there was a tendency for the Inconsistent group to exhibit a greater use of recall chunks unrelated to the linguistic structure in the strings, it could be argued that all this may simply suggest lower language ability in the Inconsistent subjects relative to the Consistent Factor 3 group. However, when an analysis of covariance using verbal IQ score on the third WISC-R assessment was carried out (Appendix F, Table 7), results indicated that verbal IQ and presumably verbal ability did not significantly affect scores, F (1, 27) = 1.46, $p < .24$.

A further note of caution is in order. Because the recall of meaningful strings in rote presentation or serial order can give the appearance of report in meaningful chunks when, in fact, no such meaning has been apprehended by the subject, it may be that incorrect inferences concerning awareness of linguistic structure have been drawn from the recall protocols of both Consistent Factor 3 and Inconsistent subjects. Although it appears that the Consistent Factor 3 groups made more use of meaningful linguistic structure, and, therefore, could be called more meta-efficient than the Inconsistent group, the possibility of error renders this evidence inconclusive and ambiguous. It appears that more direct measures of control processes are needed.

Comparisons on nassw and asswo strings. Previously reported analyses indicated that no differences occurred in level of response between the two groups on the moderately structured strings, nassw and asswo. However, since it was possible that differences could still occur in the shape of the recall curve, and by inference in rehearsal and recall strategies, recall curves were plotted and the appropriate group x serial position analyses were carried out. Visual comparisons reveal the essential similarity of the shapes of the curves of both disabled groups (Figure 8), and the analyses reported non-significant interactions (Appendix F, Tables 8 and 9).

General comparisons with able learners. The recall level of able learners across the 4 forms of the word strings was relatively high with the order of difficulty from easiest to hardest being the same as for the disabled groups (Figure 6). A single classification 1 (group) x 2 (syntax) x 2 (association) analysis of variance with repeated measures on syntax and association revealed significant effects for both

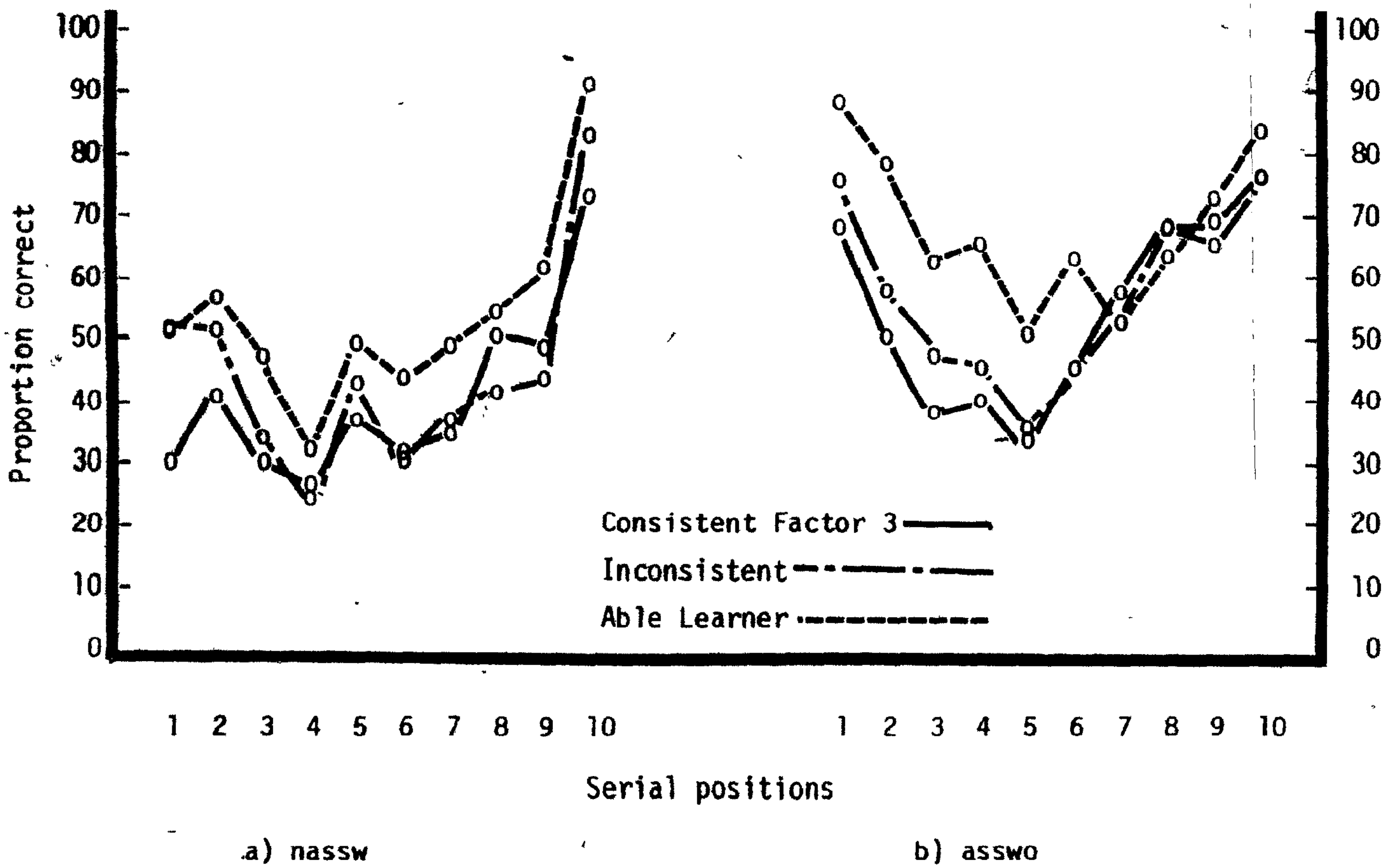


Figure 8. Mean proportion of correct responses at each serial position on strings with no associations and syntax (nassw) and strings with association and no syntax (asswo) for Consistent Factor 3, Inconsistent and Able Learner groups

association, F (1, 14) = 358.4, $p < .0001$ and syntax, F (1, 14) = 23.51, $p < .0003$ but no association by syntax interaction, F (1, 14) = 2.94, $p < .11$ (Appendix G, Table 1). That is, both association and syntax facilitated recall.

As was the case for both the Consistent Factor 3 and Inconsistent groups, Able Learner subjects preferentially used recency recall on unstructured strings (Table 19). On the most structured strings (assw), the use of linguistic structure (Table 20) was similar to that of the Consistent Factor 3 group. Correlational patterns of the Able Learners (Table 18), however, were similar to those of the Inconsistent group with there being little relationship between recall on the unstructured strings and the moderately structured strings, and correlational indices being, in general, lower than those for the Consistent Factor 3 group. This suggests that the common factor associated with Consistent Factor 3 performance across all tasks is one which is not held in common with the Able Learner group; that is, it is not in the use of control strategies, and lends weight to the hypothesis that group differences are related to the involuntary structural features of the serial memory processes.

Summary of findings: Weener strings. Significant group differences occurred in level of recall on strings varying as to levels of organization with the Consistent Factor 3 group performing as well or better than the Inconsistent group on strings with external organization, but poorer than the Inconsistent group on strings without any inherent organization. The increased effect of structure on recall level in the Consistent Factor 3 group was indicated by the greater discrepancy between recall on structured and unstructured strings. This variation has been interpreted in the literature as reflective of the use of active control processes. However, no compelling evidence, either in level of recall at different serial position or in strategies as determined by order of recall, was presented to suggest that the diminished performance of the Consistent group on the unstructured strings was due to the lack of, or in appropriate use of, control strategies relative to the Inconsistent group. Although findings concerning the relative use of control processes on the structured strings must be considered inconclusive, it does not appear that the Consistent Factor 3 group can be characterized as being either significantly less or more active and efficient in the use of appropriate control processes than their Inconsistent counterparts. This, of course does not preclude the possibility that both groups were deficient in the use of controls relative to able learners as inability to carry out appropriate statistical analyses between able and disabled learners prevented a clear resolution of this question.

Evidence concerning Temporal versus Spatial Processing: TESP Task

No significant differences between Consistent Factor 3 and Inconsistent groups were found in total recall of item order across all 4 forms of the TESP task but there was a response mode effect which varied with mode of presentation (Table 21). The highly significant presentation x response x group interaction, however, indicated that multiple mean comparisons would be required for interpretation of results. These comparisons revealed that significant between-group differences in level of recall occurred only on the temporal/temporal variation of the task (Table 22), with the Consistent Factor 3 group finding it significantly more difficult than the Inconsistent group. Further, as Figure 9 demonstrates, the

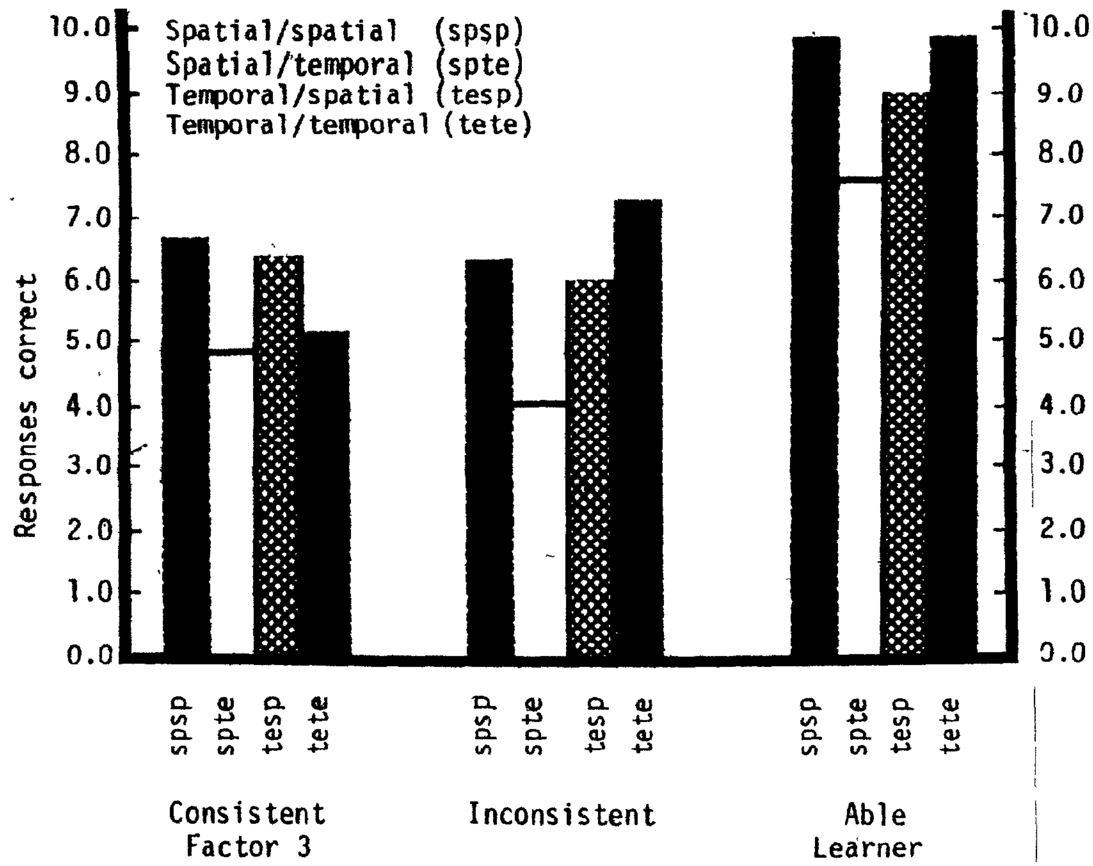


Figure 9. Mean number of responses correct on each of four variations of TESP for Consistent Factor 3, Inconsistent and Able Learner groups.

Table 21

Analysis of variance for recall of item order
on 4 variations of a temporal-spatial task, TESP,
for Consistent Factor 3 and Inconsistent groups

Source of variance	df	Mean square	F	p
between groups	1	1.20	.03	.78
error	28	15.12		
presentation modes	1	16.13	2.92	.10
presentation x group	1	16.13	2.92	.10
error	28	5.52		
response mode	1	28.03	8.89	.006
response x group	1	5.63	1.79	.19
error	28	3.16		
presentation x response	1	28.03	20.48	.0001
presentation x response x group	1	17.63	12.88	.0013
error	28	1.37		

Inconsistent group found the temporal/temporal task to be the easiest of the four versions, while the Consistent Factor 3 group found it to be among the hardest.

Highest scores were obtained by the Consistent Factor 3 group on the spatial/spatial variation (Figure 9) supporting what has been commonly reported using somewhat similar tests with more heterogeneous groups of the learning disabled (Rudel & Denckla, 1976). The Inconsistent group found this variation significantly easier than only the spatial/temporal

Table 22

Comparisons of mean scores on variations of TESP using Duncan's New Multiple Range procedure for Consistent Factor 3 and Inconsistent groups

Task version	Groups	
	Consistent Factor 3	Inconsistent
Presentation/response		
Spatial/spatial	6.7[ab*]	6.3[ab]
Spatial/temporal	4.9[c]	4.0[c]
Temporal/spatial	6.3[ab]	6.0[b]
Temporal/temporal	5.1[c]	7.2[a]

* Means followed by the same letter are not significantly different at $p = .05$.

form (Table 22), which, it should be noted, required a translation from the input dimension. For this group highest scores were obtained on the intra-dimensional temporal/temporal task and, although it was not significantly easier than the intra-dimensional spatial/spatial form, it was significantly easier than both forms of the test that required a cross-dimensional translation (spatial/temporal and temporal/spatial). Thus, the Inconsistent group found that when input was either spatial or temporal, the form of the task which required response in the same dimension (spatial/spatial or temporal/temporal) was significantly easier than the variation which required a response in the other dimension.

This suggested that the integration or translation of dimensions added a common, extra degree of difficulty for the Inconsistent group, a conclusion further supported by the high correlations between the two inter-dimensional forms of the task, temporal/spatial and spatial/temporal (Table 23).

The Consistent Factor 3 group, on the other hand, found intra-dimensional responses significantly easier than inter-dimensional ones only when the initial input was spatial (Table 22). When input was temporal, the intra-dimensional task (temporal/temporal) was significantly more difficult than the temporal/spatial form, even though the latter required an additional translation process. The non-significant correlations between the two versions requiring translation or integration (Table 23) suggested that for this group different processes were involved in each task and so a generalized integration problem could not be presumed to exist.

It will be recalled that TESP was produced to eliminate weaknesses held to be inherent in task variations derived from the initial work of Birch and Belmont (1964). The modifications made it possible to measure recall for spatial and/or temporal order without the confounding variables of sensory modality, item equivalence and item memory. Thus, the observed non-significant correlations between temporal/temporal and spatial/spatial scores must indicate independence of the processes involved for the Consistent Factor 3 group and the Inconsistent group alike (Table 23). Common elements in either presentation or response dimension could account for the remaining correlations in the Inconsistent group. However, lack of relationships between tasks, since correlations occurred only between

Table 23

Correlations among the various forms of the spatial-temporal task (TESP)

for Consistent Factor 3, Inconsistent and Able Learner groups

	Consistent Factor 3			Inconsistent			Able Learner		
	spatial/ spatial	spatial/ temporal	temporal/ spatial	spatial/ spatial	spatial/ temporal	temporal/ spatial	spatial/ spatial	spatial/ temporal	temporal/ spatial
temporal/ temporal	.03	−.17	.67**	.38	.63**	.71**	.10	−.23	.37
spatial/ spatial		.32	.54*		.82**	.76**		.30	.44
spatial/ temporal			.02			.77**			.06

* $p < .05$

** $p < .01$

the temporal/spatial version and the temporal/temporal and spatial/spatial forms respectively, meant that for the Consistent Factor 3 group, a different explanation must be sought.

Speculations in the literature suggested that low factor 3 functioning could be associated with a disability in temporal order processes. The low temporal/temporal scores of the Consistent Factor 3 group supported this notion since this variation of the task was composed of a purely temporal input and purely temporal response. The hypothesis was further supported by the significant differences between the temporal/temporal and spatial/spatial scores since the latter required purely spatial responses. However, the pattern of correlations between some of the tasks with temporal components raised questions about the nature of the general temporal order disability, if indeed it did exist for this Consistent Factor 3 group. Although equally low scores were obtained by the Consistent Factor 3 subjects on the temporal/temporal and spatial/temporal forms, the lack of correlation between these two versions suggested that the common, low levels of recall were not related to a common difficulty with temporal responses alone.

Was there, then, evidence of a common difficulty for the Consistent Factor 3 group associated with temporal input? Bakker's (1972) hypothesis that reading disabled children have a disorder in temporal order perception (TOP) would be supported if this were so. The significant correlation between the scores on the temporal/spatial and the temporal/temporal variation was perhaps indicative that a common process was associated with the temporal presentation dimension of both task forms. However, the scores on the temporal/spatial form were significantly higher than those on the temporal/temporal. If there were a common basic difficulty with temporal order perception, then in this case it could have been moderated by the spatial nature of the response format. This could be a tenable hypothesis since the temporal/spatial form correlated significantly with the spatial/spatial variation, and the scores on the temporal/spatial and spatial/spatial were both significantly higher than those on the temporal/temporal version.

It is of interest to contemplate what it was about the spatial response format that might have enhanced recall on the temporal/spatial task relative to the temporal/temporal task for the Consistent Factor 3 group considering that an added translation process was involved in the former. Perhaps the holistic format of the response grid allowed for visual rather than verbal encoding with subjects using imagery to visually order the items on an imaginary grid as they were presented temporally; perhaps the opportunity to respond to the most recently presented positions first increased recall at the recency positions and circumvented the need for rehearsal. Questioning of the subjects following the final presentation indicated that all had applied verbal labels to the novel, meaningless symbols. Therefore, the symbols could have been ordered by name rather than by position or number. It was possible that difficulty in initially labelling such novel symbols could have affected scores in a systematic way. Since there is an apparent need to explore further the means whereby spatial and temporal order is encoded and recalled, it would have been of value if serial learning curves could have been plotted for the groups on the temporal/temporal and temporal/spatial variations. However, the multi-level format of TESP precluded its use for such analyses since only 3 trials occurred at each level. TESP could be readily modified for use in future investigations by providing for fewer levels but more trials at each level. Presentation speed, the nature of the items and response delay could also be manipulated within the format to explore further the nature of the deficient temporal order performance in the Consistent Factor 3 group.

General comparisons with able learners. Although the level of recall was considerably higher in the Able Learner group than in either of the disabled groups (Figure 9), the order of difficulty of the test variations, from lowest to highest, was very similar to that for the Inconsistent group, [i.e., spatial/temporal, temporal/spatial, spatial/spatial and temporal/temporal]. Significant differences in level of recall occurred only between the spatial/temporal and the two easiest forms, temporal/temporal and spatial/spatial (Appendix G, Table 2). Surprisingly, correlations were non-significant among all test forms (Table 23), suggesting relative independence of functioning across the variations, perhaps due to ceiling effects.

McLean (1979) studied the responses to the TESP variations of normal male readers at ages 7.6, 10.7 and 13.7 years whose mean IQ scores were 119.9, 118.4 and 121.3 respectively. Her samples were drawn from the same school populations as the disabled learners in this investigation, her oldest group subsuming the able learners. She found that, while there was an increase in overall performance with age, the order of difficulty of the four forms of the test remained the same, the temporal/temporal being easiest and the spatial/spatial being hardest. Further analyses controlling for intelligence indicated that those with IQ scores over 115 showed no significant differences in recall level on the test forms while those with IQ scores below 115 found the temporal/temporal variation easier than all the others.

Given McLean's (1979) results indicating IQ score effects, data for the Consistent Factor 3 and Inconsistent groups were subjected to analyses of covariance using full scale IQ scores on the third assessment (Appendix F, Table 10). Although there were significant IQ effects, $\underline{F}$ (1, 27) = 8.24, $\underline{p}$ < .008, when the corrected multiple means were compared, group differences on the temporal/temporal task remained but were magnified, and the order of difficulty for each of the tasks in each group remained the same.

Summary of TESP results. The Consistent Factor 3 and Inconsistent subgroups displayed different patterns of recall on tasks that varied as to temporal or spatial presentation and response modes. The Consistent Factor 3 group demonstrated a relative disorder in processing and recalling temporally presented stimuli, with the most difficult task being the intra-modal temporal/temporal variation. On the basis of correlational evidence, their improved performance on the inter-modal, temporal/spatial task was interpreted to mean that the provision of a spatial organization for responses may have facilitated performance. In common with the Inconsistent and Able Learner groups, they found the spatial/spatial variation relatively easy and the spatial/temporal version relatively hard. Thus, the Consistent Factor 3 group may be said to conform to those characteristics reported for the learning disabled by Rudel and Denckla (1977). Furthermore, their relative difficulty with temporal presentations would be consonant with a temporal order perception (TOP) deficit as hypothesized by Bakker (1972).

The Inconsistent subgroup found the temporal/temporal version easiest, and the inter-modal conditions invariably more difficult than the intra-modal counterparts. Thus, their performance may be said to conform to results reported for disabled learners by Bryden (1972). In addition, their unique difficulties with cross-modal translations suggest that they also correspond to groups of disabled learners originally identified by Birch and Belmont (1964).

The findings that the Consistent and Inconsistent subgroups responded differently to tasks varied on spatial/temporal dimensions may help to explain some of the earlier contradictory results using undifferentiated groups of learning disabled children. They also suggest that, in future, attention should be paid to subgrouping when these variables are being explored in relation to learning problems.

Co-ordination of Test Results Concerning Group Differences in Attentional Selectivity, Use of Control Strategies and Sequential Processing.

Before examining the evidence of subgroup differences on dichotomous stimulation tasks, the data for attentional selectivity, use of control strategies and sequential processing will be co-ordinated and summarized. This study provided for more than one measure or index of each of the above variables in expectation that results would converge to help define the characteristics of the subgroups, Consistent Factor 3 and Inconsistent. The foregoing report has included a test-by-test account of results which now must be integrated to see if certain patterns emerged and if the results did, in fact, confirm each other. Two main questions were asked, the second in two parts:

1. Is the Consistent Factor 3 group more distractible than other learning disabled children of the same age, same educational and socio-economic background, as represented by the Inconsistent group?
2. Does the Consistent Factor 3 group exhibit disorders in sequential memory and processing, and can this be related to:
   a. deficient or incompetent use of control processes as compared with the Inconsistent group;
   b. disorders in temporal versus spatial processing and memory as compared with the Inconsistent group?

<u>Coordination of results: selective attention</u>. With regard to the first question, results from the Central-Incidental learning task indicated that the Consistent Factor 3 group could be classified as less distractible than the Inconsistent group. Results from the embedded figures test, which was included as a confirmatory measure, were, if not contradictory, at least confusing. Although embedded figures scores were higher in the Consistent Factor 3 group than the Inconsistent group, suggesting greater selectivity, the differences were not significant, and moreover, correlational patterns indicated that the embedded figures test probably was not measuring the same thing in each of the two groups (Tables 24, 25). Although the direction of the observed relationships among the indices of attentional selectivity in the Inconsistent group would not conflict with the assumption that all were measuring selective attention in the Consistent Factor 3 group (Table 24), the relationships

TABLE 24

Intercorrelations among measures of selective attention, Weener Test and TESP for the Inconsistent group, N=15

	selective attention				Weener Test				TESP			
	selective attention	central learning	incidental learning	embedded figures	ASSW	ASSWO	NASSW	NASSWO	spatial/ spatial	spatial/ temporal	temporal/ spatial	temporal/ temporal
central learning	.79**											
incidental learning	-.90**	-.45										
embedded figures	.33	.47	-.17									
association/syntax	-.21	-.04	.27	.32								
associations/no syntax	-.26	-.13	.28	.43	.88**							
no associations/syntax	-.29	-.04	.41	.33	.59*	.78*						
no associations/no syntax	-.13	.19	.31	.39	.53*	.43	.27					
spatial/spatial	.65*	.61*	-.53*	-.03	-.38	-.53*	-.39	-.24				
spatial/temporal	.55*	.60*	-.32	.21	-.38	-.46	-.24	-.24	.82**			
temporal/spatial	.55*	.68**	-.29	.12	-.42	-.50	-.08	.06	.77**	.78**		
temporal/temporal	.25	.38	-.07	.32	-.18	-.17	.23	-.18	.38	.63*	.71**	1.0

** $p < .01$; * $p < .05$

TABLE 25

Intercorrelations among measures of selective attention,

Weener Test and TESP for the Consistent Factor 3 group, N=15

	selective attention				Weener Test				TESP			
	selective attention	central learning	incidental learning	embedded figures	ASSW	ASSWO	NASSW	NASSWO	spatial/ spatial	spatial/ temporal	temporal/ spatial	temporal/ temporal
central learning	.79**											
incidental learning	-.75**	-.23										
embedded figures	-.60*	-.41	.56*									
associations/syntax	.45	.50	-.12	.15								
associations/no syntax	.38	.42	-.33	-.23	.77**							
no associations/syntax	.45	.40	-.11	.06	.83**	.74**						
no associations/no syntax	.34	.70**	-.14	-.16	.87**	.86**	.81**					
spatial/spatial	-.06	-.01	.07	.60*	.49	-.03	.34	.11				
spatial/temporal	.01	.13	.11	.18	.41	.25	.34	.33	.32			
temporal/spatial	.21	.30	.05	.25	.56*	.19	.32	.42	.54*	.02		
temporal/temporal	.52*	.60*	-.22	-.33	.50	.52*	.28	.61*	.02	-.17	.67**	

** $p < .01$; * $p < .05$

between embedded figures and the incidental task scores, while significant, were actually in the direction opposite to that required if both were measures of distractibility (Table 25). The significant positive correlations between the embedded figures test and the spatial/spatial form of TESP (Table 24), and between embedded figures and factor 1 scores ($\underline{r} = .76$, $\underline{p} = .004$) indicate that embedded figures may be more a measure of spatial, holistic processing than distractibility in the Consistent Factor 3 group. That the correlations of incidental learning with spatial/spatial (Table 25) and with factor 1 ($\underline{r} = .28$, $\underline{p} = .37$) were non-significant, however, would suggest that incidental scores may be a complex measure of both extraneous and holistic processing in the Consistent Factor 3 group.

In summary, contrary to speculation, it was the Inconsistent group that conformed most closely to the pattern of poor selective attention reported for disabled readers in the literature (see Ross, 1976, for a review), and as a result, it appears that consistently low factor 3 functioning is not associated with distractibility.

Coordination of evidence: control processes. Evidence concerning the use of control processes was obtained in several ways:

1. By visual examination and statistical analysis of serial recall curves derived from the central learning task of the Hagen test, the unrelated strings (nasswo) and the linguistically structures strings (assw) of the Weener test.
2. From self-reports of rehearsal strategies used on the central learning task of the Hagen test.
3. From analysis of recall strategies inferred from the order of report

of the unrelated (Nasswo) and linguistically structured (assw) strings of the Weener test.

4. By a repeated measures analysis of level of recall across strings of varying structure.

When the serial recall curves obtained from the central-incidental task and the various versions of the Weener strings were analyzed, no significant differences were found between the groups in recall at the different serial positions which suggested that both groups had used similar rehearsal strategies. No significant differences were found in the reported use of rehearsal strategies on the central-incidental task, and non-significant differences were observed in the use of facilitative recall strategies on the unrelated strings of the Weener test.

The Consistent Factor 3 group, however, was found to have responded more than the Inconsistent group to increasing structure across the Weener strings, which could be viewed as indicative of a more active, meta-efficient use of strategic controls than the Inconsistent group. Although evidence from the analyses of the meaningful strings was ambiguous, it seems reasonable to conclude that the Consistent Factor 3 group used equally efficient, perhaps at times better, control strategies than the Inconsistent group. Therefore, the deficient use of control processes could not account for the significant differences observed in the level of recall on the unstructured strings (nasswo) where the Consistent group performed more poorly than the Inconsistent group. This raises the possibility that group differences lie in structural rather than control processes.

<u>Coordination of evidence: sequential memory</u>. The temporal/temporal version of TESP was designated the chief measure for recall of sequential order since it is comprised of purely temporal input and responses. Consistent Factor 3 subjects performed significantly worse on this task than the Inconsistent subjects. Further evidence of a relative temporal memory disorder in the Consistent Factor 3 group was obtained from their significantly lower scores on the unrelated strings (nasswo) of the Weener task. Central learning scores on the Hagen Central-Incidental task provided further confirmatory evidence since, although the Consistent Factor 3 group did not significantly differ in level of recall from the Inconsistent group, they did not process as much incidental information and had little trade-off with incidental scores. Therefore, it should have been expected that they would have bettered the performance of the Inconsistent group if no other central task disorder had existed for them. Central learning, nasswo, and temporal/temporal all correlated highly with each other in the Consistent Factor 3 group (Table 25) but were unrelated in the Inconsistent group (Table 24).

Levels of correlation were highest between nasswo and the other sequential tasks (Table 25). Although input was temporal for nasswo, recall could be in any order and included memory for item indicating that the difficulty in the Consistent Factor 3 group was not specific to order memory alone. Thus, confirmatory evidence from various sources indicated that the Consistent Factor 3 subjects displayed sequential memory disorders that were found in both auditory and visual modalities.

<u>Interrelationships among the tasks</u>. The significant group x test version interaction that appeared for both TESP and Weener strings indicated that level of recall on any one form of these tasks may not be the best indicator of group differences. The similarity of the interaction effect between the unstructured strings (nasswo) and the linguistically structured strings (assw) of the Weener test and that between the temporal/temporal and temporal/spatial variations of the TESP is of particular interest. Recall was lower for the Consistent Factor 3 group than the Inconsistent group on nasswo and temporal/temporal, both of which, though they differed in many ways, demanded recall from a temporal-successive input. The Consistent Factor 3 group was equal to, or better than, the Inconsistent group on the assw and temporal/spatial, both of which appeared to provide for some form of holistic structure or organization (grids on the temporal/temporal and "meaning" on assw). A high correlation between the temporal/temporal and nasswo tasks has already been noted in the Consistent Factor 3 group; high correlations also existed between the temporal/spatial and assw (Table 25). At the same time, neither temporal/temporal and assw nor temporal/spatial and nasswo were correlated. What then did temporal/spatial and assw have in common that was not also common to the temporal/spatial and nasswo, and which at the same time made temporal/temporal and assw easier for the Consistent Factor 3 group than their counterparts? Perhaps the linguistic structure of assw and the grid format of the temporal/spatial task allowed for some kind of holistic, simultaneous, non-successive processing that was more facilitative for the Consistent than Inconsistent groups. It appears, then, that it may not be the level of recall on any particular task variation, but rather

it may be the discrepancy between levels of recall on two different task forms, that provides the best index of group differences. Therefore, a Weener discrepancy index (assw - nasswo/assw + nasswo) and a TESP discrepancy index similarly derived to express the difference between temporal/spatial and temporal/temporal were formed. These indices were used in analyses to be reported later.

In the Inconsistent group, none of the versions of the Weener task correlated with selective attention measures or with any of the TESP versions (Table 24). However, those forms of TESP that have a spatial component (temporal/spatial, spatial/spatial, Spatial/temporal) all correlated with the selective attention efficiency index and incidental learning while the temporal/temporal and all the variations of the Weener strings did not (Table 24). In view of these relationships, it is tentatively suggested that successive input may have been relatively facilitative for this group because it focused attention and thus allowed skills in the other cognitive processes that were required for task performance to determine level of functioning. Simultaneous presentation and response modes, on the other hand, may have been distracting because they provided extraneous stimuli and, therefore, performance on those tasks could be determined by attentional selectivity.

In conclusion, it appears that evidence from the various tests indicated that the two groups displayed very different patterns of performance, well-illustrated by the striking group differences in correlational patterns between the various TESP forms and the central-incidental task scores (Tables 24 & 25). The Inconsistent group's responses were compatible with disorders in attentional selectivity while the Consistent Factor 3 group appeared to exhibit relative disorders in sequential processing and memory. From this perspective, it is now proposed to examine the responses of the two groups to the measures of hemisphere specialization and to relate these responses to the data just reported.

Evidence Concerning Hemisphere Specialization

Statistical comparisons of dichotic listening and dichhaptic stimulation tasks are reported for right-handed subjects only. Analyses carried out with both right and left-handed subjects combined produced essentially the same results and are reported in Appendix H, Tables 1 & 2.

Dichotic listening test results. A 2 (groups) x 2 (right or left ear scores) analysis of variance with repeated measures for ear scores was carried out for all right-handed individuals, as determined by the Harris Dominance Test (Harris, 1958). The non-significant overall group effect suggested that the Consistent Factor 3 and Inconsistent groups did not differ in total recall of digits from right and left ears combined (Table 26).

Table 26

Analysis of variance for number of digits recalled for right and left ears by Consistent Factor 3 and Inconsistent groups using right-handed subjects only

Source of variance	df	Mean square	F	p
between groups	1	1.56	.01	.91
error	23+	119.98		
ear effect	1	1211.56	25.83	<.0001
ear x group	1	16.17	.34	.56
error	23+	46.91		

Level of recall was higher for the right ear than the left, and this significant right ear advantage (REA) was found for both groups (Table 26).

Table 27

Mean accuracy scores of recall for right and left ears on a dichotic digits listening task for Consistent Factor 3 and Inconsistent groups using right-handed subjects only

Groups	Right ear	Left ear	Total
Consistent Factor 3	58.2[a*]	47.4[b]	105.6
Inconsistent	56.7[a]	48.2[b]	104.9

* means followed by the same letter are not significantly different.

In accordance with interpretations in the literature, these results indicated that the left hemisphere was specialized for language in both groups of learning disabled subjects. When the number of right-handed individuals displaying REA was calculated for each group, it was found that 10 of 13 subjects in the Consistent Factor 3 group, and 12 of 13 subjects in the Inconsistent group had an REA ($\chi^2 = 1.13$, $p = .25$).

Dichhaptic stimulation test results. A 2 (groups) x 2 (right or left hand score) analysis of variance with repeated measures on hand scores was carried out on right-handed subjects only (Table 88). Consistent Factor 3 and Inconsistent groups of disabled learners did not differ in total number of correct detections (right and left hand scores combined), nor did they show differences between right and left hand scores. These results correspond to those of Witelson (1976) who found that reading disabled subjects as an undifferentiated group did not differ in hand accuracy.

Table 28

Analysis of variance for number of correct detections by right and left hands on the dichhaptic stimulation task for Consistent Factor 3 and Inconsistent groups using right-handed subjects only

Source of variance	df	Mean square	F	*p*
between groups	1	2.77	1.41	.25
error	24	1.96		
hand	1	.08	.03	.86
hand x group	1	15.08	5.95	.02
error	23	2.54		

The significant group x hand interaction effect, however, suggested that the two disabled groups in this investigation differed from one another in relative hand accuracy. It can be observed that the Consistent Factor 3 group made more correct detections with the right hand than the left hand, while the Inconsistent group made more correct detections with the left hand than the right hand (Table 29). However, multiple mean comparisons indicated that only right hand scores between groups were significantly different, the Consistent Factor 3 group making significantly more correct right hand detections than the Inconsistent group (Table 29).

A single classification analysis of variance was used to compare hand preference for each group separately and helped to further explore the meaning of these results. It was found that the Consistent Factor 3 group displayed a right hand advantage, that is, within the group right hand scores were significantly greater than left hand scores (Table 30), while the single classification analysis for the Inconsistent group revealed no significant differences between hand scores (Table 31).

Table 29

Mean accuracy scores for right and left hands on the dichhaptic test for Consistent Factor 3 and Inconsistent groups using right-handed subjects only

Groups	Right hand	Left hand	Total
Consistent Factor 3	5.8[a*]	4.6[ab]	10.4
Inconsistent	4.2[b]	5.2[ab]	9.4

* means followed by the same letter are not significantly different.

Table 30

Single classification analysis of variance for dichhaptic scores for the Consistent Factor 3 group using right-handed subjects only

Source of variance	df	Mean square	F	p
hand effect	1	8.65	4.75	.05
error	12	1.82		

Table 31

Single classification analysis of variance
for dichhaptic scores for the Inconsistent group using
right-handed subjects only

Source of variance	df	Mean square	F	p
hand effect	1	6.50	2.00	.18
error	12	3.25		

Furthermore, when results for individuals were examined within each of the groups, it was found that eight of 13 individuals in the Consistent group had higher right than left hand scores, four of 13 individuals displayed equal hand scores and only one individual had a normal pattern of scores, that is, higher left than right hand scores. By contrast, in the Inconsistent group, seven of 13 had higher left than right hand scores while equal hand scores and higher right than left hand scores were each obtained by three of the 13 individuals. Chi-square analysis indicated that these differences were significant ($\chi^2 = 7.48$, $p < .05$).

Taken in total, these results could reflect meaningful group differences in patterns of abnormal hemisphere lateralization. If the Consistent Factor 3 group preferentially process spatial information in the left hemisphere, then according to accepted interpretations in the literature, they could be said to have their spatial processing lateralized in the left hemisphere along with their language processes. The Inconsistent group, however, would be said to have incomplete or bilateral representation of spatial processing.

With reference to the three hypothesized positions arising out of the hemisphere specialization literature to explain observed group differences in WISC factor functioning, it appears that data presented here do not support the first explanation which suggested that differences in patterns of language lateralization as indicated by the degree of right ear advantage (REA) were responsible for group differences. The subgroups, though differing significantly on factor 3 scores, did not differ on ear measures. The second position held that the presence of spatial, holistic processing in the left hemisphere would interfere with sequential language processing for which that hemisphere is normally specialized. On this the data are less clear. If this position were correct, it might be expected that an index of right hand preference or advantage (RHA), derived by subtracting left hand scores from right hand scores, would correlate negatively with measures of sequential language processing such as right ear scores. In the Consistent Factor 3 group, the group with higher right than left hand scores, the correlation though not quite statistically significant, was in the direction predicted (Table 32). In the Inconsistent group, the correlation coefficient was not significant though it is interesting to note it was in the opposite direction.

The third hypothesis arising from the literature suggested that dichotomous stimulation scores from the hand ipsilateral to the hemisphere specialized for processing spatial input could be viewed as indices of intrusions, reflecting poor attentional selectivity. These ipsilateral hand intrusions presumably occur when, through boredom or fatigue, the subject switches attention, activating the other hemisphere, thus

Table 32

Correlation of RHA with level of right ear scores for Consistent Factor 3 and Inconsistent groups using right-handed subjects only

Group	*r*	*p*
Consistent Factor 3	-.51	.08
Inconsistent	.20	.52

reducing the degree of apparent hemisphere specialization (Kinsbourne, 1975). Since the Inconsistent group has been shown to have poor attentional selectivity with incidental learning scores that were indicative of high extraneous processing, it might have been expected that these scores would correlate with those hand scores which are ipsilateral to their spatial hemisphere. A highly significant correlation was obtained within the Inconsistent group between incidental learning scores and right hand scores on the dichhaptic test (Table 33), indicating that right hand scores and incidental learning may share common features of extraneous processing. These results are of interest for several reasons: (1) They give additional support for the existence of poor attentional selectivity in the Inconsistent group; (2) They suggest that the Witelson Dichhaptic Stimulation Test may be susceptible to attentional variables; (3) They could imply that right-hand scores are inflated, giving the impression of bilateral spatial representation in a group that may actually have normal hemisphere lateralization, a notion which could be tested by modifications of the dichhaptic test

Table 33

Correlations of right hand and left hand dichhaptic scores with incidental learning for Consistent Factor 3 and Inconsistent groups using right-handed subjects only

Group	Correlation	F	p
Consistent Factor 3	right hand x incidental learning	.07	.82
	left hand x incidental learning	.53	.057
Inconsistent	right hand x incidental learning	.77	.002
	left hand x incidental learning	-.35	.24

procedures to eliminate or reduce attentional variables. In the present investigation, training procedures, which were often quite prolonged, and test procedures were necessarily used in the same test period. In future, some separation of initial training procedures and actual test procedures would be advisable. The use of cuffs to prevent arm movements might also be of help by reducing the training time.

The data of Table 33 are also of considerable interest for the Consistent Factor 3 group. If, as suggested by the single classification analysis (Table 30), spatial processing is lateralized in the left hemisphere, then the left hand scores rather than the right hand scores would be designated as intrusions and would be expected to correlate with the incidental learning scores. Accordingly, data in Table 33 for this group indicate that the relationship between incidental learning and left hand scores approached significance, while the correlation between incidental learning and right hand scores showed a non-significant relationship. This pattern would seem to support an interpretation of preferential spatial processing in the left hemisphere among Consistent Factor 3 subjects. That incidental learning was associated with the left hand scores in the Inconsistent group, but with right hand scores in the Consistent group is certainly indicative of an interaction between group membership and degree of hemisphere specialization.

Left ear scores which could also be considered to indicate intrusions did not correlate with incidental learning in either the Consistent Factor 3 (r = -.26, p = .40), or the Inconsistent group (r = .24, p = .43). Perhaps this was so because care was taken to minimize the effects of boredom and fatigue on the dichotic testing by limiting the length of the test and giving it at the beginning of the test period.

General comparisons with able learners. A single classification analysis of variance (Appendix G, Table 3) with repeated measures on ear scores revealed that right-handed able learners demonstrated an REA F(df 1, 14) = 9.78; p<.007), when administered the same dichotic listening under the same conditions as the disabled learner groups (Table 34).

As with the Inconsistent group, mean left hand scores were higher than mean right hand scores. A single classification analysis of variance with repeated measures on hand scores (Appendix G, Table 4) indicated that these hand score differences were significant, F(df 1, 14)= 4.51, p = .05. Incidental learning scores were unrelated to either right hand scores (r = 0.04, p = .90), or left hand scores (r = .15, p = .60).

Table 34

Mean accuracy scores on tests of hemispheric specialization

for the Able Learner group,

right-handed subjects only; N=12

Tests							
Dichotic Listening				Dichhaptic Stimulation			
right ear		left ear		right hand		left hand	
mean	sd	mean	sd	mean	sd	mean	sd
64.7	4.98	59.9	6.3	5.3	1.50	6.4	1.50

Higher right than left hand scores were found in 67% of the individuals, 20% had higher right than left hand scores, while 13% had equal hand scores. In general, then, this sample of able learners presented a pattern of performance similar to that of Witelson's (1977) control group of able learners of the same age, i.e. they had a pattern of normal hemisphere specialization.

Summary and implications of dichotic and dichhaptic test results. In review, it must appear that, while the dichotic listening test suggested language processes were appropriately lateralized in the left hemisphere in both groups, the dichhaptic test yielded somewhat inconclusive evidence concerning group differences in hemisphere specialization for spatial processing. That there are group differences in the level of right hand scores on the dichhaptic test is clear, but the within group differences between left and right hand scores is uncertain. However, single classification analyses for each group separately, and the interactions between the hand scores and incidental learning suggested that to conceptualize both groups as having bilateral spatial representation could be an oversimplification and, therefore, misleading. Some evidence has been presented to suggest that the Consistent Factor 3 group may have left hemisphere lateralization of spatial processes while the Inconsistent group may have normal hemisphere patterns. If subsequent investigations with larger numbers of subjects could strengthen or clarify these interpretations, then it might be possible to address the questions of those who, like Rourke (1978), have asked how disabled learners could have a lack of hemisphere specialization for spatial functioning but enhanced spatial processes. If the Consistent Factor 3 group with high factor 1 scores can be demonstrated to have lateralized spatial processing, albeit in the left hemisphere, then strong spatial functioning would not be improbable. Further, if it could be confirmed that the right hand scores of the Inconsistent group are inflated, and that their hemisphere patterns are, in fact, like those of the normal male population, then disabled male readers, both Consistent and Inconsistent, and normal female readers would be shown to have three different patterns of hemisphere specialization, and it would not be necessary to assume contradictory explanations for the effects of bilateral representation of spatial processes on reading ability in male and female populations.

Relationships Between Dichotomous Stimulation Task Scores and Other Differentiating Variables

In this section, the scores on the dichotomous stimulation tasks will be related to measures that differentiated the groups. The purpose is to see if the interpreted hemisphere specialization patterns can contribute to an understanding of the group differences that were observed and reported earlier, and also to see if performance on the other tasks provides support for the assumptions behind the laterality indices and the interpreted hemisphere patterns. An index from each of the dichotomous tests has been derived to represent the degree of hemisphere specialization that each is presumed to measure. For the dichotic test, this is REA (right ear scores-left ear scores/right ear scores + left ear scores). For the dichhaptic test, this is RHA (right hand scores-left hand scores/ right hand scores + left hand scores), an index of degree of bilateral or abnormal hemisphere lateralization of spatial processes. In addition, right ear (RE), left ear (LE), right hand (RH and left hand (LH) relationships will be studied independently of the suggested hemisphere patterns. Right handed subjects only will be used for these particular analyses.

Correlations for the combined groups appear in Table 35 and indicate relationships between hand scores and the Weener Strings, between ear scores and TESP and between ear scores and selective attention.

Dichhaptic scores and Weener strings. There was a significant, positive correlation between RHA and Weener discrepancy scores with a trend for a similar relationship with the TESP discrepancy index (Table 35). Thus, it appears that there was an association between degree of

Table 35

Relationship of dichotomous stimulation test scores and laterality indices of differentiating variables in Consistent Factor 3 and Inconsistent groups using right-handed subjects only, N=26

	Weener Strings			TESP			Selective Attention		
	discrep. index	assw	nasswo	discrep. index	temporal/ spatial	temporal/ temporal	index (%C - %I)	incidental learning	central learning
RHA	.47**	.48**	-.05	.33t	-.21	.10	-.05	.08	.00
RH	.45*	.58**	.11	.17	-.01	.19	.01	.14	.18
LH	-.35t	-.25	.18	-.32	.25	-.04	.03	.03	-.02
REA	.14	-.22	-.36t	.39*	-.30	-.19	-.03	-.15	-.26
RE	-.02	.06	-.06	.03	.18	.21	.39*	-.12	.59**
LE	-.08	.22	.25	-.31	.31	.24	.23	.01	.45*

** $p < .01$

* $p < .05$

t $p < .10$

abnormal right hemisphere specialization and enhancement of recall of sequentially presented stimuli when holistic structure was provided. Further, it could be observed that RHA and right hand scores were positively correlated with recall on the meaningful strings (assw), but not on the unstructured, meaningless strings (nasswo). The significant RHA-assw relationship is depicted in Figure 10 where it can be seen that, although there is a continuum in the relationship across the groups, there is also a clear demarcation of the two groups, the levels of RHA and recall on assw both being higher in the Consistent Factor 3 group.

The correlation of right hand scores and meaningful sequences (assw) seems to suggest that the detection of spatial shapes and verbal meaning may be facilitated by a common process. Zaidel's (1980) work with split-brain and half-brain subjects would support this association. He demonstrated that although each hemisphere processes both verbal and spatial material, each has a characteristic style of doing so. The style of the left hemisphere is analytical, sequential and logical; the style of the right holistic, simultaneous and intuitive. Phonemic segmentation and syntactical aspects of language were, therefore, found to be handled in the left hemisphere, but the processing of linguistic meaning was shown to be accomplished in the right hemisphere. All this seems to indicate that recall of meaningful verbal sequences, such as assw, though primarily sequential and verbal, would optimally require the use of holistic, simultaneous, right hemisphere processes as would detection and recall of the haptic shapes. One would therefore expect an association between hand scores contralateral to the spatial

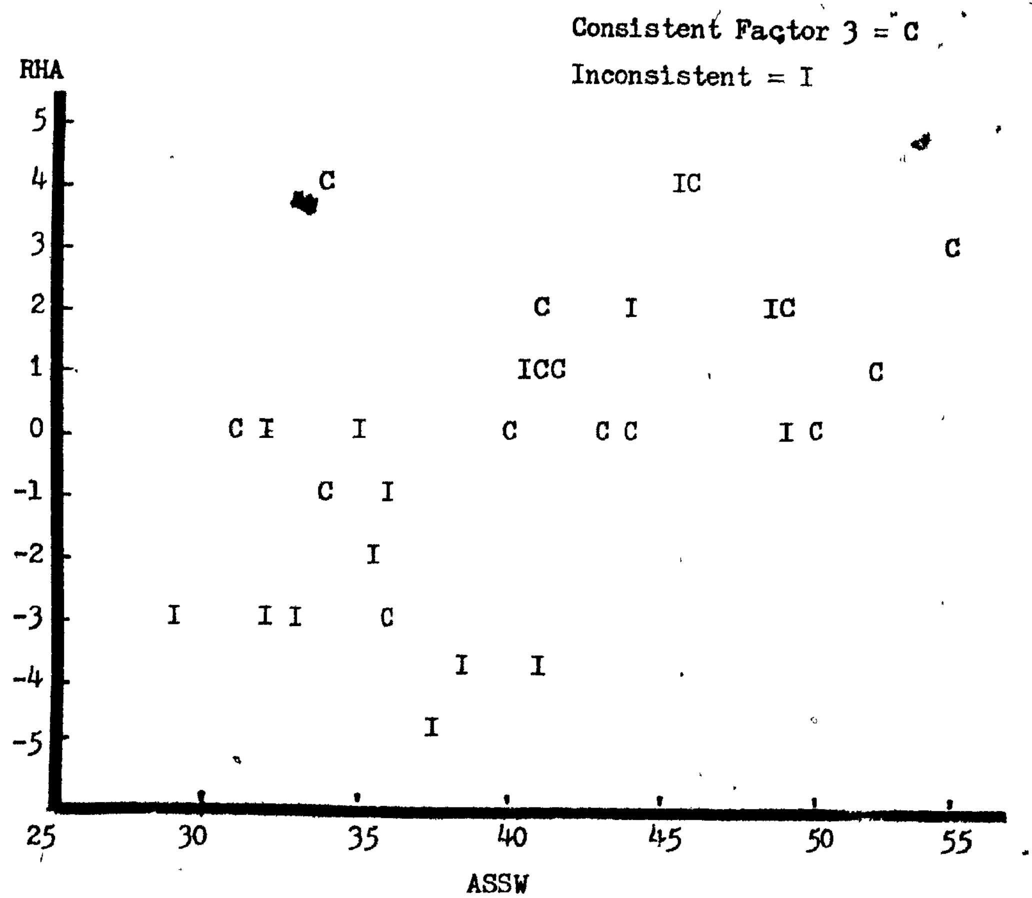


Figure 10. Scatter diagram of relations between measures of right hand advantage (RHA) and recall of words from meaningful strings (ASSW), for Consistent Factor 3 and Inconsistent groups.

hemisphere and assw. Yet, in this study, it was the right hand scores, that is the scores ipsilateral rather than contralateral to the right hemisphere, that were associated with the sequences. Therefore, two possible interpretations might be acknowledged:

1. Right hand scores and meaningful sequences were associated because abnormal bilateral representation of holistic, simultaneous functions allowed the processing of both shapes and meaning to occur in the left hemisphere.
2. Right hand scores and meaningful sequences were associated because both were processed in the left hemisphere in the analytical, sequential style that is characteristic of that hemisphere. It has been suggested (cf. Miller, 1972) that spatial processing in the left hemisphere could be the result of the use of an analytical style and/or of verbal mediation on spatial tasks.

The first interpretation would be in accord with the analyses indicating that the Consistent Factor 3 group had at least bilateral, and possible preferential, left hemisphere processing of holistic, spatial stimuli. It would also appear to support the existence of bilateral spatial representation in the Inconsistent group. However, this interpretation is somewhat in conflict with other evidence indicating that right hand scores in the Inconsistent group were highly associated with incidental learning scores and could denote poor attentional selectivity rather than bilateral, spatial representation. If the Inconsistent group processed right hand shapes as intrusions in the style of the left hemisphere, while the Consistent group processed them holistically in the style of the right hemisphere, then this should be apparent in group differences in the patterns of relationships between right hand scores and the four versions of the Weener strings. Since it is likely that all versions of the strings could require some sequential processing, it would be expected that right hand scores, if processed in a sequential, analytical style, would correlate with all the versions, but particularly with those which have no meaningful structure such as nasswo, the unstructured strings, and nassw, the strings with syntax only. Alternately, if right hand scores reflect spatial, holistic processing, then it might be expected that they would correlate most strongly with those strings that had meaningful structure only, that is with asswo, the strings with associations but no syntax. They might also be expected to be associated with assw, the strings with associations and syntax, but not with the non-meaningful strings, nassw and nasswo.

When hand score relationships with all versions of the Weener strings were examined for each group separately, it was found that the only significant relationship in the Consistent Factor 3 group was between right hand scores and asswo (Table 36), a finding which concurs with the interpretation that, in this group, right hand scores were processed holistically in common with meaning. Additional evidence to suggest that spatial, holistic processes were used by the Consistent Factor 3 subjects is found in the significant correlation between right hand scores and the spatial factor, factor 1 ($\underline{r}$ = .54; $\underline{p}$=.05). In the Inconsistent group, however, right hand scores correlated significantly with all versions of the Weener strings and did not correlate with the spatial factor ($\underline{r}$ = .08; $\underline{p}$ = .80). Since, as previously mentioned, all four variations of the Weener strings could be said to require some processing in the sequential style of the left hemisphere, these relationships suggest that right hand shapes, too, may have been processed in a left-hemisphere style. Thus, the Inconsistents, with higher scores relative to the Consistents on the meaningless, unstructured strings (nasswo), could well have used an analytical, sequential process that was more facilitative when holistic structure was absent. This interpretation would suggest that the incidental stimuli on the central-incidental task, being so strongly related to right hand scores, were also processed analytically and sequentially to interfere with similar processing of the central task stimuli. If this were so, then distractibility could be defined as the inappropriate, analytical processing of extraneous, holistic input, a notion supported by the negative association between indices of selective attention and the spatial, but not temporal, forms of TESP (Table 24).

Thus, circumstantial evidence and single classification analyses appear to support differing interpretations for hand scores in the Consistent and Inconsistent groups. Clearly, the full meaning of right hand scores, and presumed right hemisphere patterns in each group, awaits future insights. It is suggested that one way to gain such insights would be to monitor processing styles and strategies on non-verbal spatial tasks, a procedure not attempted in this study. The spatial/spatial form of TESP could be modified for this purpose. It would be particularly informative to study individual and group differences in palpation styles on the Dichhaptic Test. Until further studies have clarified the meaning of right hand scores, the interpretation of hemisphere patterns in disabled readers will remain somewhat speculative.

Table 36

Relationships between hand scores and Weener string variations in Consistent Factor 3 and Inconsistent groups using right-handed subjects only

	Weener Strings			
	assw	asswo	nassw	nasswo
Consistent Factor 3				
RH	.42	.57*	.21	.45
LH	.17	.02	.17	-.21
Inconsistent				
RH	.60*	.63*	.67**	.54*
LH	-.39	-.31	-.25	.09

** $p < .01$; * $p < .05$

REA-TESP relationships. Surprisingly, it was the index of language lateralization, REA, that was positively associated with TESP discrepancy scores, the measure of the degree of advantage of a spatial response format over a temporal response format when sequential stimuli were presented successively (Table 25). This puzzling relationship was further explored by breaking down the REA into right and left ear components and the association to each group separately (Table 34). No significant TESP-ear relationships were found in the Inconsistent group. However, in the Consistent Factor 3 group, the TESP discrepancy index was negatively related to left ear scores reflecting the significant relationship between left ear scores and the temporal/temporal component of the index.

In the absence of group differences in patterns or levels of ear functioning (Table 26), it is difficult to interpret these divergent results in terms of hemisphere specialization patterns. However, the high variability of left ear scores (sd = 13.6) in the Consistent Factor 3 group suggested heterogeneity within the group insofar as the processing of left ear signals is concerned. Variability in left ear scores also has been reported by others in both the learning disabled population (Hynd, Obrzut, Weed & Hynd, 1979; Obrzut, 1979), and in young children (Hiscock & Kinsbourne, 1980). Hynd et al. (1979) and Obrzut (1979) hypothesized that difficulties in selectively attending to the right ear might account for observed variability and for the left ear association with other processing measures. Data presented here for the Consistent Factor 3 group, however, would not support this hypothesis since, although left ear scores correlated significantly with selective attention ($r = .62$, $p = .02$), it was in the direction opposite to that required if such an interpretation were defensible.

Hiscock and Kinsbourne (1980), following Bryden and Allard (1976), have used a processing capacity explanation to interpret the meaning of left ear scores. They contend that since right ear scores are usually reported first, left ear scores could reflect individual limitations in sequential processing and storage capacity. Data appearing in Table 37 would seem to support this interpretation for the Consistent Factor 3 group since significant and positive correlations between levels of left ear performance and levels of performance on other sequential

Table 37

Relationships of right and left ear scores to other variables for Consistent Factor 3 and Inconsistent groups using right-handed subjects only

	TESP index	spatial/ temporal	temporal/ temporal	central learning	nasswo
Consistent Factor 3					
right ear	-.33	.08	.19	.62*	.49
left ear	-.55*	.35	.65**	.68**	.57*
Inconsistent					
right ear	.22	.54t	.30	.53t	-.54t
left ear	.09	.06	-.03	.15	-.28

** $p<.01$

* $p<.05$

t $p<.10$

memory tasks (nasswo and central learning) also occurred for this group. No such left ear relationships were observed for the Inconsistent group, for whom right ear performance appeared more closely associated with levels of sequential processing. Further, when order of report was tabulated for each ear for each group, remarkably similar response modes were noted. Right ear signals were reported first on 61.5% of the trials in the Consistent Factor 3 group, and in 62.8% of the trials in the Inconsistent group. Therefore, differences in response order itself could not account for the differences in the patterns of ear score relationships.

Able learners in this study displayed relatively high left ear scores (Table 34) and a high overall dichotic recall (89%). Correlation between left and right ear scores was positive (r = .56, p = .03) which, in accordance with a processing capacity interpretation, suggests the Able Learners had an ability to handle information via both ear channels, the higher the left ear scores the higher the capacity. These relationships taken in concert for the Able Learner and Consistent Factor 3 groups would be supportive of a sequential processing capacity hypothesis, and would appear to augment evidence of a diminished sequential processing capacity in the Consistent Factor 3 group.

Relationship of hand and ear scores to attentional measures. The meaning of the selective attention index in the Consistent Factor 3 group became somewhat clearer when hand and ear score relationships were examined for each group separately, and interpreted in the light of the foregoing results. Given the high correlations between central learning and left ear scores (Table 38), the selective attention index appeared to be largely a measure of sequential processing capacity. For the Inconsistent group, it appeared to reflect selectivity, that is, the processing of extraneous holistic stimuli when a sequential memory task is central. If one wished to determine the relative roles that sequential processing capacity and distractibility play in the performance of the central learning task, one would need a baseline measure of central task performance, perhaps using stimulus cards with the central stimuli only, prior to introducing the experimental condition with both central and incidental stimuli.

Summary and implications. These somewhat complex results indicate that quite different processes in each of the groups may be determining level of scores on some of the dichotomous stimulation measures, thus affecting the apparent degree of hemisphere lateralization in each of the two groups. Possible differences in the meaning of left ear scores suggests that REA should not be used to indicate degree of language lateralization since diminished sequential memory capacity and differing response strategies could artificially inflate or diminish the degree of REA. Questions have also been raised in this study about the use of RHA to designate degrees of abnormal right hemisphere lateralization since right hand scores were found to be strongly related to intrusion measures and to selective attention in the Inconsistent group, and so equal hand scores could reflect attentional disorders rather than bilateral spatial representation. In this regard, the weight of evidence in the present investigation would suggest that the performance of the Inconsistent group is better understood if no assumptions of bilateral spatial representation are made.

Bryden and Allard (1976) have offered the opinion that inconsistencies in response strategy would probably not affect the usefulness of the Dichotic Listening Test as a means for determining whether or not lateralization has occurred. However, the Witelson Dichhaptic Test is a relatively new research tool, and so it is not clear if its possible susceptibility to distraction effects would compromise its validity for determining if lateralization of holistic, spatial processing has taken place. However, if the assumption of validity can be accepted for the Consistent Factor 3 group, with the possible attentional limitations being kept in mind for the Inconsistent group, it might be of value to search for a model that could explain the origin, nature and consequences of the inferred patterns and concommittant behaviours in the two groups.

A theoretical model. The very term "hemisphere specialization" encourages acceptance of the notion that language is exclusively controlled in the left hemisphere and spatial input is processed via the right hemisphere. Yet, as an adequate explanation of the relationship between hemisphere function and learning disability, this generalization must be regarded as the simplified, rudimentary source of a more complete, evolved theory. Such a theory seems to be emerging from the work of Zaidel (1980) who has indicated that knowledge of the general processing styles of the two hemispheres is more germane to learning dysfunction than knowledge of hemisphere localization for content or sensory input. Thus, he has suggested that the left hemisphere functions in an analytical, logical, sequential manner and, therefore, presumably processes most successfully that input which is amenable to this mode of processing, whether that input be verbal or non-verbal, whether it be haptic, visual or auditory. The right hemisphere processes input in a holistic, intuitive and simultaneous way, and is most facilitative for stimuli that is amenable to this particular style.

The results from the present investigation appear to fit quite comfortably into such a framework. They indicated that abnormal right hemisphere specialization, as demonstrated by equal hand scores or possibly an RHA, was accompanied by relatively strong holistic functioning,

Table 38

Relationships of ear and hand scores to the Selective Attention Index and Central-Incidental Scores

for Consistent Factor 3 and Inconsistent groups

using right-handed subjects only

	Consistent Factor 3			Inconsistent		
	selective attention	central learning	incidental learning	selective attention	central learning	incidental learning
RH	.07	.10	.01	$-.49^{t}$	.09	$.77^{**}$
LH	-.17	.31	$.54^{t}$	.20	-.17	-.35
RE	.32	$.62^{*}$	.18	.43	$.53^{t}$	.43
LE	$.62^{*}$	$.68^{**}$	-.26	.11	.15	.11

** $p < .01$

* $p < .05$

t $p < .10$

but poor sequential functioning over a wide variety of input. These findings, in turn, raised questions about whether there might be a reciprocal relationship between the two processing styles or functions, especially when it appeared that holistic processes could be seen as operating within the left as well as the right hemisphere.

Harris (1978), drawing from the clinical observations of Levy (1969) and Milner (1969), has explicated a model which assumes incompatability of the two types of coding operations within the same cerebral locus. He hypothesized that individual, genetic blueprints may predispose the development of sequential, analytical processes for one hemisphere and holistic, simultaneous processes for the other, with control of organization being possible, not only for the designated hemisphere, but for the second as well. Although Harris was largely concerned with left hemisphere processes (which he designated as verbal) gaining control of the right, and with the consequent diminution of spatial function, for the purposes of this investigation it is of interest to speculate about what could occur if holistic processes gained control of both hemispheres. Under the given genetic blueprint, the designated hemisphere would become specialized for holistic, simultaneous functions, and, in addition, the other hemisphere would also become committed to these processes and then be inappropriately designed for analytical, sequential functions.

With reference to the diverse performances of the two groups, could it then be said that, in view of the evidence of preferential left hemisphere processing of spatial stimuli and high left hand detections, spatial, holistic processes have gained control of both hemispheres in the Consistent Factor 3 group, and so these subjects are locked into a holistic, simultaneous style of processing for all stimuli? If this were so, the individual would be limited to a "right hemisphere style" of functioning. Therefore, language processing would be expected to rely heavily on the use of meaning and contextual cues and sequential function might be expected to be deficient. However, in the Inconsistent group, analytical, sequential processes would presumably still be in control in the left hemisphere and so any spatial processing in this hemisphere would be done in an analytical style, perhaps resulting in somewhat diminished spatial competence. The evidence that the Consistent Factor 3 subjects displayed enhanced performance over the Inconsistents on linguistic strings that contained meaning and holistic structure, but diminished performance on meaningless strings is consonant with this interpretation. The pattern of scores on TESP could also be comprehended from this perspective. The suggestion that distractibility in the Inconsistent group is the result of inappropriate or deficient spatial, holistic processing is also compatible with this model since it would suggest that spatial processing in the left hemisphere would be done in a sequential, analytical manner, interfering with other sequential, analytical processing.

Within this model it might also be predicted that the sequential disability would vary in relation to the amount of relative control assumed by the spatial, holistic processes in the left hemisphere. It was earlier noted that in the Consistent Factor 3 group the correlations between RHA and right ear scores were in the predicted direction if this were so (Table 32), although the strength of the relationship was not statistically significant. No significant, negative correlations between RHA (or right hand scores) and other measures of verbal, sequential processing were found for the Consistent Factor 3 group, however (Table 39). Although it might be argued that relationships would be stronger were it not for the small sample size and the possible insensitivity of the RHA index to degrees of specialization, it appears that there is little support in the present data for the existence of such a simple, direct relationship.

Yet, before such an hypothesis could be eliminated, more adequate tests are needed using purer measures of the holistic and sequential processes. A case in point is the temporal/temporal form of TESP. It was designed as a measure of purely temporal input and response and so might have been expected to correlate negatively with right hand scores in the Consistent Factor 3 group. Instead, there was a significant positive correlation between the two measures (Table 39). It appears that the ability to attach meaning to the meaningless symbols might have been the essential process that affected relative level of response within the Consistent Factor 3 group rather than level of sequential processing ability. Modifications of the temporal/temporal symbols, or prior rehearsal of meaningful labels, could perhaps illuminate the role meaningful, right hemisphere processes play in such tasks. In any case, it would appear that further tests of this model would require the use of tests with known left or right hemisphere properties. Studies with half-brain and split-brain subjects (cf. Zaidel, 1980) provide some insights concerning such "hemispherically pure" measures.

Table 39

Correlations of RHA and right hand scores with sequential tasks for the Consistent Factor 3 group using right-handed subjects only

Variable	central learning	nasswo	nassw	asswo	assw	temporal/ temporal	temporal/ spatial	right ear	left ear
RHA	-.27	.02	.18	.10	.23	.11	.33	-.51[t]	-.26
RH	.10	.45	.21	.57*	.41	.58*	.38	-.03	.43

* $p < .05$

t $p < .10$

Test Scores and Academic Competence in Reading and Spelling

Measures of dichotomous stimulation. Since it appears that quite different cognitive processes could be related to level of performance on the same dichotomous stimulation variables in each of the two groups, it is most instructive to examine the relationships between the dichotomous test scores and the academic variables for each of the groups independently (Table 40). In the Consistent Factor 3 group, right ear scores correlated significantly with all reading measures, while left ear scores correlated with spelling and with all of the reading measures except speed. These relationships appear to reflect the role that good sequential processing plays in reading and spelling competence and, once again, demonstrate that left ear performance may be a sensitive index of sequential processing capacity. Right hand scores showed a trend relationship with word recognition and were significantly associated with spelling achievement, suggesting that holistic, spatial processes may be important factors in the academic performance of this group, although, surely, both word recognition and spelling must depend primarily on good sequential, analytical skills. It is proposed that the more than 4-year retardation of the Consistent Factor 3 group may be explained, in part, by a dependence on spatial processing.

In the Inconsistent group, none of the ear or hand measures were related to level of performance on any of the academic measures. Thus, although the two groups did not differ in level of competence on any of the academic skills measured in this study, very different factors were associated with their failure to achieve.

Table 40

Correlations between dichotomous stimulation measures and reading and spelling variables for Consistent Factor 3 and Inconsistent groups using right-handed subjects only

	Reading Measures			
	Accuracy	Speed	Word Recognition	Spelling
Consistent Factor 3				
right ear	.69**	.63*	.62*	.39
left ear	.57*	.41	.60*	.66*
right hand	.23	.08	.47t	.58*
left hand	.40	.26	.12	.37
Inconsistent				
right ear	.38	.13	-.06	.16
left ear	.39	-.21	-.10	-.02
right hand	-.07	-.13	-.06	-.02
left hand	-.14	.19	-.07	-.05

** $p < .01$

* $p < .05$

t $p < .10$

Measures of selective attention and spatial-sequential processes. The index of selective attention, and central learning score, a component of that index, were positively correlated with reading accuracy in the Inconsistent group (Table 41). This is in accordance with the earlier finding that this subgroup, unlike the Consistent Factor 3 subgroup, exhibited a pattern of performance that could be said to indicate poor attentional selectivity. Correlations between reading accuracy and assw, the meaningful strings, may reflect the relative difficulties the Inconsistent group appeared to have in the apprehension of holistic structure or meaning (Table 19).

In the Consistent Factor 3 group, word recognition and spelling were positively related to measures of sequential processing (ear scores, temporal/temporal, selective attention), and were negatively related to those measures which presumably required spatial, holistic processes (embedded figures, spatial/spatial). Moreover, level of academic competence in these areas was also related negatively to the discrepancy scores derived to express the relative advantage of holistic structure on the Weener strings and TESP. The relationship between the TESP discrepancy scores and spelling achievement is of particular interest, suggesting again that that the preference for holistic structure is disadvantageous to spelling competence. These relationships would appear to be in accord with the interpretations from the model based on the hypotheses of Zaidel (1980) and Harris (1978), suggesting that the Consistent Factor 3 group is heavily dependent on, if not actually locked into, the use of holistic, spatial processing.

Table 41

Correlations[1] between measures of selective attention and sequential processes and academic variables for Consistent Factor 3 and Inconsistent subgroups, using right-handed subjects only

	central learning	incidental learning	selective attention	embedded figures	assw	asswo	nassw	nasswo	spsp	spte	tesp	tete	Weener discrep.	TESP discrep.
Consistent Factor 3														
Reading														
accuracy				-.48					-.48				-.49	-.54
speed														
word recognition			.51	-.59									-.53	-.58
Spelling									-.49			.53		-.80
Inconsistent group														
Reading														
accuracy	.53		.50											
speed														
word recognition					.51									
Spelling														

[1] Only those correlations of p<.10 are included.

These results not only indicate that the two subgroups differed as to variables associated with reading and spelling achievement, but also reaffirm the view that reading is a complex task and failure to attain competence is unlikely to be related to a single variable in the learning disabled population. These results point to the need to explore in greater detail the nature of the subgroup differences in reading and spelling performance. Analysis and classification of error types according to Boder's (1973) scheme might be a promising way to initiate such research. It will be recalled that she found three types of poor readers: 1) dysphonetic, in which performance was characterized by difficulties in phonetic analysis and synthesis of words; 2) dyseidetic, in which performance reflected deficiencies in the perception of letters and words as visual wholes, and; 3) alexic, which reflects both types of disabilities. Zaidel (1980) has presented evidence to suggest that the deficiencies of the dysphonetic subtype correspond to those exhibited by subjects with single right hemispheres. It would be predicted, on the basis of their performance in this investigation, that the Consistent Factor 3 group would be found to conform to the dysphonetic type. The Inconsistent group, because of its observed cross-dimensional integration difficulties and relative deficiencies in holistic, spatial functioning might be said to reflect problems associated with bilateral parietal abnormalities (Gaddes, 1980; Geschwind, 1965). Therefore, they would be predicted to conform to the dyseidetic type (Zaidel, 1980).

Summation of Results: Study No. 2

In addition to indicating that there were group differences in levels of functioning on measures of selective attention, sequential recall and hemisphere specialization, this study has provided evidence of meaningful group differences in patterns of performance. These patterns, as expressed by the Weener, TESP and RHA indices were interrelated and appeared to reflect competency in spatial-holistic versus sequential-verbal functioning, the Consistent Factor 3 group showing diminished skill on the sequential tasks, but relative strength on those with holistic features. Although there was little evidence of a direct reciprocal relationship between amount of presumed holistic processing in the left hemisphere (RHA) and diminution of sequential left-hemisphere functioning, the relationships between the indices derived to express holistic versus sequential processes, (Weener and TESP indices) and the index of abnormal hemisphere specialization (RHA) imply that different patterns of hemisphere functioning in the two groups could subserve the observed differences in cognitive functioning. That the academic measures were related to measures of hemisphere functioning and sequential processing in the Consistent Factor 3 group, the group with presumed abnormal specialization patterns, but not in the Inconsistent group, would seem to lend support to this notion. It remains now to be seen if these characteristic group differences are also related to the WISC/WISC-R factor score patterns that originally identified the two groups.

CHAPTER IV

RELATIONSHIPS BETWEEN IDENTIFYING WISC-R VARIABLES AND MEASURES THAT DIFFERENTIATED THE GROUPS

In this chapter the group differences in selective attention, sequential processing and hemisphere specialization as observed and recorded in Study No. 2 will be related to the defining WISC-R characteristics of the groups as observed and recorded in Study No. 1. The chief purpose is to investigate the usefulness of the WISC-R for predicting or diagnosing subtypes.

It will be recalled that the two groups were originally differentiated on the basis of lowest factor scores over three WISC-R assessments. The Consistent Factor 3 group was so named because its lowest factor score was always factor 3, while the Inconsistent group was found to have varying lowest factor scores. Since the two groups differed significantly as to level of factor 3, and the Consistent Factor 3 group was always lowest on that factor, it was predicted that they would exhibit disorders in an area related to factor 3 functioning. Yet, although the weight of evidence has pointed to the existence of a sequential processing disorder in the Consistent Factor 3 group, surprisingly, none of the presumed measures of sequential processing correlated with level of factor 3 functioning (Table 42). Moreover, none of the other dependent measures which discriminated the groups was associated with factor 3 scores (Table 42). On the other hand, factor 1 scores correlated with right hand scores, RHA, the selective attention index and the Weener and TESP discrepancy indices (Table 42). Factor 1 - factor 3 discrepancy scores, in addition to the foregoing,

TABLE 42

Correlations between variables that differentiated the groups and the WISC-R factor score indices for Consistent Factor 3 and Inconsistent groups combined and independently

	right hand	incidental learning	nasswo	assw	temporal/ temporal	selective attention	Weener discrp.	TESP discrp.	RHA
Combined									
Factor 3	.06	.32	.26	.06	.29	-.11	-.20	-.21	-.09
Factor 1	.50**	-.36^{t}	-.32	.23	-.13	.39*	.57**	.47**	.45**
Factors 1-3 discrepancy	.42*	-.46*	.40*	.18	-.25	.40*	.60**	-.51**	-.37*
Consistent Factor 3									
Factor 3	.23	.63**	.16	.18	.17	-.25	.01	-.23	.10
Factor 1	.51*	.21	.02	.16	.05	-.17	.33	-.21	.53**
Factors 1-3 discrepancy	.49^{t}	-.11	-.06	.08	-.05	-.05	.40	-.11	.58*
Inconsistent									
Factor 3	.32	-.04	.01	.25	.11	.25	.35	.07	-.45
Factor 1	.13	-.41	-.16	-.05	.28	.55*	.06	-.05	-.11
Factors 1-3 discrepancy	-.07	-.36	-.16	-.20	.20	.37	-.15	-.09	.17

$^{**}p < .01$; $^{*}p < .05$; $^{t}p < .10$

correlated significantly with nasswo and incidental learning. These provocative findings generated questions as to which of the test measures, alone or together, best forecast the groups into which the subjects had been assigned. To determine this, several discriminant analyses were carried out.

Results of Discriminant Analyses

In a step-wise discriminant analysis, variables are selected on the basis of their power to discriminate the groups, with the first one selected having the highest discriminatory power and each subsequent one being selected on the basis of the additional power it adds to the prediction, given the variables already selected. Four different step-wise discriminant analyses were performed to explore the relative usefulness for classification purposes of various predetermined configurations of test scores. The results are summarized in Table 43. In the first analysis, all the single, subtest measures (14) were offered for selection. As it can be seen, nasswo, assw, central learning and temporal/temporal were successively selected and added to the equation and, since these variables were those presumed to measure sequential processes, this discriminant analysis largely confirmed previous findings using analysis of variance techniques. It should be noted that all the subjects originally assigned to the Consistent Factor 3 group were correctly classified and 11 out of 15 of the Inconsistent group were correctly placed, for a total of 86.7% correct.

The second analysis included indices derived from test and subtest scores to represent accepted interpretations of what the various instruments were presumed to measure: REA (right ear - left ear scores;

TABLE 43

Summary table of discriminant analyses

for Consistent Factor 3 and Inconsistent groups

Sets of Measures	Variables selected	Correct Classifications by group	No.	%	% Correct Classifications*
I. All test measures RE, Le, Rh, Lh, central learning, incidental learning, assw, asswo, nassw, nasswo, sp/sp, sp/te, te/sp, te/te.	Steps 1. nasswo 2. assw 3. central learning 4. te/te	Consistent Factor 3	15	100	86.7
		Inconsistent	11	73.3	
II. Differential Scores Selective attention, REA, LHA, Weener Discrepancy, TESP discrepancy	Steps 1. Weener Disc. 2. TESP disc. 3. Selective attention	Consistent Factor 3	15	100	93.3
		Inconsistent	13	86.7	
III. Factor Discrepancy index, and all measures in I.	Steps 1. Factor Index	Consistent Factor 3	14	93.3	90.0
		Inconsistent	13	86.7	
IV. Factor Discrepancy index and all indices in II.	Steps 1. Factor Index 2. Weener Disc.	Consistent Factor 3	14	93.3	93.3
		Inconsistent	14	93.3	

*All % were duplicated when jacknifed.

right ear advantage), RHA (right hand scores - left hand scores), selective attention index (% central learning - % incidental learning), Weener discrepancy (assw - nasswo), and TESP discrepancy (temporal/spatial - temporal/temporal). The Weener discrepancy scores, TESP discrepancy scores and the selective attention index were entered into the analysis in that order and correctly forecast placement of all the Consistent Factor 3 subjects and all but two of the Inconsistent subjects for a total of 93.3% correct. Thus, the second analysis indicated that differential indices were better predictors of group membership than single, level-of-performance scores.

For the third analysis, an index of discrepancy between factor 1 and factor 3 scores on the third WISC-R assessment was entered into the analysis along with each of the single test scores. It will be recalled that, although the initial grouping procedure was based on consistency of lowest factor score only, it was found that the two groups so formed also differed as to the amount of observed disparity between factor 1 and factor 3 scores, the Consistent group displaying a significant discrepancy. Moreover, this disparity was maintained across the three assessments. Therefore, as hinted previously, factor discrepancy may be just as important, or more so, than consistency of low factor 3 scores. The question arises, would such a factor score discrepancy index alone, or together, with any one or some of the single test measures discriminate the two groups? The third analysis indicated, as might have been predicted, that the factor discrepancy score was selected to enter the equation first, and none of the single test measures could augment its classificatory power. It was observed that the factor discrepancy index alone correctly classified 90% of the subjects (Table 43).

Finally, the differential indices rather than single test scores were entered into the analysis along with the factor discrepancy score. Since it had been speculated that the TESP and Weener discrepancy indices might both be measuring temporal (sequential) versus spatial (holistic) abilities, an assumption which could also perhaps apply to the factor discrepancy score, it was of interest to see if the factor discrepancy score would subsume the classificatory power of these indices. This fourth analysis indicated that the factor discrepancy index was again the best discriminator. Only the Weener discrepancy score added to the classificatory prediction. Once again, 93.3% of the subjects were properly classified with one subject in each group being misplaced.

Several points of interest have emerged from the results of these analyses. First, the initial analyses confirmed that, when single test measures indicating level of performance were used, group membership was best predicted by variables requiring memory for temporally presented sequences that were unrelated to factor 3 scores. Thus, although the Consistent Factor 3 group had been initially identified because its subjects consistently exhibited lowest functioning (and presumably, their area of disorder) in factor 3, their observed area of weakness in this investigation could not be understood in relation to level of factor 3 scores alone. All this suggests that consistency might be the meaningful defining characteristic, or that there may be more than one kind of low factor 3 functioning either within the Consistent group, or across the Consistent and Inconsistent populations. The last hypothesis seems to be tenable in view of the overlap in factor 3 scores between the two groups as indicated by the mean values and standard deviations on the final assessment (Table 10).

The congruence between the classifications based on the consistency of low factor 3 functioning over an extended period of time, and the classification based on factor 1 - factor 3 discrepancies derived from a single, recent WISC-R assessment suggests that factor discrepancy might be related to consistency. Put another way, it appears that discrepancy on a single assessment could be a satisfactory, alternate means of determining consistency over time. Since it was shown that the index of factor score discrepancy alone accurately classified 90% of the subjects, and subsumed the classificatory power of all other differentiating variables except the Weener discrepancy index (Table 43), and since the variables that discriminated the groups correlated with factor score discrepancy rather than with level of factor 3 functioning (Table 42), classification based on discrepancy scores could be a more meaningful way of identifying the groups. If so, this would have important practical implications since subtyping could be made after a single WISC-R assessment.

To test this possibility, regression analyses were carried out to see if the discriminating variables explained more of the variance in the factor score discrepancy index than in either the factor 1 or factor 3 scores alone. In addition, subjects were reclassified according to their factor discrepancy scores, and a discriminant analysis was performed using the same variables that differentiated the groups formed on the basis of the original classification scheme. If factor discrepancy and factor 3 consistency are analagous, then the new groups should also be discriminated with a high degree of accuracy by these same variables.

Relationship of the Factor Score Discrepancy Index to the Consistency x Disability Classification Scheme

All measures which produced significant, between group differences were regressed against the relevant factor score variables in step-wise fashion to see how much of the variance of each variable was predicted by the differentiating test measures. Results indicated that the test scores predicted 29% of the factor 3 variance, 63% of the factor 1 variance and 67% of the variance of the factor discrepancy index (Table 44). Thus, the observed differences in functioning between Consistent Factor 3 and Inconsistent groups were related more to the degree of discrepancy between factors 1 and 3 than to differences in level of functioning on factors 1 or 3 alone. Moreover, it should also be noted that group differences in factor score discrepancy patterns were present on the first assessment (Table 9). The Consistent Factor 3 group displayed a significant factor 1 - factor 3 disparity of nine points, but the Inconsistent group did not. When scores from the dependent variables in the present investigation were regressed against factor discrepancy scores from the initial WISC assessment, 66% of the variance was explained (Appendix I, Table 1). This suggests that these meaningful relationships may be relatively enduring, a notion that requires further investigation using a longitudinal, rather than retrospective, research design.

Evidence from previous discriminant analyses (Table 43) suggested that Consistent Factor 3 subjects and those with discrepant factor patterns

TABLE 44

Summary of Stepwise Regression Analyses

all variables that differentiated the groups regressed against

WISC-R factor score indices for Consistent Factor 3 and Inconsistent groups combined.

Index	Step	Variable entered	R^2	B-value (final equation)	Standard error (final equation)	F	P>F
Factor 3	1	incidental learning	.103	1.811	.813	4.96	.036
	2	selective attention	.226	.005	.003	2.65	.117
	3	TESP discrepancy score	.247	.003	.000	.40	.535
	4	right hand advantage	.255	- .469	.470	1.23	.279
	5	right hand score	.288	- .687	- .687	1.08	.310
	6	temporal/temporal	.291	.118	.370	.10	.752
Factor 1	1	Weener discrepancy score	.330				
	2	right hand score	.440	2.373	.002	8.53	.008
	3	selective attention	.536			4.49	.045
		Weener discrepancy replaced by TESP discrepancy	.541	- .001	.001	3.83	.062
		selective attention replaced by incidental learning	.550				
	4	nasswo	.589	- .379	.292	1.69	.206
		incidental learning replaced by selective attention	.613	.005	.292	1.69	.206
	5	temporal/temporal	.625	.457	.511	3.83	.381
	6	Weener discrepancy	.635	.122	.150	.66	.423
Factor 1-Factor 3 Discrepancy	1	Weener discrepancy	.361				
	2	selective attention	.472				
	3	TESP discrepancy	.526	- .002	.001	5.59	.027
		Weener replaced by right hand	.526	3.357	1.094	9.41	.006
		selective attention replaced by incidental learning	.597	-1.644	.572	8.25	.009
	4	nasswo	.648	- .361	.310	1.25	.256
	5	right hand advantage	.661	.774	.691	1.25	.275
	6	Weener discrepancy	.673	.144	.162	.79	.384

could be largely synonymous; discrepancy might be an indicator of consistency. Therefore, all subjects were reclassified according to the presence or absence of this disparity, the criterion being a 9-point, or more, discrepancy between factors 1 and 3 (see Chapter 2). This system yielded 15 subjects in each of two groups labelled Discrepant Factor 3 and Nondiscrepant, respectively. The former name was applied since it was observed that all members of the group, in addition to having significantly discrepant factor scores, also had lowest scores on factor 3. The discriminant analysis indicated that the group classifications were forecast by the discriminating variables with an accuracy of 90%, the selective attention index, right hand scores and nasswo entering the prediction equation in that order (Table 45). From these results it can be concluded that in the present sample of subjects, the classifications based on the disability x consistency criteria were largely duplicated by the classification based on factor score discrepancies. Moreover, the step-wise regression and correlational findings suggested that the discrepancy classification is probably a more meaningful, or useful, way of conceptualizing the differences between the groups.

The results of this investigation may, therefore, be placed in the context of previous studies that subdivided the learning disabled population on the basis of discrepancies in WISC verbal and performance IQ scores. These subscale discrepancy studies grew out of a psychoneurological approach that saw performance scores (factor 1) reflecting functioning of the right hemisphere and verbal scores (factor 3) representing the functioning of the left hemisphere in normal populations.

TABLE 45

Summary of discriminant analysis using variables that discriminated Consistent Factor 3 and Inconsistent groups using reclassified Discrepant and Non-discrepant groups

Sets of Measures	Variables Selected	Correct Classifications by group			% Correct classifications
All Discriminating variables:		Group	No.	%	
	1. selective attention	Discrepant Factor 3	14	93.3	90.0
		Non-discrepant	13	86.7	
	2. right hand				
	3. nasswo				

This, along with the role right hand scores have been observed to play in the differentiation of the subgroups (Table 45), suggests that the differences between the groups may be usefully viewed in terms of the interpreted patterns of hemisphere specialization.

Finally, the foregoing evidence suggests that the WISC/WISC-R factor scores from a single assessment may be a reliable means of classifying learning disabled subjects if patterns, rather than levels, of performance on factor scores are used.

CHAPTER V

CONCLUSIONS, LIMITATIONS, IMPLICATIONS

The focus of most of the research done to date in the learning disabilities field has been to differentiate learning disabled children from their achieving peers. The present investigation has attempted to differentiate subgroups of the learning disabled from each other. The chief findings can be summarized in relation to two main areas: (1) Those concerning the characteristics of the defined subgroups, and (2) those concerning the usefulness of the WISC-R factor scores in the identification of these subgroups.

Subjects who had been clinically diagnosed as learning disabled were initially classified into two subgroups on the basis of the consistency of their lowest WISC-R factor score over time and were compared on measures of selective attention, the voluntary use of control processes, spatial-temporal recall for position, free recall of items presented serially and hemisphere specialization patterns. It is important to note that these subgroups could not be statistically distinguished by their degree of academic retardation on standardized tests of reading and spelling. Nor were they easily discriminated clinically on the basis of IQ scores.

Summary of Chief Findings

Characteristics of the Defined Subgroups

Contrary to predictions, the Consistent Factor 3 subgroup, so labelled because of a stable pattern of low factor 3 scores, did not exhibit deficiencies in selective attention relative to their peers in the Inconsistent subgroup. The latter group, so labelled because of a changing pattern of lowest factor scores, processed more extraneous information and showed a greater trade-off between extraneous, incidental learning and the central learning task. The Consistent Factor 3 subgroup, however, did exhibit lower levels of recall for unrelated temporal sequences than the Inconsistent group. This was true whether free recall of items was required from word strings presented in an auditory temporal fashion, or whether ordered recall for position was demanded from a successive string of symbols presented in the visual mode. Thus, the sequential processing deficiency of the Consistent Factor 3 group was neither material nor modality specific.

No compelling evidence was found to indicate that the lower performance of the Consistent Factor 3 group on these temporal sequential tasks could be attributed to less efficient use of voluntary rehearsal and recall procedures as measured by self-report, tabulated order of recall and analysis of the shape of serial recall curves. Some indirect support was found for Bakker's (1972) theory that disorders in temporal order perception could account for the difficulties since diminished recall appeared to be associated with a temporal sequential form of presentation. Although the specific nature of the serial processing difficulties experienced by the Consistent Factor 3 group could not be determined, it was suggested that TESP, a spatial-temporal memory task designed for this study could be modified and improved to further investigate this matter.

Group differences in patterns of performance across varying types of successive and spatial sequences were also noted. Although the Consistent Factor 3 group showed diminished recall on unrelated strings, they actually recalled more items than the Inconsistent group on word strings that contained meaningful structure. Further, in the Consistent Factor 3 group recall of a temporally presented sequence was higher when the required response was in a spatial-sequential format than when it was required within the same temporal-sequential mode. In contrast the Inconsistent group demonstrated a relative decrease in recall when the response required translation to the spatial-sequential format. This suggested that the Inconsistent group might represent that portion of the learning disabled population reported to have difficulties with integration. On the other hand, the improved performance of the Consistent Factor 3 group suggested that the processing and recall of verbal sequences may have been assisted by structure in the form of meaning (syntax and associations) or grids (spatial format).

The results of dichotomous stimulation tasks administered to determine patterns of hemisphere specialization, indicated that both groups had verbal, sequential processes appropriately lateralized in the left hemisphere, but that there were group differences in patterns of hemisphere specialization for spatial, holistic processing. The Consistent Factor 3 group made significantly more correct right hand detections than the Inconsistent group and a single classification analysis of variance indicated that their right hand detections were significantly higher than their left hand detections. Moreover, their right hand scores correlated with other presumed measures of holistic processing suggesting they had at least bilateral representation of spatial holistic processes in the left hemisphere.

The Inconsistent group, however, was seen to have normal hemisphere representation of both verbal-sequential and spatial holistic processes.

This interpretation was based on evidence that their right hand scores could be intrusions reflecting poor attentional selectivity rather than bilateral spatial representation. It was further supported by evidence that their right hand scores correlated with measures of sequential, verbal processing rather than measures of holistic, spatial processing such as WISC-R factor 1.

A model derived from the work of Zaidel (1980) and the hypotheses of Harris (1978) was offered to explain group differences in patterns of hemisphere specialization and spatial-sequential performance. This model assumes that processing in the right and left hemisphere is neither modality nor material specific, but that different, incompatible styles of processing are genetically programmed for control of each hemisphere. Although spatial, holistic processes typically gain control of the right hemisphere and sequential, analytical processes usually gain control of the left, it is also possible, under a given genetic program, for one processing style to gain control of both hemispheres. In general, then, both verbal and spatial input could be processed in either hemisphere, but would be handled with varying degrees of success in the predominating mode of that hemisphere. Under certain conditions, an individual could be locked into one particular style of functioning for all material if both hemispheres were committed to the same processing mode.

In terms of this model, it is suggested that holistic processes may be in control of both hemispheres of the Consistent Factor 3 subjects and so they possess left hemispheres that are poorly designed for sequential, analytical functions. This would account for the relatively strong holistic-spatial processing and weak sequential-verbal functioning that was observed in this group. The importance of the existence of bilateral, holistic processing, as represented by a right hand advantage, to the understanding of the cognitive performances of the two groups is seen in the relationships between RHA and the Weener and TESP indices of spatial versus sequential functioning, as well as in the relationship of RHA to the WISC-R factor discrepancy scores. These associations would seem to suggest that differences in hemisphere specialization patterns could underly the observed group differences in cognitive functioning.

Left ear scores were found to correlate strongly with other measures of sequential processing in the Consistent Factor 3 group and so were interpreted to be sensitive indicators of sequential processing capacity. Thus, significant correlations between left ear scores and central learning as well as with the selective attention index suggested that the Hagen Central-Incidental learning task was measuring sequential processing capacity rather than selective attention in the Consistent Factor 3 group.

Interestingly, ear scores and right hand scores were both found to be positively related to measures of reading and spelling, which one must suppose to be essentially sequential and verbal in nature. Further, there was a trend in the Consistent Factor 3 group for ear scores to correlate negatively with the degree of right hand advantage. This would suggest that efficient use of sequential processing as represented by ear scores is diminished relative to the level of holistic processing in the left hemisphere, and that functioning could be limited to an holistic-spatial mode if these processes were in control in both hemispheres. Other evidence of a direct trade-off or interference between spatial and sequential processing, as would be evidenced by negative correlations between RHA and other measures of sequential recall, was not found. However, it is acknowledged that this particular hypothesis requires additional testing and suggestions for further exploration of this question have been made.

Differences between the two groups were frequently found in patterns rather than in levels of performance. Further, on most of the tasks, both of the groups performed at a level numerically below that of a group of able learners who were drawn from the same population. However, the able learners could only be used for general contrast purposes because they differed significantly in mean IQ and in age variability from the disabled groups. Patterns, though not levels, of performance of the Inconsistent group were like those of the Able Learners, while those of the Consistent Factor 3 group were clearly different both as to level and pattern. The possibility that the Inconsistent group may represent, in part, the lower end of a normal IQ distribution of readers and spellers, therefore must be entertained.

Evidence for this inference can be derived from the following test results:

1. Lack of discrepancy among WISC-R factor scores characterized both Able and Inconsistent learners whereas disparity characterized the patterns of the Consistent Factor 3 group.

2. Order of difficulty of subtest variations on TESP differed with the temporal/temporal variation being the easiest for both the Inconsistent and Able Learners, but proving to be among the most difficult for the Consistent Factor 3 group.

3. Correlational patterns among the forms of the Weener strings were highly similar for the Able Learner and Inconsistent groups whereas all forms were highly correlated in the Consistent Factor 3 group.

In addition to the above observations, it should be noted that the author attempted without success to obtain a sample of Able Learners of the same mean IQ and age from the same school population as the learning disabled sample by testing two complete classes of grade 7 and 8 students on a shortened form of the WISC-R. This failure could suggest that at least a part of the lower end of a normal IQ distribution may be subsumed in the Inconsistent learning disabled group. It would, indeed, not be difficult to understand how subjects with a low normal IQ, who are reading below average levels on standardized tests, might be seen as disabled when they exist in a population whose teachers identify as "average" those students who have a mean IQ of 116 and who score on standardized reading tests two grades above the published mean for their ages.

On the other hand, strong evidence to counter the inference that the Inconsistent group merely represents the lower end of a distribution of normal learners can also be adduced. There were indications they had specific, and unique, difficulties with integration. More importantly, they displayed a disorder in selective attention which was related to their performance on the academic variables. Although Douglas and Peters (1979), noted that children with a history of failure may be susceptible to the effects of extraneous stimuli as a means to relieve boredom and discomfort in learning situations, and thus have suggested that attentional deficits may result from, rather than cause, learning problems, it would be difficult to explain why one group of long-term disabled learners, the Inconsistents, became distractible as a result of adverse educational experiences while another group, the Consistent Factor 3 did not. This is particularly true since both groups evidenced the same degree of academic retardation, were identified as having learning disabilities for an equally long time, and were not subjected to any systematic differences in the form of educational treatments within the same school system.

The most telling argument against defining the Inconsistent group as normal learners of low ability is the evidence of their degree of academic retardation relative to their IQ. Expected underachievement, if calculated on the basis of mental age derived from the mean IQ of 91, should not exceed one year (Cruickshank, 1977); yet, their reading retardation is approximately two years and their spelling retardation is nearly 4 years. Moreover, this underachievement has been sustained in spite of supportive, and presumably ameliorative, educational interventions over a period of 6 to 8 years.

In summary, the weight of evidence presented here indicated that inefficient attentional selectivity and poor integration characterized the Inconsistent group, two characteristics that have long been associated with learning disabilities (Torgesen, 1975; Vellutino 1979). Since both these characteristics could reflect an inability to deal with holistic, spatial material separately from sequential or analytical functioning, it could be that these Inconsistents also represent those disabled learners that conform to Boder's (1973) dyseidetic subtype, and/or to those associated with bilateral-parietal impairment (cf. Gaddes, 1980; Zaidel, 1980). This does not preclude the appearance among the Inconsistent group of some low "normal" children. Clearly, further studies are needed to explore the characteristics of the Inconsistent group over a wider range of variables implicated in learning failure.

Regardless of whether some of them can be shown to be part of a distribution of normal achievers or not, implications for educational practice exist, for surely the issue is not whether they should receive appropriate interventions to foster achievement commensurate with ability.

The group labelled Consistent Factor 3 appears to be well-represented in other learning disabled populations since poor sequential processing has been identified as a characteristic of the learning disabled (Torgesen, 1975). The group appears to correspond generally to those subtypes defined by high performance, low verbal IQ scores on the WISC (Rourke, 1975) and display behaviors analagous to those in the classification known as "familial dyslexia". Two studies can be cited to support this view.

Symmes and Rapoport (1972) carefully defined a group of learning disabled subjects on the basis of the usual exclusionary criteria. Although the authors did not look at factor score patterns, the data provided in their study allow such calculations to be made. Their group exhibited a mean factor 1 - factor 3 discrepancy of 9 points in favor of factor 1 which makes them similar to the Consistent Factor 3 group in this regard. On the basis of family histories, a high incidence of familial dyslexia was found, and this along with the fact that nearly all were boys led the authors to conclude that a genetic factor might underlie the learning problem.

Gordon (1980), studying a group of dyslexic children and their families, as well as a control group of unrelated subjects, found that the dyslexics and first degree family members were consistently better on tests of right hemisphere function (e.g. block design) than on tests of left hemisphere function (e.g. digit span). Control subjects were equally divided as to strong right or left hemisphere profiles. Reading ability in the dyslexics, but not in the family members or in the controls, was correlated with performance on tests of each hemisphere separately and together. Gordon concluded that this pattern of results could be explained if a single cognitive mode governed the behavior of the dyslexics, that is if they were limited to a right hemisphere style of processing, whereas the others were able to employ multiple processing modes. Since the correlational patterns of hand and ear scores with the academic variables in the Consistent Factor 3 group of this study also followed the pattern of the relationships in Gordon's dyslexics, it could be that the groups are similar.

No family data were available for the sample in this present study. However, the suggested similarities between the Consistent Factor 3 group and the populations of both Symmes and Rapoport (1972) and Gordon (1980) raise the possibility that genetic dyslexia and presumed abnormal right hemisphere specialization may be related. Thus, future studies examining patterns of hemisphere specialization in familial dyslexics could contribute to a further understanding of the nature of the learning deficit and also to the etiology of abnormal right hemisphere specialization in disabled readers.

The Use of WISC-R Factor Scores in the Identification of Subgroups

Although the two subgroups were originally identified on the basis of the consistency of lowest WISC-R factor score, it was found they also differed as to the amount of discrepancy between factors 1 and 3. This discrepancy was observed to be more meaningful in conceptualizing their relative performances on the various tasks than their levels of functioning on a single factor. A re-classification of the subjects on the basis of their factor 1 - factor 3 disparity correctly replicated 90% of the original groupings based on consistency of disability over time. All this suggested that discrepancy scores on a single assessment may be predictive of consistency. However, confirmation is needed that discrepancy on an initial testing in a random sample is replicated on subsequent testing over the age span. If this were found to be true, the probability would be increased that a diagnostic classification could be made on a single WISC-R assessment.

The previously well-documented finding that learning disabled groups are characterized by low performance on factor 3 of the WISC-R was replicated in this study over the total group of disabled learners. Contrary to expectation, however, no clear cut evidence was found that a common psychological process such as poor sequential memory or distractibility could account for low functioning on factor 3 on a single assessment across the combined groups. Although poor memory for temporal-sequential stimuli was found in the group with low factor 3 functioning, none of the measures of this psychological process correlated with factor 3 scores. The second variable hypothesized to be associated with factor 3, poor selective attention, was found to exist in the group with relatively higher factor 3 scores. Moreover, the relationship across the groups between level of factor 3 scores and distractibility was observed to be in the direction opposite to that predicted if factor 3 were associated with distractibility.

It should be noted, however, that although the Consistent Factor 3 group was significantly lower on factor 3 than the Inconsistent group, there was much overlap in scores on the final WISC-R assessment. It appears that low factor 3 scores in learning disabled populations are pervasive, but non-diagnostic, because they are a result of heterogenous functions, and thus, discrimination of learning disabled groups on the basis of level of factor 3 functioning alone could be insufficient and misleading. Alternatively, the results of this investigation suggest that identification on the basis of low factor 3 functioning accompanied by significantly higher factor 1 scores may show promise.

Limitations

Caution must be exercised in the evaluation of the foregoing results. Four areas in which limitations lie are indicated below. These are with respect to the nature of the sample of subjects, the lack of a normal learner control group, the nature of the dependent measures, and the intended scope of the research.

The Nature of the Sample

The population of subjects used in this school-based, retrospective study departed from the selective, clinically-referred samples that so often appear in other research of this type. However, it did not comprise a random sample of long-term, learning disabled students within the particular middle to upper middle class school system from which it was drawn. Rather, it was composed of the available children for whom three consecutive diagnoses of learning disability had been made over a period of some six years, the availability having been reduced by the mobile nature of the suburban population, and perhaps other unknown factors.

It is also recognized that possible bias could have affected the sample selection since the initial referral of subjects for diagnosis was based on opinion of school personnel rather than on any, systematic, objective screening program for all children. Consequently, generalizations concerning incidence and prevalence of various subtypes cannot be made from their relative proportions within the present sample, and further studies with larger samples drawn from a broader population base are needed before the findings concerning the characteristics of the two subtypes can be accepted with confidence.

The limited number of available subjects required the inclusion at final testing of subjects of a wide age range (12 and one half to 15 and one half years) in order to have subgroups of an acceptable size. Given the present knowledge of possible age effects, it would have been preferable to have had a more restricted age range. It was perhaps fortuitous that the disabled subgroups happened to be exceedingly well matched as to mean age and variability since this minimized the effect of age on between group differences, but it did not eliminate the effect of age variability within the groups. Caution, therefore, must be exercised when describing characteristics of the subtypes in relation to age. Further, although consistency or lack of it over age, with reference to WISC factor patterns, is known for the subtypes, it cannot be assumed that their relative performances on the measures of distractibility, sequential memory and hemispheric dominance would also mirror the consistency or inconsistency of the WISC patterns over time. Only studies, preferably longitudinal, with subjects at appropriate age levels, could confirm if the characteristic differences revealed in this study existed at ages prior to the present assessment.

The Lack of a Normal Learner Control Group

The major purpose of the present study was to attempt to classify from the vantage of hindsight, subgroups within a learning disabled population, and to attempt to further differentiate them on the basis of specified variables which many researchers had presumed to be associated with learning disabilities. In such efforts it is, of course, desirable to have a control sample of normal learners, matched on overall WISC-R scores, and of the same age variability, so that comparisons of the level of performance on many measures can be made. For reasons stated previously this was not possible within the school system in question. This lack means that questions remain about observed or postulated differences in functioning, not merely between able and disabled readers, but between subgroups of the disabled themselves. This becomes even more important because of the lack of standardized, normative data on some of the dependent measures selected for examination.

The Nature of the Dependent Measures

The lack of tests of known psychometric characteristics to measure distractibility, spatial-sequential processing and hemisphere specialization must limit the confidence that can be placed in the conclusions, as it must surely limit conclusions reached by others who have used such tests. Although more than one index for strategic control, spatial-sequential processing and selective attention was included to allow for convergence of results and thus to provide for some form of validation, the failure to find such convergence in the attentional measures in the Consistent Factor 3 group raises the possibility that this variable was inadequately assessed. Since others (Peters, 1979) have also noted the lack of congruity among purported measures of attentional selectivity, it seems important that research be directed towards defining the psychometric properties of these tasks.

The use of a multi-level format to adapt the TESP test to varying age levels was restricted, for practical reasons of time and subject fatigue, to the inclusion of only 3 trials at each level which may have reduced the reliability of its results. It also made it virtually impossible to construct meaningful serial memory curves to provide for further analysis of memory processes. Modification of these aspects of the task is needed before it should be used in further investigations.

The Scope of the Study

The investigation of group differences was limited to those processes associated with selective attention, spatial-sequential functioning and hemispheric specialization. Although the limited number of variables enabled a more detailed analysis of patterns as well as level of performance to be made, at the same time it reduced the breadth of information about characteristics associated with the subtypes. It is true that group differences were found in these processes, but other explanations, or possible explanations could also exist. It is, therefore, likely that unexplored characteristics associated with the subgroups, such as labelling, verbal encoding or the development of syntactic awareness, would contribute to a greater understanding of the relative functioning of the identified subgroups.

Implications

Granted the limitations of this study, the possible existence of two identifiable subtypes with in the learning disabled population has implications for the clinical-diagnostic, educational and research areas.

Implications for the use of the WISC-R as a clinical diagnostic tool have emerged from this study. Should the evidence accumulate that patterns of discrepancy between factor scores on a single testing are useful criteria for predicting consistency of performance over repeated testing, then the subgroups so defined could be expected to persist over the years of elementary schooling. Thus, a diagnostic subtyping could be made on the basis of a single WISC-R assessment, and early, suitable educational interventions could be initiated.

Educational implications derive from the finding that different variables appeared to be associated with the equally low levels of academic achievement in each of the two groups. In addition, the Inconsistent subjects frequently performed in patterns, if not levels, that were similar to those of able learners which suggests that appropriate educational instruction would not differ from that of able learners so much in kind as perhaps in pace or amount of repetition. Apparent disorders in selective attention, however, would appear to require remediation. For the Consistent Factor 3 group, which differed from the able learners group both as to levels and patterns of performance, there may be a need to develop a different kind of instructional program, once that capitalizes on their observed advantage in, or preference for, spatial, holistic processing or, perhaps, one that attempts to induce efficient sequential processing may be needed.

Implications for future research are numerous. This investigation would suggest that research with learning disabled populations will be misleading unless such subgroups are differentiated since their scores on many variables tend to cancel each other out, leaving mean values that misrepresent both groups. Further, data presented here appear to support Rourke's (1975) conclusion that level of performance on a single variable at a single assessment, is of minimal value in differentiating subtypes. However, the results of this present investigation imply that patterns of performance on holistic, simultaneous versus analytical, sequential tasks might be useful discriminators.

There is, further, a need to delineate the parameters of these two subgroups. For example, do these categorizations and characteristics hold at younger age levels? In particular it seems important to see if the Inconsistent group displays evidence of disorders in selective attention prior to prolonged exposure to adverse learning experiences, and to see if the Consistent Factor 3 group exhibits sequential versus spatial processing discrepancies at an early age. A more detailed identification of the characteristics of the subgroups in terms of variables not explored in this study is also required. It would be especially important to determine clearly and specifically the academic skills and sub-skills of each group for educational purposes.

Future studies controlling for possible attentional variables and using "hemispherically pure" tests of the two main processing styles to validate the interpreted hemisphere patterns are needed. The findings presented in this study, confirming and elaborating Witelson's earlier report of abnormal hemisphere specialization patterns in the reading disabled, require further exploration. There is a need to determine if and how these patterns develop over the age span, and what they may mean in relation to academic competence. An investigation of hemisphere specialization patterns in familial dyslexics could advance knowledge in this regard. Such studies may be of special interest given the developing context of research and practice in the learning disabilities field. The advent of a more dynamic interaction between neuropsychology and special education has been signalled by the recent publication of Learning Disabilities and Brain Function: A Neuropsychological Approach, (Gaddes, 1980) in which the author describes how the principles of neuropsychology can be applied to help solve educational problems. He optimistically states:

> "The 1950's, 60's and 70's have been time of exciting and rapidly expanding knowledge in neuropsychology and special education. The 1980's promise to bring these two disciplines closer together by increasing our knowledge of their relationship and providing new and better forms of remediation for the children who need them."
>
> (Gaddes, 1980, p. 323)

Further exploration of the several promising areas of research that have emerged from this present study could make a valuable contribution within the framework of the growing partnership that he envisages.

NOTES

1. Weener, Paul. Personal Communication, April 5, 1978. Copies of Dr. Weener's Test of Sensitivity to Linguistic Structure were given to the author by Dr. Weener. Hence the test will be referred to as The Weener Strings in this investigation.

2. Machine used was Wallensak 3M AV Cassette System, Model No. 2520.

3. The visual displays which were not included in the article were made available through the courtesy of Dr. Sandra F. Witelson, Dept. of Psychiatry, Chedoke Hospitals, McMaster University, Hamilton, Ontario.

Appendix A

Raw scores and descriptive statistics
for age, IQ and Factor Scores Total Sample,
N=49.

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M (SEE FOLLOWING PAGE FOR CODE KEY)

OBS	NO	AGE1	V1	P1	FS1	AF1	AF2	AF3	AGE2	V2	P2	FS2	BF1	BF2	BF3	AGE3	V3	P3	FS3	CF1	CF2	CF3	CAT
1	1	102	82	111	96	33	26	25	132	84	106	93	33	25	18	156	82	105	92	44	23	22	1
2	2	94	101	110	106	39	37	24	128	109	126	119	48	37	26	168	101	126	113	41	34	28	1
3	3	96	106	110	109	35	39	27	120	97	105	101	33	33	26	157	85	114	98	40	25	21	1
4	4	88	96	89	92	24	35	18	122	90	104	96	32	26	25	159	96	108	101	33	29	26	1
5	5	96	79	92	83	33	31	20	129	90	101	95	29	21	17	181	82	93	87	31	22	22	1
6	6	106	80	99	88	33	23	18	143	80	78	80	21	22	18	182	80	100	88	29	20	21	1
7	7	85	108	118	114	43	33	30	111	96	129	113	42	33	28	183	96	114	104	39	30	26	1
8	8	76	100	100	100	30	33	25	128	90	86	96	35	26	21	163	102	105	100	33	33	24	1
9	9	83	110	129	121	47	42	36	121	101	130	116	50	33	25	150	95	129	111	49	28	27	1
10	10	106	106	117	112	42	37	31	131	106	102	104	33	34	31	165	105	112	109	39	35	26	1
11	11	89	97	110	104	36	32	28	140	95	96	95	31	32	31	179	90	100	93	35	28	20	1
12	12	83	110	115	114	41	39	30	108	110	104	108	37	39	31	174	111	111	112	45	35	25	1
13	13	103	95	96	95	31	35	22	134	95	99	96	28	31	24	175	86	105	94	38	24	20	1
14	14	94	90	122	106	30	30	20	118	96	114	104	42	28	23	152	92	100	95	33	25	23	1
15	17	93	95	76	85	21	34	21	149	96	89	92	25	35	17	185	97	86	91	26	30	17	1
16	21	106	100	103	101	28	32	27	135	109	94	102	29	38	24	178	105	92	99	25	32	28	2
17	22	92	110	115	114	37	40	32	126	102	106	104	30	28	34	169	88	108	97	33	24	28	2
18	23	83	95	83	88	19	26	26	113	80	97	87	23	18	19	152	84	81	81	22	23	23	2
19	24	85	109	106	108	33	31	30	127	106	111	109	31	35	37	182	97	98	97	29	22	36	2
20	25	105	99	93	96	29	32	29	144	88	96	91	29	25	21	173	97	91	93	22	29	[illegible]	2
21	26	82	95	92	93	30	31	25	120	105	85	95	24	34	31	173	95	95	94	27	28	25	2
22	27	101	128	100	116	35	46	38	131	108	97	103	29	34	33	185	101	91	96	27	22	26	2
23	28	82	91	92	91	27	25	26	108	96	92	93	25	27	32	156	91	81	85	19	26	28	2
24	29	105	94	108	101	36	30	28	129	94	111	102	33	31	30	178	78	106	90	33	20	23	2
25	30	91	97	103	100	32	31	27	115	84	92	87	21	23	25	152	81	100	89	29	25	26	2
26	31	107	100	90	95	24	34	28	135	81	86	82	23	24	21	183	85	90	86	25	23	28	2
27	32	85	74	96	83	31	14	22	125	82	97	88	29	26	22	176	77	96	84	31	25	30	2
28	33	99	94	120	107	43	28	26	121	86	112	98	40	22	31	152	87	117	101	41	24	26	2
29	34	80	82	96	88	28	21	23	144	90	88	88	20	29	25	180	96	87	91	24	33	21	2
30	35	67	104	85	94	26	34	28	130	77	93	84	26	19	20	151	90	81	85	19	31	22	2
31	15	88	105	97	113	40	32	19	113	109	108	110	34	34	29	167	108	103	112	41	32	25	1
32	16	90	105	111	109	30	30	24	114	91	93	91	30	31	18	186	95	96	95	30	33	22	1
33	20	77	83	90	86	28	23	21	101	94	104	99	29	24	30	156	92	91	92	24	30	24	2
34	42	98	99	100	99	30	28	30	125	97	110	104	38	29	29	192	112	120	118	43	41	29	2
35	44	123	104	107	106	36	35	30	153	100	108	104	35	36	27	180	90	106	97	34	25	20	1
36	45	101	108	75	91	18	35	36	127	103	78	90	19	28	31	165	96	75	85	16	29	29	5
37	46	110	84	106	93	31	26	21	139	92	121	107	42	33	23	189	102	112	107	38	36	25	1
38	47	101	94	108	101	35	29	28	148	101	101	101	33	36	22	193	98	106	102	38	33	23	1
39	49	95	90	96	92	28	26	28	156	80	96	86	27	21	25	204	72	90	79	24	16	21	4
40	50	92	92	99	95	28	27	31	122	82	90	85	29	23	23	150	88	93	90	29	27	25	2
41	51	115	90	101	95	28	27	22	145	91	106	98	33	33	18	190	85	88	85	35	24	18	1
42	53	92	96	100	98	32	31	27	130	104	101	103	32	35	24	188	102	91	96	29	34	24	1
43	54	88	96	89	92	19	32	25	143	94	101	96	29	30	25	189	96	105	100	31	28	30	2
44	55	76	104	101	103	32	29	37	144	89	91	90	30	23	26	168	95	101	97	31	28	30	4
45	56	120	95	90	92	22	30	23	152	91	118	104	38	26	33	207	91	102	96	36	23	26	2
46	61	100	99	93	96	27	36	24	133	87	85	87	24	26	18	166	84	83	85	23	24	21	1
47	64	88	90	87	89	26	29	20	122	84	101	91	34	22	17	170	93	88	101	32	29	19	1
48	65	76	94	106	99	36	31	22	105	91	107	99	32	30	25	164	88	112	100	38	28	24	1
49	66	83	72	96	82	29	19	20	131	82	95	87	28	24	27	158	82	115	97	40	22	30	4

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	C.V.
AGE1	49	93.40816327	11.92497094	67.00000000	123.00000000	12.767
V1	49	96.46938776	10.43851450	72.00000000	128.00000000	10.821
P1	49	100.57142857	11.57043647	75.00000000	129.00000000	11.505
FS1	49	98.59183673	9.67582548	82.00000000	121.00000000	9.814
AF1	49	31.24489796	6.44699740	18.00000000	47.00000000	20.634
AF2	49	30.93877551	5.80735225	14.00000000	46.00000000	18.770
AF3	49	26.08163265	4.91950512	18.00000000	38.00000000	18.862
AGE2	49	128.97959184	13.21534745	101.00000000	156.00000000	10.246
V2	49	93.57142857	9.12642683	77.00000000	110.00000000	9.753
P2	49	100.81632653	11.91755265	78.00000000	130.00000000	11.821
FS2	49	97.00000000	8.99305287	80.00000000	119.00000000	9.271
BF1	49	31.16326531	6.70928132	19.00000000	50.00000000	21.529
BF2	49	28.81632653	5.43013762	18.00000000	39.00000000	18.844
BF3	49	25.22448980	5.19721603	17.00000000	37.00000000	20.604
AGE3	49	172.46938776	14.64169566	150.00000000	207.00000000	8.489
V3	49	92.26530612	8.92742850	72.00000000	112.00000000	9.676
P3	49	99.97959184	12.18176540	75.00000000	129.00000000	12.184
FS3	49	95.71428571	8.86942313	79.00000000	118.00000000	9.267
CF1	49	32.10204082	7.47564071	16.00000000	49.00000000	23.287
CF2	49	27.55102041	4.99191523	16.00000000	44.00000000	18.119
CF3	49	24.67346939	3.72149027	17.00000000	36.00000000	15.083

CODE KEY

AGE 1	AGE ON FIRST ASSESSMENT
VI	VERBAL IQ ON FIRST ASSESSMENT
PI	PERFORMANCE IQ ON FIRST ASSESSMENT
FSI	FULL SCALE IQ ON FIRST ASSESSMENT
AFI	FACTOR I FIRST ASSESSMENT
AF2	FACTOR 2 FIRST ASSESSMENT
AF3	FACTOR 3 FIRST ASSESSMENT
AGE 2	AGE ON 2ND ASSESSMENT
V2	VERBAL IQ 2ND ASSESSMENT
P2	PERFORMANCE IQ 2ND ASSESSMENT
FS2	FULL SCALE IQ 2ND ASSESSMENT
BFI	FACTOR I " "
BF2	FACTOR 2 " "
BF3	FACTOR 3 " "
AGE 3	AGE THIRD ASSESSMENT
V3	VERBAL IQ THIRD ASSESSMENT
P3	PERFORMANCE IQ THIRD ASSESSMENT
FS3	FULL SCALE IQ " "
CFI	FACTOR I " "
CF2	FACTOR 2 " "
CF	FACTOR 3 " "

CAT = CATEGORY

1 = CONSISTENT F3

2 = INCONSISTENT

4 = CONSISTENT F2

5 = CONSISTENT F1

STATISTICAL ANALYSIS SYSTEM

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	C.V.
CONSISTENT FACTOR 3						
AGE1	25	95.08000000	11.47431915	76.00000000	123.00000000	12.068
V1	25	96.64000000	9.14184518	79.00000000	110.00000000	9.460
P1	25	104.40000000	11.92336642	76.00000000	129.00000000	11.421
FS1	25	100.96000000	9.97697349	83.00000000	121.00000000	9.882
AF1	25	33.56000000	6.20537402	21.00000000	47.00000000	18.490
AF2	25	32.48000000	4.55631430	23.00000000	42.00000000	14.028
AF3	25	24.48000000	4.66476152	18.00000000	36.00000000	19.055
AGE2	25	128.64000000	13.30689045	105.00000000	153.00000000	10.344
V2	25	95.40000000	8.11890797	80.00000000	110.00000000	8.510
P2	25	104.00000000	13.00640868	78.00000000	130.00000000	12.506
FS2	25	99.96000000	9.14002188	80.00000000	119.00000000	9.144
BF1	25	33.92000000	6.79411510	21.00000000	50.00000000	20.030
BF2	25	30.84000000	5.01398045	21.00000000	39.00000000	16.258
BF3	25	23.28000000	4.73039815	17.00000000	31.00000000	20.320
AGE3	25	172.88000000	12.73551465	150.00000000	193.00000000	7.367
V3	25	93.80000000	8.57321410	80.00000000	111.00000000	9.140
P3	25	103.72000000	11.64588626	83.00000000	129.00000000	11.228
FS3	25	98.72000000	8.56601813	85.00000000	113.00000000	8.677
CF1	25	35.72000000	6.08632347	23.00000000	49.00000000	17.039
CF2	25	28.76000000	4.65725241	20.00000000	36.00000000	16.194
CF3	25	22.76000000	2.89078997	17.00000000	28.00000000	12.701
INCONSISTENT						
AGE1	20	92.25000000	12.76869115	67.00000000	120.00000000	13.841
V1	20	96.85000000	11.21688108	74.00000000	128.00000000	11.582
P1	20	97.50000000	9.63272930	83.00000000	120.00000000	9.880
FS1	20	96.95000000	8.92940147	83.00000000	116.00000000	9.210
AF1	20	29.25000000	5.91941498	19.00000000	43.00000000	20.237
AF2	20	29.75000000	6.67181819	14.00000000	46.00000000	22.426
AF3	20	27.25000000	3.90512484	21.00000000	38.00000000	14.331
AGE2	20	127.30000000	12.79432440	101.00000000	152.00000000	10.051
V2	20	92.30000000	9.92657253	77.00000000	109.00000000	10.755
P2	20	99.00000000	9.63546082	85.00000000	118.00000000	9.733
FS2	20	95.05000000	8.15297814	82.00000000	109.00000000	8.578
BF1	20	28.75000000	5.47602430	20.00000000	40.00000000	19.047
BF2	20	27.25000000	5.33977133	18.00000000	38.00000000	19.595
BF3	20	27.25000000	5.35944813	19.00000000	37.00000000	19.668
AGE3	20	171.70000000	16.38709377	150.00000000	207.00000000	9.544
V3	20	91.55000000	8.75078944	77.00000000	112.00000000	9.558
P3	20	96.25000000	10.97784851	81.00000000	120.00000000	11.406
FS3	20	93.20000000	8.16023735	81.00000000	118.00000000	8.756
CF1	20	28.45000000	6.53311403	19.00000000	43.00000000	22.963
CF2	20	26.80000000	4.92683308	20.00000000	41.00000000	18.384
CF3	20	26.50000000	3.37950479	21.00000000	36.00000000	12.753

Appendix B

Analyses of variance

for

Total Sample, N = 49

Table 1

Analysis of variance for verbal and performance IQ scores over 3 assessments for the long term learning disabled group, N = 45

Source of variance	df	Mean square	F	p
Time or age	2	141.41	2.79	.07
error	96	50.61		
Subscale IQ score	1	2967.20	15.62	.0003
error	48	189.96		
Time x subscale score	2	95.51	2.63	.08
error	96	35.96		

Table 2

Analysis of variance for verbal IQ scores over 3 assessments total long term learning disabled group

Source of variance	df	Mean square	F	p
Verbal score x time	2	226.86	5.88	.004
error	96	38.60		

Means: 96.5 a 93.6 92.3

Table 3

Analysis of variance for performance

IQ scores over 3 assessments

total long term learning disabled group

Source of variance	df	Mean square	F	p
Performance IQ score x time	2	9.06	.19	.828
error	96	47.97		

Means: 100.6   100.8   100.0

Table 4

Analysis of variance for full scale

IQ scores over 3 assessments

for long term learning disabled group

Source of variance	df	Mean square	F	p
Full scale IQ score x time	2	116.71	4.12	.02
error	96	28.29		

Means: 98.6   97.2   95.5

a (98.6 — 97.2)

b (97.2 — 95.5)

Table 5

Analysis of variance for factor scores over 3 assessments for long term learning disabled group

Source of variance	df	Mean square	F	p
Time or age	2	66.20	2.95	.06
error	96	22.41		
Factor scores	2	1457.88	29.70	< .0001
error	96	49.09		
Time x factor scores	4	61.29	4.56	.002
error	192	13.45		

Appendix C

Analyses of variance

for

Consistent Factor 3 and Inconsistent groups

N = 45

Table 1

Analysis of variance for full scale

IQ scores over 3 assessments

Consistent Factor 3 and Inconsistent groups

Source of variance	df	Mean square	F	p
Group	1	772.27	4.28	.05
error	43	180.43		
Age or time	2	99.70	3.51	.03
IQ score x time	2	6.41	.23	.798
error	86	28.37		

	Consistent Factor 3	Inconsistent
Mean IQ x group	99.9[a]	95.1[b]

Table 2

Analysis of variance for verbal and performance

IQ scores over 3 assessments

Consistent Factor 3 and Inconsistent groups

Source of variance	df	Mean square	F	*p*
Group	1	1112.48	3.54	.07
error	43	314.26		
Time	2	141.06	2.83	.06
Time x group	2	12.77	0.26	.77
error	86	49.78		
Subscale score	1	2720.72	17.74	.0001
Subscale score x group	1	374.99	2.44	.125
error	43	153.40		
Time x subscale score	2	80.09	2.14	.124
Time x subscale score x group	2	38.65	1.03	.361
error	86	37.47		

Table 3

Analysis of variance for factor scores over

3 assessments for Consistent Factor 3

and Inconsistent groups

Source of variance	df	Mean square	F	p
Group	1	264.97	2.56	.12
error	43	103.40		
Time or age	2	60.42	2.89	.06
Time x group	2	1.64	.08	.925
error	86	20.93		
Factor scores	2	1388.54	55.04	.000
Factor score x group	2	713.56	28.28	.000
error	86	25.23		
Time x factor score	4	45.78	3.36	.01
Time x factor x group	4	17.89	1.31	.266
error	172	13.61		

Appendix D

Tests and Test Instructions

The Central-Incidental Learning Test

General Instructions

The test was administered individually in a single session lasting approximately 20 minutes. The central stimuli consisted of six 8 x 12 cm cards each of which contained a black line drawing of an animal and a common household object. The same animal and object were always paired together, but the subjects were instructed to remember only the animals and to not pay attention to the other things. Twelve six-item test trials were given with each item being presented for two seconds and then turned face down to form a horizontal row. Immediately following presentation of the last item in each series an 8 x 12 cm card containing only an animal drawing was presented and the subject was asked to turn over the test card containing the identical animal picture. Only correct first responses were recorded. However, if the first response was incorrect the subject was allowed to continue to turn over the cards until the correct one was chosen.

Each of the six animals and each of the serial positions was probed twice during the twelve trials. Order was randomized, but to control for effects of fatigue and boredom the presentation of the twelve series was rotated, i.e., the first child began with series #1 and continued through to series #14, the second child began with series #2 and ended with series #1. Central recall score was the proportion of correct first responses, corrected for possible response bias. This was accomplished using a procedure whereby correct first choice frequency at each position was expressed as a proportion of total choice frequency at that position (Donaldson and Strang, 1968).

Immediately following the completion of the twelve series, the subject was presented with six animal cards and six cut-out pictures of the common household objects, and was asked to match animals and objects as they had appeared during the test trials. Proportion of correct responses constituted the incidental recall score.

Verbal Instructions

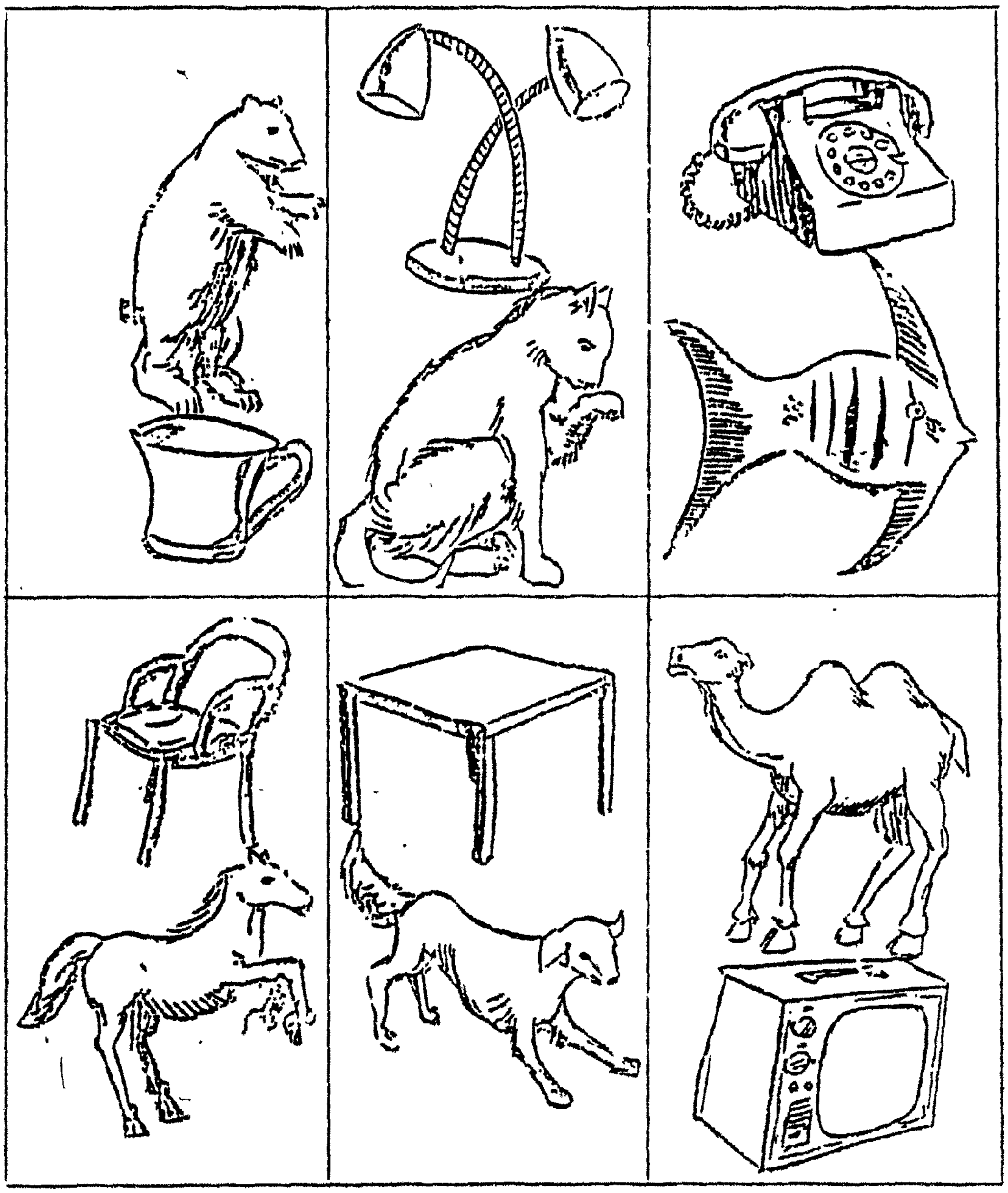
Say, "We are going to play a memory game. I will show you some cards like this with animals and other things on them. Look carefully at the animals because you will be asked to remember their order, but don't look at the other things. I will show you the cards one at a time and then turn them over and put them in front of you like this. Then I will show you a card with only an animal on it and you will be asked to turn over the card in front of you that has the same animal on it. Let's do one for practice."

A practice trial was given using 4 cards containing animals and household objects not used in the test itself.

Following the presentation of the last series, say, "I know that you were told not to bother looking at the other things on the cards, but let's just see if you can tell which object went with each animal. Which object goes with this animal?"

Stimuli for the Central-Incidental Test

(actual size 8 x 12 cm)



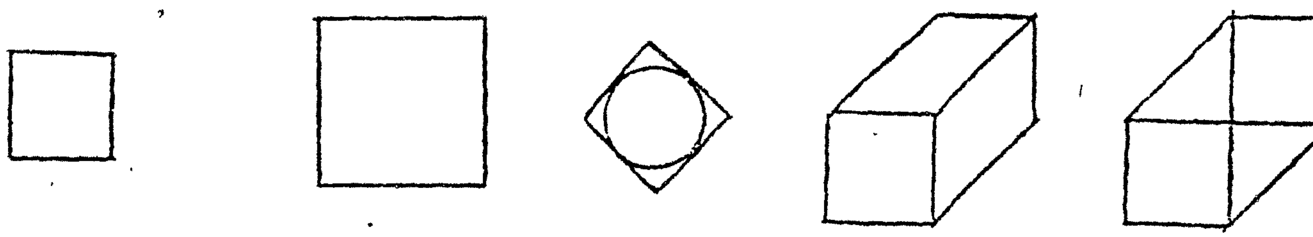
EMBEDDED FIGURES

Code Number

In each of the items of this test you have a Figure on the left, and four Drawings on the right. You are to decide whether or not the Figure is concealed in each of the Drawings. Put a check mark (✓) in the brackets under a Drawing if it contains the Figure. Put a zero (0) in the brackets under a drawing if it does not contain the figure.

Look at this example.

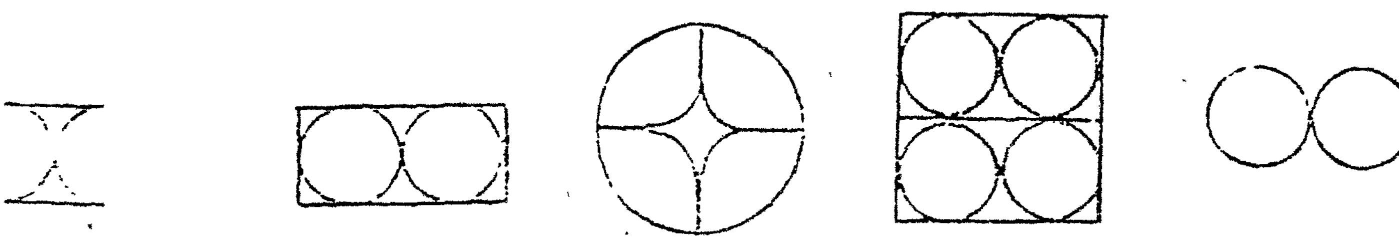
Figure — Drawings 1, 2, 3, 4



(o) (o) (✓) (✓)

In the row of Drawings, a zero (0) has been written in the brackets under Drawing 1. The first drawing is a square, but it is larger than the figure. A zero (0) has been written under drawing 2. Although the second drawing contains a square of exactly the same size as the figure, it has been turned. Check marks (✓) have been written under the third and fourth drawings since they each contain a square of exactly the same size as the figure, and have not been turned It does not matter that the figure contained in drawings three and four is on a different level from the figure at the left.

Here is another example for practice. Try it.



( ) ( ) ( ) ( )

You should have placed check marks (✓) in the brackets under the first and third drawings, and zero (0) in the brackets under the second and fourth drawings

Do not turn the page until the signal is given. Then do each of the items in the following pages in the same way. You will have only a short time, so work as fast as you can.

WEENER STRINGS OF VARYING STRUCTURE

Items:

1.	Happy children play funny games.	Sharp tools cut fresh meat.
2.	Girls pretty good wear coats.	Climb lions trees tall strong.
3.	Walls magic kind spin ears.	Spiders hot leaves wrong build.
4.	Little deer jump high fences.	Nice people help sick boys.
5.	Fish small ducks young like.	Hair long wind warm blows.
6.	Wet birds take special parents.	Quiet papers run middle hills.
7.	Babies fast deep draw metals.	Snow eggs flat glad give.
8.	Hard cats sail silver legs.	Proud baskets drive square roses.
9.	Big horses pull heavy wagons.	Brave soldiers fight bad men.
10.	Waters dry cool sand wash.	Eat apples sweet bears hungry.
11.	Ants south fact days sell.	Drink tin ships flowers narrow.
12.	Good girls wear pretty coats.	Strong lions climb tall trees.
13.	Children happy games play funny.	Tools fresh meat sharp cut.
14.	Great skin drops easy shoes.	Poor forest save thin books.
15.	Parrots birds wet take special.	Papers middle hills quiet run.
16.	Deep metals draw fast babies.	Flat eggs give glad snow.
17.	Young ducks like small fish.	Warm wind blows long hair.
18.	Fences jump high deer little.	Nice help boys people sick.
19.	Legs silver hard sail cats.	Baskets square proud drive roses.
20.	Fat days sell south ants.	Narrow flowers drink tin ships.
21.	Horses heavy big pull wagons.	Soldiers bad brave men fight.
22.	Cool waters wash dry sand.	Hungry bears eat sweet apples.
23.	Shoes easy skin great drops.	Books thin poor save forests.
24.	Kind walls spin magic ears.	Hot leaves build wrong spiders.

Instructions for Administering the Weener Strings of Varying Structure

General Instructions

A tape recorder, preferably with a pause button, and a listening station with two sets of headphones are required for administration of this test. Both experimenter and subject listen to pre-recorded 10-word strings over the headsets. At the end of each series, the experimenter stops the tape, simultaneously signalling with an orange card for the subject to recall as many of the words as he can remember. Following the subject's response, the experimenter reactivates the tape recorder. The subject's responses are recorded on a second tape recorder for later verification. The experimenter records the responses by numbering the words as they are recalled on a response sheet. The test is individually administered in one session and requires approximately twenty minutes.

Word strings are delivered without inflection or intonation at the rate of one word per second. The strings vary as to organization: associations with syntax, no associations with syntax, syntax with no associations, and no associations and no syntax. There are six examples of each for a total of 24 strings in all. Order of strings is randomized, but is the same for each subject.

Verbal Instructions

say,"You are going to hear a string of words. At the end of the string, when I hold up this orange card, you are to say back as many of the words as you can remember. Say them in any order you please."

Three practice strings are normally given. At the end of the practice trial the subject is asked if there are any questions. Following any further explanations, say, "Let's begin." (Remember to turn on the second tape recorder to record responses.)

TESP: A TEST OF TEMPORAL-SPATIAL RECALL

General Instructions

The test has four variations: spatial/spatial, spatial/temporal, temporal/spatial and temporal/temporal. The subject is shown the spatial or temporal presentation and is asked to reconstruct it temporally or spatially. Three practice trials are given for each condition. Before testing begins, the subject is shown a sample spatial presentation and is instructed as to its interpretation.

Time allowed for viewing the symbols varies according to the number of symbols in each presentation, one second being allowed for each symbol. Therefore, the spatial and temporal presentations range from two to six seconds each. An interval of five seconds is imposed between presentation and response, but no time limit is placed on the response. Testing ceases when three consecutive errors are made at any one level. One point is given for each correct response. Maximum score on each variation is 12.

Instructions for Initial Presentation of Spatial (Grid) Pattern

Say, "I'll show you how to read this pattern of X's (show pattern #1). See, we have signs here and numbers here (point appropriately). The X's tell about the order the signs are in. See, this sign (point to first symbol) is first because the X across from it is under number 1. This sign (point to second symbol) is second because the X across from it is under number 2."

"Now look at this pattern (show pattern 2). Look at the X's. Put your finger on the sign that the X says is first".

If the subject cannot do this, say, "It is this sign because the X across from it is number number 1."

"Put your finger on the sign the X says is second."

Go back to card number 1 and say, "Is this sign first or second?" Go to card #2 and say, "Put your finger on the first sign."

Continue in this manner until you are confident that the subject clearly understands the pattern. Proceed to the appropriate test variation.

Since it was believed that directions for administering should be the same across age groups, very explicit language is used to ensure that those subjects of younger ages would understand.

Directions for Administering the Four Variations

Spatial/spatial: The Experimenter displays grids with spatial patterns. The Subject has empty grids and a pencil.

Say, " I am going to show you some patterns. After you look at a pattern and have waited for five seconds, I will say 'ready' and you may begin to make the pattern with your pencil on this paper by putting the X's in the right spaces".

Patterns #1 and #2 are displayed again as practice trials. Present each one for 2 seconds, wait five seconds and say, "Ready, now make the pattern on your paper."

Present card #3 and say, "Look at this pattern. See, now we have one more sign and one more number." Display it for 3 seconds; wait 5 seconds and say, "Ready, now make the pattern on your paper."

Proceed to card #4, which is also a practice trial, in the same manner.

Each time a new sign is introduced, show the blank grid first and say, "See, we have one more sign and one more number." Proceed with successive patterns until three consecutive errors are made at any one level.

Spatial/temporal: The Experimenter displays grids with spatial patterns. The Subject is given a set of appropriate symbols on individual cards. Initially, the Subject has only two cards and is given an additional card each time a new symbol is introduced.

Say. "Now I am going to give you some cards with the signs on them. I will show you a pattern and after five seconds I will say, 'ready' and you may put the cards down so that the signs will be in the same order as in the pattern."

Cards #1 and #2 are used as practice trials. Each is shown for two seconds. After the five second pause say, "Ready, put down your cards so that the signs are in the same order as shown in the pattern."

Show card #3 and say, " See, now we have one more sign and one more number."

Show card # 4 (also a practice trial) for three seconds, wait five seconds and say, "Ready, place your cards so that the signs are in the same order as shown in the pattern."

Each time a new sign is introduced, show the blank grid first and say, "See, now we have one more sign and one more number." Remember to display each grid one second for each symbol. Proceed with successive patterns until three consecutive errors are made.

Temporal/spatial: The Experimenter displays individual cards with symbols on them and the Subject has empty grids and a pencil.

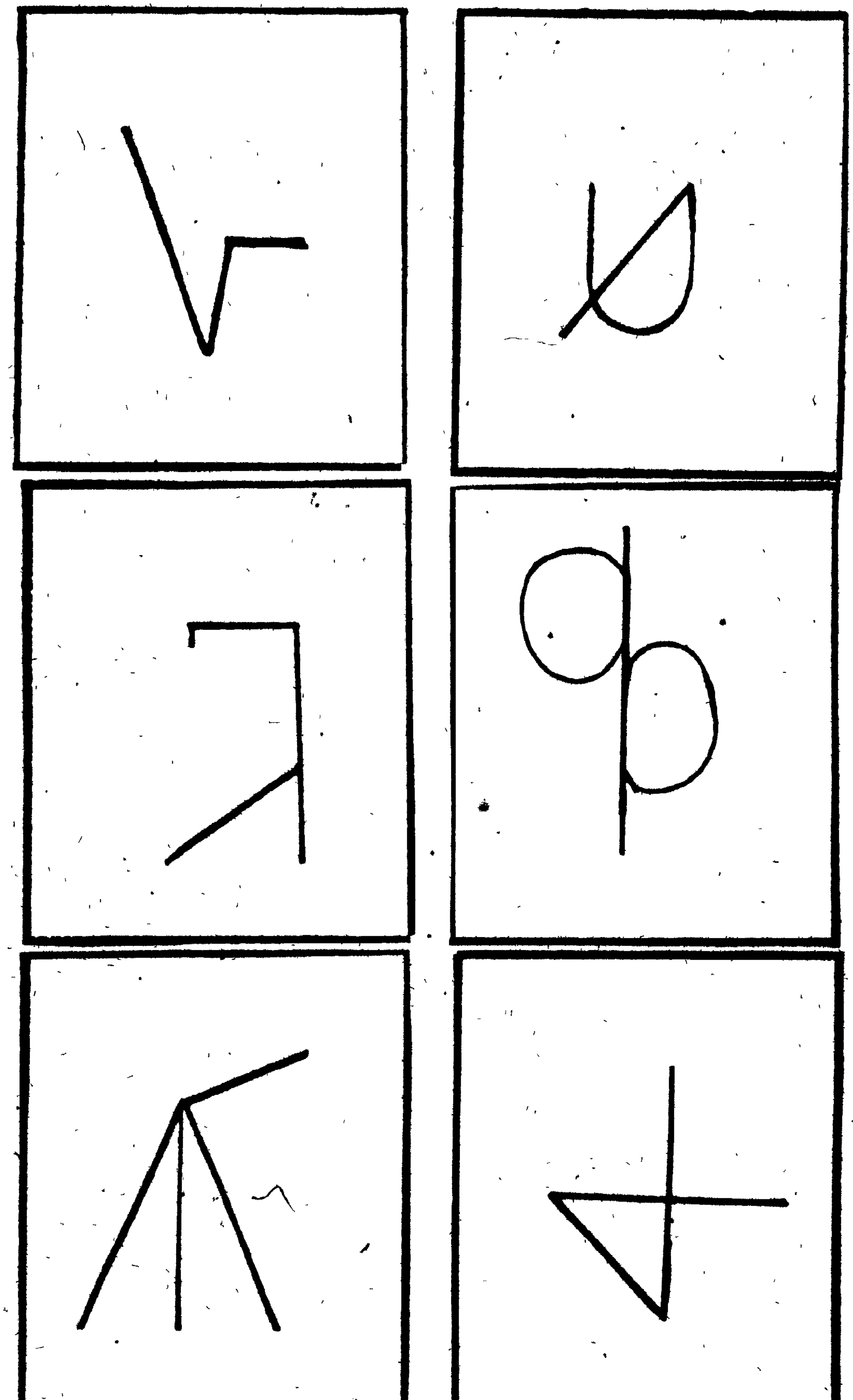
Say, "I have some cards with signs on them. I am going to show them to you one at a time in a special order. After I have shown them to you, we will wait for five seconds. Then I will say, 'ready', and you may put the X's in the pattern so that they are in the same order as I showed you. The sign that you see first should have an X across from it under the number 1. The sign that you see second should have an X across from it under the number 2. Here are the first ones."

Show sequence 1 and then sequence 2 as practice trials. Then say, "Now we are going to use one more sign." Show the new sign and grid pattern each time a new symbol is introduced. Proceed until three consecutive errors are made at any one level.

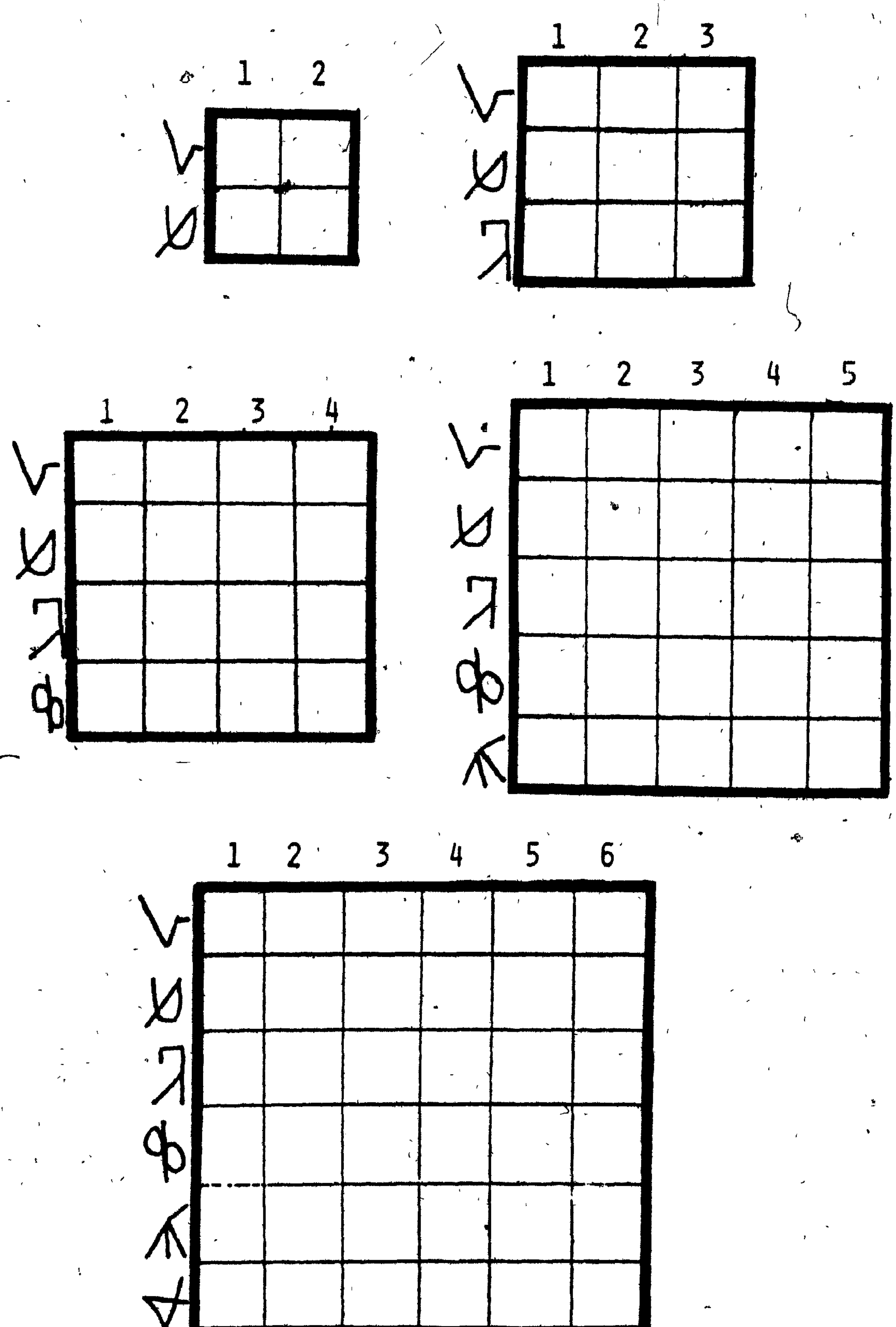
Temporal/temporal: The Experimenter and Subject each has individual cards with symbols on them. Initially the subject has only the first two cards and is given an additional card each time a new symbol is introduced.

Say, "I have some cards for you and some cards for me. Each card as a different sign on it. I am going to show you my cards in a special order and after five seconds, I will say, 'ready' and you may place your cards on the table in the same order. Let's start with these." Show sequences #1 and #2 (practice trials). After each one say, "Now put down your cards in the same order as I showed them to you." Then say, "Now I am going to show you one more sign." Give the Subject a card with the new sign on it. Display the third sequence (also a practice trial). Proceed with the remaining sequences until three consecutive errors are made at any one level.

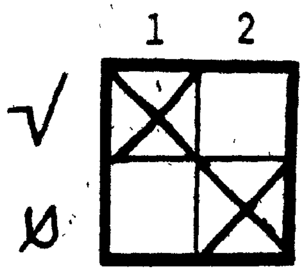
TESP: Stimuli for Temporal Presentations and Responses



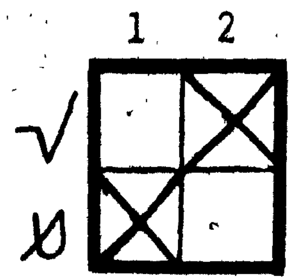
TESP: Grids for Spatial Presentations and Responses



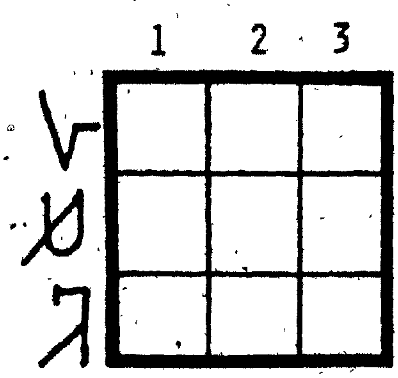
TESP: Patterns for Practice Trials



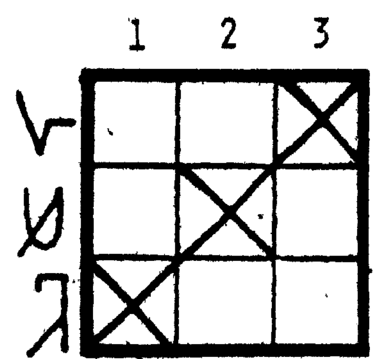
Pattern #1.



Pattern #2.

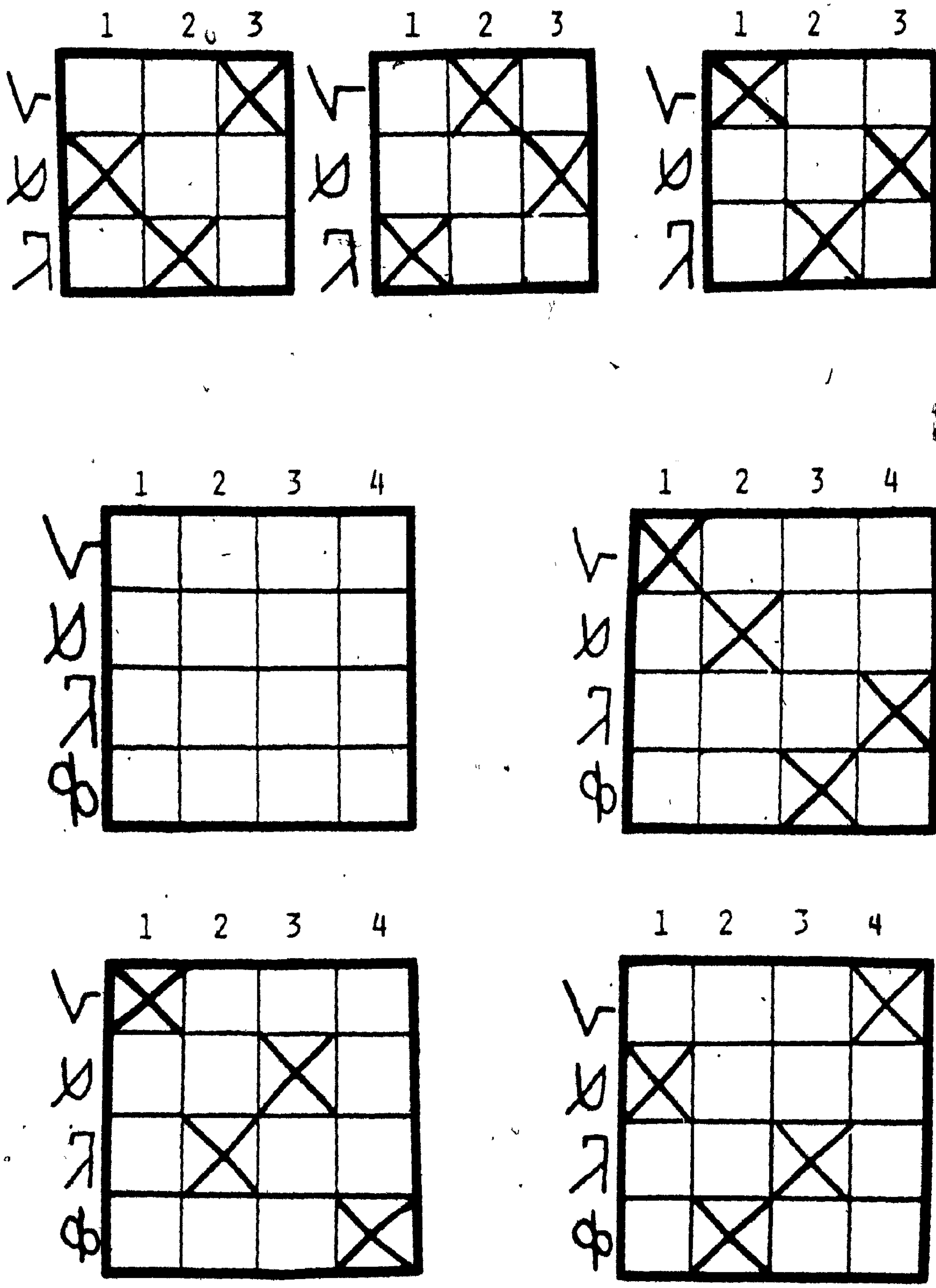


Practice Grid

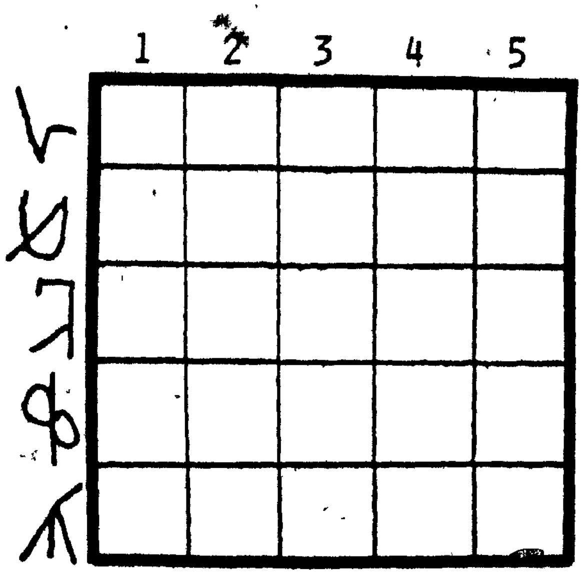


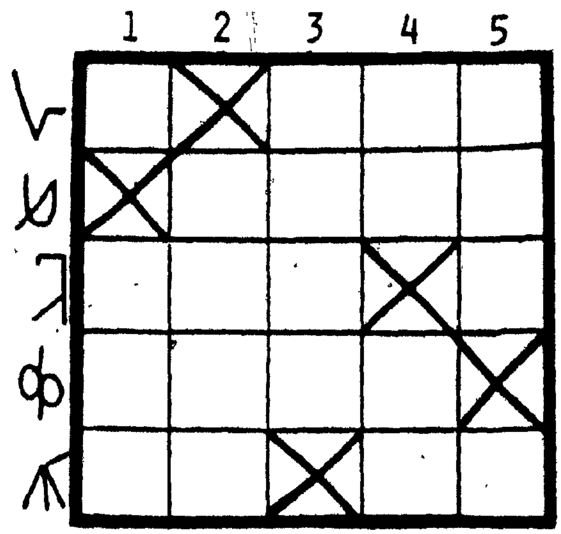
Pattern #3.

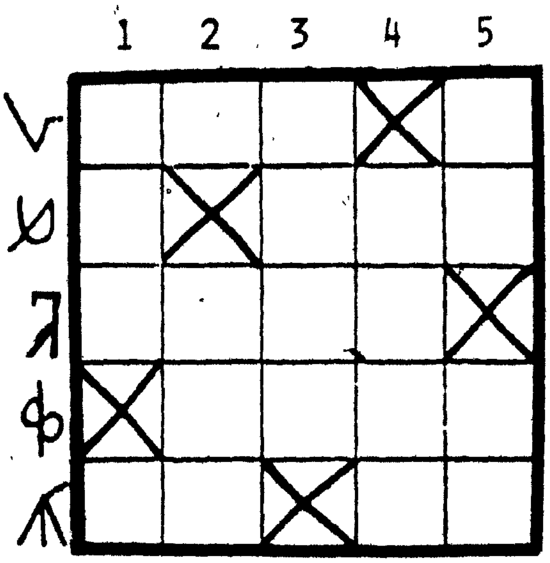
TESP: Levels 3 and 4

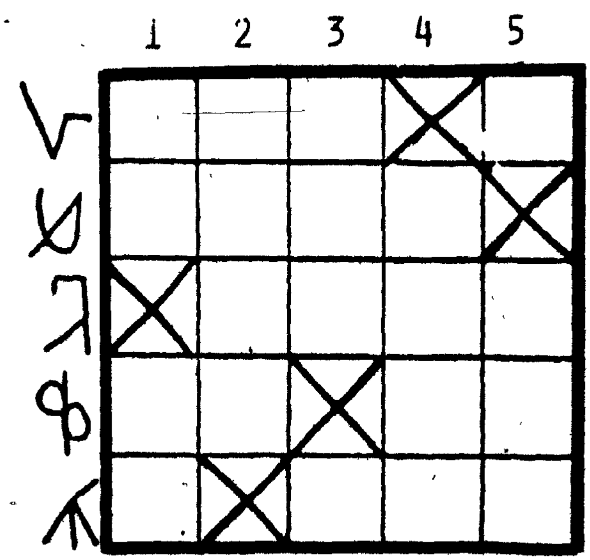


TESP: Level 5

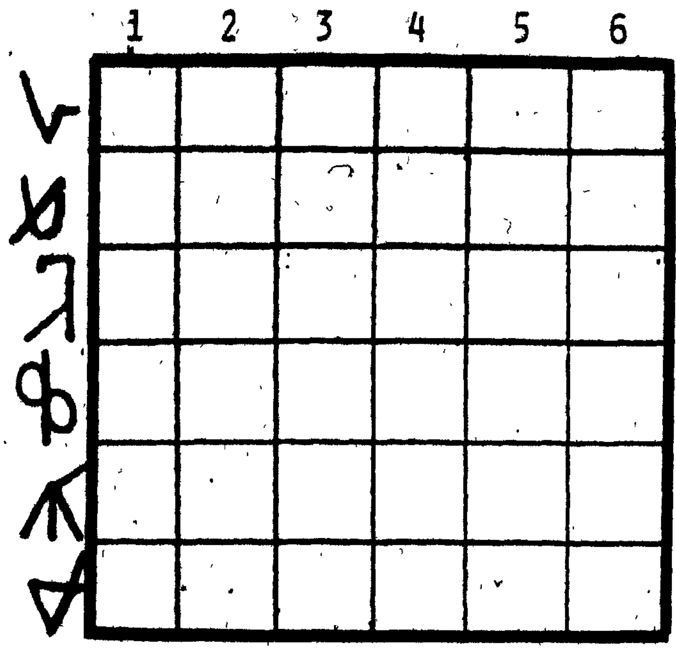


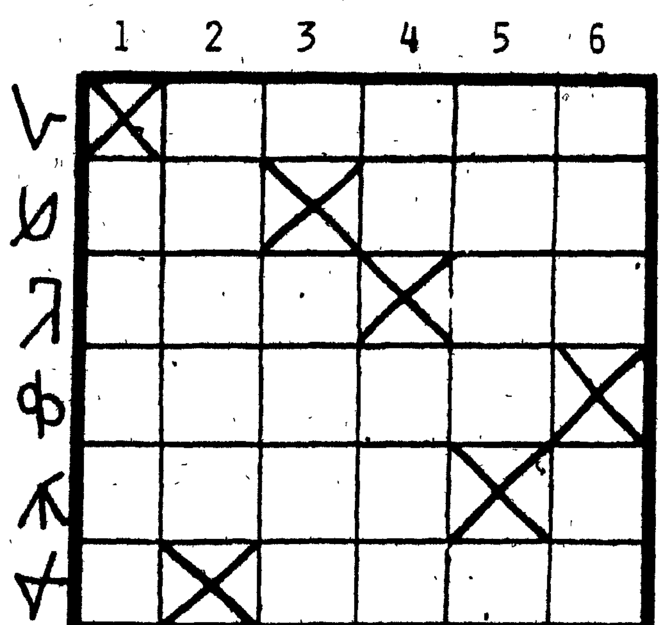


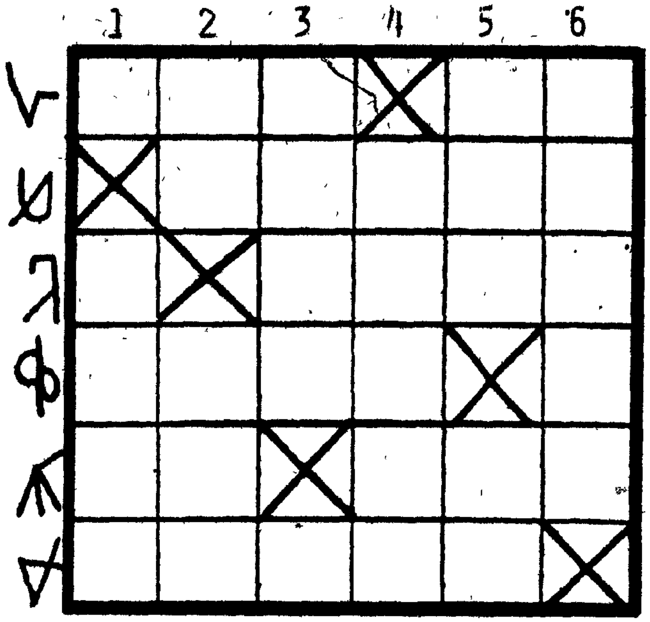


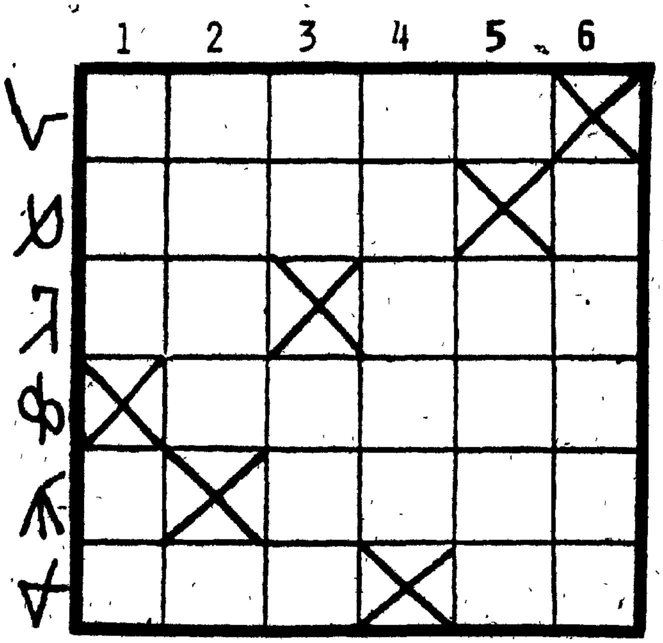


TESP: Level 6






1
2
3
4
5
6


1
2
3
4
5
6

DICHOTIC LISTENING TEST

Instructions for the Dichotic Listening Test

Twenty-four sequences of three-digit pairs were administered following the presentation of two practice sequences. The first test of twelve sequences was presented at the rate of two pair per half second. The second test was presented at the rate of two pair per one and a half seconds. At the half way point, earphones were switched intra-individually to counterbalance for possible channel effects. Order was counterbalanced inter-individually as well.

Instructions were as follows: " When you put on these earphones you will hear different numbers coming to each ear at the same time. Then there will be a pause. When the pause occurs, please repeat, in any order, as many of the numbers as you can remember hearing."

Digits reported from the right and left ears were totalled separately. Maximum score = 72 for each ear.

Dichotic Test

Order ______

		Right	Left	Both
Earphone 1 on right ear				
Test 1 (1/2 sec.)				
395	680			
750	293			
284	107			
132	584			
461	579			
023	748			
total test 1				
Test 2 (1 and 1/2 sec.)				
587	649			
417	832			
069	257			
504	196			
265	380			
431	976			
total test 2				
Order ______				
Earphone 1 on left ear				
Test 1				
680	395			
293	750			
107	284			
584	132			
579	461			
748	023			
total test 1				
Test 2				
649	587			
832	417			
257	069			
196	504			
380	265			
976	431			
total test 2				

Grand Total

Appendix E

Raw Scores and Descriptive Statistics

of

Dependent variables for

Consistent Factor 3, Inconsistent and Able Learner Groups

CODE KEY

centot	central learning score
incidtot	incidental learning score
embfig	embedded figures
assw	associations with syntax, Weener Strings
asswo	associations without syntax, Weener Strings
nassw	no associations with syntax, Weener Strings
nasswo	no associations and no syntax, Weener Strings
spsp	spatial presentation and spatial response, TESP
tesp	temporal presentation and spatial response, TESP
spte	spatial presentation and temporal response, TESP
tete	temporal presentation and temporal response, TESP
re	right ear score, dichotic listening score
le	left ear, dichotic listening score
rh	right hand score, dichhaptic stimulation test
lh	left hand score, dichhaptic stimulation test
spellgr	grade level spelling score, Wide Range Achievement Test
gracc	reading accuracy, standard score, Gates-Meginitie Test
speed	reading speed, standard score, Gates-McGinitie Test
slosso	word recognition, score from Slosson Oral Reading Test

Cat = category

Consistent Factor 3 = 1
Inconsistent = 2
Able Learner = 3

Consistent Factor 3 Group

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   12:00 MONDAY, JUNE 1, 1981   1

CAT=1

OBS	CENTOT	INCIDTOT	FMRFIG	ASSW	ASSWO	NASSW	NASSWO	SPSP	TESP	TETE	SPTE	RE	LE	RH	LH	SPELLGR	GRACC	SPEED	SLOSSU	EXPECT	DUM
1	3	1	93	34	26	19	14	5	4	2	5	49	30	6	2	43	48	47	62	79	1
2	11	4	96	50	33	28	27	8	10	7	9	65	50	6	6	43	86	51	64	89	1
3	6	1	97	46	31	26	22	11	8	5	6	50	25	5	1	30	27	32	33	79	1
4	3	3	89	34	28	21	16	7	7	4	3	68	44	2	3	37	35	32	55	79	2
5	12	1	56	41	33	28	26	4	7	7	1	62	59	5	4	37	48	33	64	99	1
6	6	3	82	36	28	24	18	5	2	1	3	58	30	3	6	26	38	35	30	99	1
7	8	4	87	31	20	16	16	6	3	2	7	63	35	5	5	40	74	45	64	99	1
8	8	2	59	42	34	23	22	5	8	9	3	59	56	7	5	67	56	40	71	77	1
9	6	4	113	49	40	30	27	6	7	5	5	54	47	8	6	40	33	30	47	67	1
10	11	1	87	55	41	34	28	9	8	5	8	63	59	6	3	40	68	45	82	89	1
11	10	0	59	43	37	28	24	6	5	5	7	54	54	4	4	58	56	40	81	99	2
12	11	1	77	41	37	20	23	5	6	8	2	56	58	7	6	61	98	48	80	99	1
13	8	2	93	40	22	16	17	8	9	5	2	51	55	5	5	38	33	29	24	99	1
14	9	2	87	52	39	30	25	9	6	6	5	58	44	6	5	46	32	30	43	79	1
15	8	1	53	43	40	21	25	3	4	5	7	68	68	6	6	74	124	48	87	99	1

Inconsistent Group

CAT=2

OBS	CENTOT	INCIDTOT	FMRFIG	ASSW	ASSWO	NASSW	NASSWO	SPSP	TESP	TETE	SPTE	RE	LE	RH	LH	SPELLGR	GRACC	SPEED	SLOSSU	EXPECT	DUM
16	11	3	92	49	40	32	35	5	6	7	4	51	46	5	5	72	98	50	91	99	1
17	11	4	93	35	28	26	30	12	11	11	9	63	44	5	5	67	74	44	84	89	1
18	3	6	34	35	32	[illegible]	21	4	6	6	2	64	50	3	5	43	52	43	65	79	2
19	10	1	63	35	30	25	20	12	8	10	8	70	66	3	4	49	92	53	71	99	1
20	4	4	63	41	36	23	32	3	3	3	3	49	45	4	8	37	56	60	63	79	1
21	7	2	64	39	30	17	23	5	5	5	1	61	51	4	5	76	92	51	82	89	1
22	8	1	63	44	38	28	25	11	7	7	5	62	63	6	4	72	56	35	89	99	2
23	6	4	32	32	28	23	25	6	5	3	1	53	58	4	4	46	44	43	53	79	1
24	9	1	94	28	29	20	25	8	6	5	6	57	36	3	6	26	38	37	37	99	1
25	6	6	88	46	39	27	28	6	4	5	3	57	49	5	1	37	55	42	63	79	1
26	6	6	90	41	41	37	28	2	5	10	2	52	46	6	5	37	43	35	66	99	1
27	6	6	92	49	44	35	27	1	4	6	1	61	55	6	4	49	46	37	63	99	1
28	9	1	93	33	32	27	22	6	8	10	4	58	46	4	7	40	49	41	59	67	1
29	4	1	85	38	33	26	24	6	5	9	4	51	32	2	7	65	56	35	87	97	1
30	6	6	53	32	26	21	26	7	7	11	7	54	52	4	7	37	52	42	49	67	1

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	C.V.
Consistent Factor 3						
CENTOT	15	8.00000000	2.80305955	3.00000000	12.0000000	35.038
INCIDTOT	15	2.00000000	1.30930734	0.00000000	4.00000000	65.465
EMBFIG	15	81.86666667	17.62249644	53.00000000	113.0000000	21.526
ASSW	15	42.46666667	7.00883796	31.00000000	55.00000000	16.504
ASSWO	15	32.60000000	6.66333250	20.00000000	41.00000000	20.440
NASSW	15	24.26666667	5.41778377	16.00000000	34.00000000	22.326
NASSWO	15	22.00000000	4.64450520	14.00000000	28.00000000	21.111
SPSP	15	6.46666667	2.16684981	3.00000000	11.00000000	33.508
TESP	15	6.26666667	2.28243813	2.00000000	10.00000000	36.422
TETE	15	5.06666667	2.21896587	1.00000000	9.00000000	43.795
RE	15	58.53333333	6.22054966	49.00000000	68.00000000	10.627
LE	15	47.60000000	12.73801958	25.00000000	68.00000000	26.761
RH	15	5.40000000	1.54919334	2.00000000	8.00000000	28.689
LH	15	4.46666667	1.59761727	1.00000000	6.00000000	35.768
SPELLGR	15	45.33333333	13.61546739	26.00000000	74.00000000	30.034
GRACC	15	57.06666667	28.16651169	27.00000000	124.00000000	49.357
SPEED	15	39.00000000	7.81938982	29.00000000	51.00000000	20.050
SLOSSO	15	59.13333333	20.04233614	24.00000000	87.00000000	33.893
Inconsistent			Inconsistent			
CENTOT	15	7.06666667	2.52039302	3.00000000	11.00000000	35.666
INCIDTOT	15	3.46666667	2.16684981	1.00000000	6.00000000	62.505
EMBFIG	15	73.26666667	21.71723038	32.00000000	94.00000000	29.641
ASSW	15	38.46666667	6.44611363	28.00000000	49.00000000	16.758
ASSWO	15	33.73333333	5.54805843	26.00000000	44.00000000	16.447
NASSW	15	26.46666667	5.46242576	17.00000000	37.00000000	20.639
NASSWO	15	26.06666667	4.09645608	20.00000000	35.00000000	15.715
SPSP	15	6.26666667	3.34806269	1.00000000	12.00000000	53.427
TESP	15	6.00000000	2.00000000	3.00000000	11.00000000	33.333
TETE	15	7.20000000	2.78259899	3.00000000	11.00000000	38.647
RE	15	57.53333333	5.93857446	49.00000000	70.00000000	10.322
LE	15	49.26666667	9.02747130	32.00000000	66.00000000	18.324
RH	15	4.26666667	1.22279929	2.00000000	6.00000000	28.659
LH	15	5.13333333	1.72654348	1.00000000	8.00000000	33.634
SPELLGR	15	50.20000000	15.98302671	26.00000000	76.00000000	31.839
GRACC	15	60.20000000	19.33612459	38.00000000	98.00000000	32.120
SPEED	15	43.20000000	7.42774721	35.00000000	60.00000000	17.194
SLOSSO	15	68.13333333	15.82884648	37.00000000	91.00000000	23.232

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   12:05 MONDAY, JUNE 1, 1981

Able Learner Group

OBS	AGE3	ES3	V3	P3	CE1	CE2	CE3	CENTOT	INCIOTOT	EMBFIG	ASSW	ASSWD	NASSW	NASSWD	SPSP	FFSP	TETE	SPTF	RE	LE	RH	LH	SPELLGR	GRACC	SPEED	SLOSSU	EXPECT	DOM
1	165	110	109	109	36	37	27	9	2	49	46	44	33	26	8	10	10	7	62	60	5	5	96	86	50	8	86	1
2	162	96	102	91	25	31	32	6	4	65	46	39	34	30	6	7	11	0	68	58	5	6	87	86	54	90	86	1
3	164	109	100	120	41	31	30	12	3	101	47	39	35	32	12	11	11	4	67	58	5	7	72	92	52	87	86	1
4	164	93	92	96	30	28	30	6	4	86	45	41	28	26	6	10	12	4	62	62	5	5	78	79	54	90	86	1
5	165	109	112	105	31	35	30	10	1	97	53	49	30	28	7	5	9	11	58	66	7	8	93	126	59	80	86	1
6	165	118	115	115	38	38	39	11	4	87	54	39	33	32	12	6	9	7	66	62	2	4	136	126	61	90	86	1
7	166	118	106	128	38	34	39	12	2	86	36	44	23	25	11	9	12	12	69	68	3	7	93	73	52	90	86	1
8	166	121	118	118	34	39	42	11	0	112	51	42	36	31	12	9	10	8	68	59	7	7	90	126	62	88	86	1
9	163	121	130	105	29	43	32	10	1	54	53	48	40	32	12	9	10	5	69	57	7	5	108	126	59	90	86	1
10	163	123	122	120	39	46	30	8	0	92	49	37	27	27	7	7	6	8	58	43	4	8	99	92	54	90	86	1
11	166	123	114	123	34	40	36	11	6	76	51	42	37	31	12	10	10	6	61	58	6	5	.	126	59	90	86	1
12	164	124	112	132	45	39	37	12	6	111	59	51	44	30	12	11	9	11	71	70	6	9	87	99	52	90	86	1
13	164	121	122	115	35	38	44	9	2	75	57	51	40	33	12	12	10	9	70	69	6	7	105	126	64	90	86	1
14	166	128	123	129	42	40	48	8	6	100	51	40	25	37	11	10	11	11	66	57	5	8	70	126	60	84	86	1
15	167	126	115	131	48	38	28	10	6	76	57	51	37	37	9	10	9	9	55	52	7	5	105	126	59	90	86	1

Able Learner Group

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CAT=3

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	C.V.
AGE3	15	164.66666667	1.39727626	162.00000000	167.00000000	0.849
FS3	15	116.00000000	10.52887187	93.00000000	128.00000000	9.077
V3	15	113.13333333	10.06313404	92.00000000	130.00000000	8.895
P3	15	115.80000000	12.52540276	91.00000000	142.00000000	10.816
CF1	15	36.33333333	6.21825270	25.00000000	48.00000000	17.114
CF2	15	37.13333333	4.71875690	28.00000000	46.00000000	12.708
CF3	15	34.93333333	6.36358689	27.00000000	48.00000000	18.216
CENTUE	15	9.66666667	1.98805959	6.00000000	12.00000000	20.566
INCIDFOT	15	3.13333333	2.19956706	0.00000000	6.00000000	70.194
EMBFIG	15	84.46666667	18.89771969	49.00000000	112.00000000	22.373
ASSW	15	50.33333333	5.83911278	36.00000000	59.00000000	11.601
ASSWI	15	43.80000000	4.95983871	37.00000000	51.00000000	11.324
NASSW	15	33.46666667	5.95059021	23.00000000	44.00000000	17.781
NASSWI	15	30.46666667	3.66190167	25.00000000	37.00000000	12.019
SPSP	15	9.93333333	2.46306043	6.00000000	12.00000000	24.796
TFSP	15	9.06666667	1.98086080	5.00000000	12.00000000	21.848
TFTF	15	9.93333333	1.48644671	6.00000000	12.00000000	14.964
SPTF	15	7.46666667	3.29212625	0.00000000	17.00000000	44.091
RF	15	64.66666667	4.98091596	55.00000000	71.00000000	7.702
LF	15	59.93333333	6.93301281	43.00000000	70.00000000	11.568
RH	15	5.33333333	1.49602648	2.00000000	7.00000000	28.050
LH	15	6.40000000	1.50237407	4.00000000	9.00000000	23.475
SPELLGR	14	94.21428571	16.78451013	70.00000000	136.00000000	17.815
GRACC	15	107.66666667	21.07356728	73.00000000	176.00000000	19.573
SPEED	15	56.73333333	4.35015052	50.00000000	64.00000000	7.668
SEQSSD	15	83.13333333	20.98593633	8.00000000	90.00000000	25.244

Appendix F

Analyses of Variance

Not included in text: Study No. 2

Table 1

Analysis of variance for full scale IQ scores over 3 assessments for Consistent Factor 3 and Inconsistent subgroups (N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	780.27	3.57	.07
error	28	218.29		
Time	1	173.34	8.46	.0006
Group x time	1	41.94	2.05	.14
error	56	20.49		

Means: 100.0 97.4 95.2

a (100.0, 97.4)
b (97.4, 95.2)

Table 2

Analysis of variance for verbal and performance IQ scores over 3 assessments for Consistent Factor 3 and Inconsistent subgroups

(N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	1366.76	3.58	.07
error	28	381.33		
Time	2	227.17	5.78	.005
Time x group	2	90.54	2.30	.11
error	56	39.33		
Subscale IQ	1	2149.36	11.40	.002
Subscale IQ x group	1	642.22	3.41	.08
error	28	188.50		
Subscale IQ x time	2	61.24	1.45	.24
Subscale IQ x time x group	2	30.41	.72	.49
error	56	42.25		

Table 3

Analysis of variance for factor scores over 3 assessments for Consistent Factor 3 and Inconsistent subgroups (N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	358.22	2.82	.10
error	28	126.97		
Time	2	138.42	7.38	.001
Time x group	2	11.39	.61	.55
error	56	18.76		
Factor scores	2	906.58	28.93	<.001
Factor scores x group	2	562.05	17.94	<.001
error	56	31.33		
Time x factor scores	4	47.41	3.56	.009
Time x factor scores x group	4	28.82	2.16	.08
error	112	13.33		

Table 4

Analysis of variance for number of words recalled

by levels of association and syntax

for Consistent Factor 3 and Inconsistent groups

Source of variance	df	Mean square	F	p
Between groups	1	21.67	0.21	.65
error	28	101.86		
Levels of association	1	4404.41	395.35	<.0001
Levels of association x group	1	156.41	14.04	.0008
error	28	11.14		
Levels of syntax	1	559.00	66.93	<.0001
Levels of syntax x group	1	91.88	11.00	.0025
error	28	8.35		
Association x syntax	1	267.01	25.80	<.0001
Association x syntax x group	1	20.01	1.93	.18
error	28	10.35		

Table 5

Analysis of variance for serial position effects on naswo strings for Consistent Factor 3 and Inconsistent subgroups (N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	10.83	5.69	.02
error	28	1.90		
Serial position	9	37.81	24.01	<.0001
Serial position x group	9	2.67	1.69	.10
error	252	1.57		

Position:	10	9	1	8	6	2	7	3	5	4
Means:	4.8	3.3	3.0	2.9	2.5	1.9	1.7	1.6	1.4	1.1

a ———————— (3.3 through 2.5)

b ———————— (2.5 through 1.6)

c ———————— (1.9 through 1.1)

Table 6

Analysis of variance for serial position effects on assw strings for Consistent Factor 3 and Inconsistent subgroups

(N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	12.40	2.74	.10
error	28	4.54		
Serial position	9	19.77	16.44	.00
Serial position x group	9	2.20	1.83	.06
error	252	1.20		

Position:	10	8	2	7	9	3	5	1	4	6
Means:	5.5	4.8	4.6	4.4	4.1	4.1	3.7	3.4	3.2	2.8
a	———	———								
b		———	———	———	———	———	———			
c					———	———	———	———		
d							———	———	———	———

Table 7

Analysis of covariance of verbal IQ scores on recall of Weener strings for Consistent Factor 3 and Inconsistent subgroups

(N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	46.52	.46	.50
Verbal IQ	1	146.65	1.46	.24
error	27	100.20		
Associations	1	4404.41	395.35	<.001
Associations x group	1	156.41	14.04	.0008
error	28	11.14		
Syntax	1	559.01	66.93	<.0001
Syntax x group	1	91.88	11.00	<.003
error	28	8.35		
Association x syntax	1	267.01	25.80	<.0001
Association x syntax x group	1	20.01	1.93	.18
error	28	10.35		

Adjusted Means

String variations	Consistent Factor 3	Inconsistent
Assw	42.3[a*]	38.7[a]
Asswo	32.4[b]	33.9[b]
Nassw	24.1[c]	26.7[c]
Nasswo	21.8[d]	26.3[c]

* Means followed by the same letter are not significantly different.

Table 8

Analysis of variance for serial position effects on nassw strings for Consistent Factor 3 and Inconsistent subgroups

(N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	3.63	1.23	.28
error	28	2.96		
Serial position	9	23.86	11.84	<.0001
Serial position x group	9	2.17	1.08	.38
error	252	2.01		

Table 9

Analysis of variance for serial position effects on asswo strings for Consistent Factor 3 and Inconsistent subgroups

(N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	.96	.26	.62
error	28	3.76		
Serial position	9	25.08	16.02	<.0001
Serial position x group	9	.70	.45	.91
error	252	1.57		

Table 10

Analysis of covariance of full scale IQ scores on TESP recall scores for Consistent Factor 3 and Inconsistent subgroups

(N = 15, each subgroup)

Source of variance	df	Mean square	F	p
Group	1	32.72	2.72	.11
IQ effect	1	98.99	8.24	.0079
error	27	12.01		
Presentation mode	1	16.13	2.92	.10
Presentation mode x group	1	16.13	2.92	.10
error	28	5.53		
Response mode	1	28.03	8.89	.006
Response mode x group	1	5.63	1.79	.19
error	28	3.15		
Presentation mode x response mode	1	28.03	20.48	.0001
Presentation mode x response mode x group	1	17.63	12.88	.0013
error	28	1.37		

Adjusted Means

TESP variation	Consistent Factor 3	Inconsistent
Spatial/spatial	6.0[b*]	6.8[ab]
Spatial/temporal	4.4[c]	4.5[c]
Temporal/spatial	5.8[b]	6.5[ab]
Temporal/temporal	4.6[c]	7.7[a]

* Means followed by the same letter are not significantly different.

Appendix G

Single classification analyses of variance for the Able Learner group: Study No. 2

Table 1

Single classification analysis of variance for number of words recalled by levels of association and syntax of the Weener strings for the Able Learner group

Source of variance	df	Mean square	F	p
Levels of association	1	3420.15	358.40	<.0001
error	14	9.54		
Levels of syntax	1	340.82	23.51	.0003
error	14	14.50		
Association x syntax	1	46.82	2.94	.11
error	14	15.92		

Table 2

Single classification analysis of variance for recall by levels of presentation and response on TESP forms for the Able Learner group

Source of variance	df	Mean square	F	p
Levels of presentation	1	9.6	1.45	.25
error	14	6.64		
Levels of response	1	9.6	2.32	.15
error	14	4.14		
Presentation x response	1	41.67	10.84	.005
error	14	3.85		

Means: 9.9 9.9 9.1 7.5

Table 3

Single classification analysis of variance of dichotic listening scores for the Able Learner group using right handed subjects

Source of variance	df	Mean square	F	p
Ear effect	1	168.03	9.78	.007
error	14.	17.18		

Table 4

Single classification analysis of variance of dichhaptic test scores for the Able Learner group using right handed subjects only

Source of variance	df	Mean square	F	p
Hand effect	1	8.53	4.51	.05
error	14	1.89		

Appendix H

Analyses of variance for

dichotomous stimulation tasks

for Consistent Factor 3 and Inconsistent groups

(right and left handers combined)

Table 2

Analysis of variance for number of correct detections for right and left hands for Consistent Factor 3 and Inconsistent groups right and left handers combined

Source of variance	df	Mean square	F	p
Group	1	.82	.36	.55
error	28	2.27		
Hand effect	1	.02	.01	.93
Hand x group	1	12.15	4.98	.03
error	28	2.44		

Means: 5.4 5.1 4.5 4.3

Table 1

Analysis of variance for number of

digits recalled for right and left ears

for Consistent Factor 3 and Inconsistent groups

right and left handers combined

Source of variance	df	Mean square	F	p
Group	1	1.67	.01	.90
error	28	111.32		
Ear effect	1	1382.40	29.08	<.0001
Ear x group	1	26.67	.56	.46
error	28	47.53		

Appendix I

Multiple Regression Analysis

Table 1

Summary table of the multiple regression analysis of derived indices on the factor discrepancy scores from the first assessment

Variable	Multiple R	Simple R	B-value	Beta
Selective attention	.43	.43	.56	.44
Right ear advantage	.60	.35	.20	.33
Weener index	.65	.38	15.02	.23
TESP index	.66	.39	- 4.35	-.13
Right hand advantage	.66	.08	- .22	-.05
(Constant)			.19	

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